PRO-GRACE

PROMOTING A PLANT GENETIC RESOURCE COMMUNITY FOR EUROPE

DELIVERABLE 5.2

Identification of the scientific services, stakeholders, promoters and utilizers of the proposed RI (v1)

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Author(s)	Filippo Guzzon, Lorenzo Maggioni, Sandra Goritschnig, Nora Capozio, Gabriele Bucci, Lorenzo Barchi, Ezio Portis, Nigel Maxted, Joana Magos Brehm, Imke Thormann, Sarah Sensen, Béla Bartha, Michael Lyngkjaer, Anna Palmé, Lise Lykke Steffensen, Ignazio Verde, Jelka Sustar Vozlic, Jan Bartos, Anne-Francoise Adam-Blondon, Stephan Weise, Theo van Hintum, Riccardo Bocci, Giovanni Giuliano.
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Contents

List of acronyms

AEGIS: A European Genebank Integrated System

ABS: Access and Benefit Sharing

CGRFA: Commission on Genetic Resources for Food and Agriculture

CSB: Community Seed Bank

CWR: Crop Wild Relatives

D: Deliverable

DSI: Digital Sequence Information

ECPGR: European Cooperative Programme for Plant Genetic Resources

EU: European Union

EURISCO: European Search Catalogue for Plant Genetic Resources

FAO: The Food and Agriculture Organization of the United Nations

GHU: Germplasm Health Unit

GRC: Genetic Resources Centre

IP: Intellectual Property

ITPGRFA: The International Treaty on Plant Genetic Resources for Food and Agriculture

LR: Landraces

NGO: Non-Governmental Organization

OECM: Other Effective area-based Conservation Measures

PA: Protected Areas

PGR: Plant Genetic Resources

QMS: Quality Management System

RI: Research Infrastructure

SME: Small and medium-sized enterprise

SMTA: Standard Material Transfer Agreement

SOP: Standard Operating Procedure

1. Executive summary

Despite the high number of accessions stored in European genebanks, several issues still affect the conservation and hinder the use of plant genetic resources (PGR) in research and breeding at the European level. Some gaps that are often encountered in the current PGR European scenario are: lack of quality management systems for PGR conservation, inadequate integration of *in situ* and *ex situ* conservation strategies, inconsistent accessibility and interoperability of data; lack of access to advanced –omics technologies and services, difficulties in interpreting and applying policies and legislations on PGR. The proposed research infrastructure dedicated to PGR, GRACE-RI, will have the opportunity to tackle these issues, and, through enabling research activities on PGR prevent the loss of PGR diversity and promote their use to support the transition to a more sustainable and productive agriculture in a changing climate.

The main aim of this deliverable was to identify the stakeholders and services of GRACE-RI in a first iteration. This deliverable also includes the results of a stakeholder survey carried out in October 2023 in the framework of a PRO-GRACE workshop.

We identified ten groups of stakeholders (i.e. *in situ* genetic reserves; genetic resources centers; farmers; seed companies; other private service providers; other research infrastructures; public research centers; non-governmental organizations; PGR conservation and research networks; policymakers, legislators and policy experts) and highlighted their roles in the long-term conservation and sustainable use of PGR at European level.

Moreover, we identified and described nine main areas where GRACE-RI could provide services (i.e. quality management systems for PGR conservation; taxonomy; data storage, completeness, and availability of PGR; phenotyping; genotyping; metabolic profiling; data analysis; phytosanitary aspects; policy and regulatory aspects; education and dissemination) and that can fill current gaps in PGR conservation, access and use. We also envisioned how the abovementioned stakeholder groups can contribute to and benefit from these services.

This deliverable will be further developed in a second iteration in Deliverable 5.5 and should consider some key aspects in the next version, namely: 1) include the findings of other deliverables that are currently in preparation; 2) carry out wider surveys of potential stakeholders; 3) pinpoint in better detail the types of services that GRACE-RI will ultimately provide, and how the responsibility of providing services can be assigned to the appropriate stakeholders; 4) inform the proposal for a well-defined governance structure that will enable the provision of GRACE-RI services and facilitate the interaction between providers and utilizers of the RI.

2. Introduction

Humankind is facing increasing challenges from climate change and its negative impact on food security, food quality and sustainability. Plant genetic resources (PGR) are one of the main assets to adapt, improve and reorient our agricultural systems. Like other regions, Europe is rich in PGR and holds the critical responsibility and strategic opportunity to optimally conserve these resources and enable their use for the benefit of humankind.

In Europe, more than 2 million accessions of PGR are conserved *ex situ* by around 400 institutes and are listed in the European Search Catalogue for Plant Genetic Resources (EURISCO, http://eurisco.ecpgr.org). These accessions account for half of the total PGR accessions listed in the global Genesys database (Genesys, 2023) and about a quarter of all PGR accessions actively conserved in genebanks globally (FAO, 2010). Despite this large number of conserved germplasm materials, the quality of conservation and access, the representativeness of these accessions, as well as the quality and completeness of their passport and characterization data varies greatly across institutions (EURISCO, 2023). These PGR accessions are often stored *ex situ* with limited attention to complementarity with very few active long-term on-farm conservation programmes for landraces (LR)

and *in situ* genetic reserves for crop wild relatives (CWR), even though southern Europe is considered a centre of domestication and diversity for many crop species (Vavilov, 1926; Vincent *et al*, 2013). European genetic resource centres (GRCs) vary greatly in their mission, and their genebanks vary in the number of conserved accessions, conservation and distribution methodologies, and compliance to international genebank standards (e.g. Genebank Standards for Plant Genetic Resources for Food and Agriculture (FAO, 2014)). Many genebanks currently lack resources, capacities, infrastructures and adequate quality management systems (QMS) to ensure the long-term conservation of the safeguarded germplasm material. Moreover, many genebanks do not currently have access to advanced phenotyping and -omics technologies, limiting the characterization, evaluation, breeding and research activities on the accessions they conserve. Additionally, a significant amount of the available characterization and evaluation data was captured using different protocols and is dispersed in different databases and scientific publications. Furthermore, implementation of on-farm and *in situ* actions is limited, as their application remains novel and largely untested, including making the necessary link between active *in situ* conservation and user accessibility. It is also worth noting that irrespective of how the resources are conserved, whether *in situ* or *ex situ,* they must then be accessible for utilization, active conservation itself not being the endpoint in the pathway (Maxted *et al*, 2016).

To further complicate this scenario, the policies and legislation on PGR vary among different European countries. These issues are detrimentally impacting the effective conservation of PGR in Europe as well as the availability of PGR and related data for research and breeding activities (ECPGR, 2021).

The general objective of PRO-GRACE is to identify strategies to fill these gaps in PGR conservation and to enhance their use pathways at the European level, developing the bridging concepts and enacting the proof-of-concept actions, for the development of a European Research Infrastructure (GRACE-RI) fully dedicated to PGR. In this framework, the main objectives of the services provided by the GRACE-RI will be to:

- Foster high-quality research and innovation on PGR to support the transition to a more sustainable and productive agriculture
- Systematize and strengthen PGR conservation planning and implementation
- Promote and support sustainable, fair and equitable use of PGR
- Raise awareness on the value of PGR, build stakeholder networking, advance policy engagement and improve capacity for PGR conservation and use

Through the delivery of these objectives, the GRACE-RI will fill identified gaps in current scientific PGR services, increase the value of European PGR collections through research and ultimately contribute to enhancing European consumer choice and food and nutritional security. Overall, the GRACE-RI will strengthen the long-term conservation and use of PGR at European level, preventing losses of materials as well as rationalizing the conservation and research efforts, by reducing redundancies in European PGR collections and coordinating research activities. This RI will also enhance the availability of PGR material and associated data, enabling an increase in the use of these conserved resources to breed the nutritious, productive, and resilient crop varieties that are needed to face the challenges posed by a changing climate.

In this deliverable, the main stakeholder groups and potential services of the future GRACE-RI are listed (Chapters 3 and 4, respectively), including possible links and synergies among them. This deliverable also includes the findings of an interactive workshop held in Chania, Greece on 4 October 2023 (the main results and findings of the workshop are presented in **Appendix I**). The current deliverable will be further developed in Deliverable 5.5, incorporating the results of other deliverables that are currently under development.

The main stakeholders and services are listed in the document in a logical order and grouped into four main categories of PGR activities (Conservation & Documentation, Use, Policy, Networking & Capacity) that are illustrated in **Figure 1**.

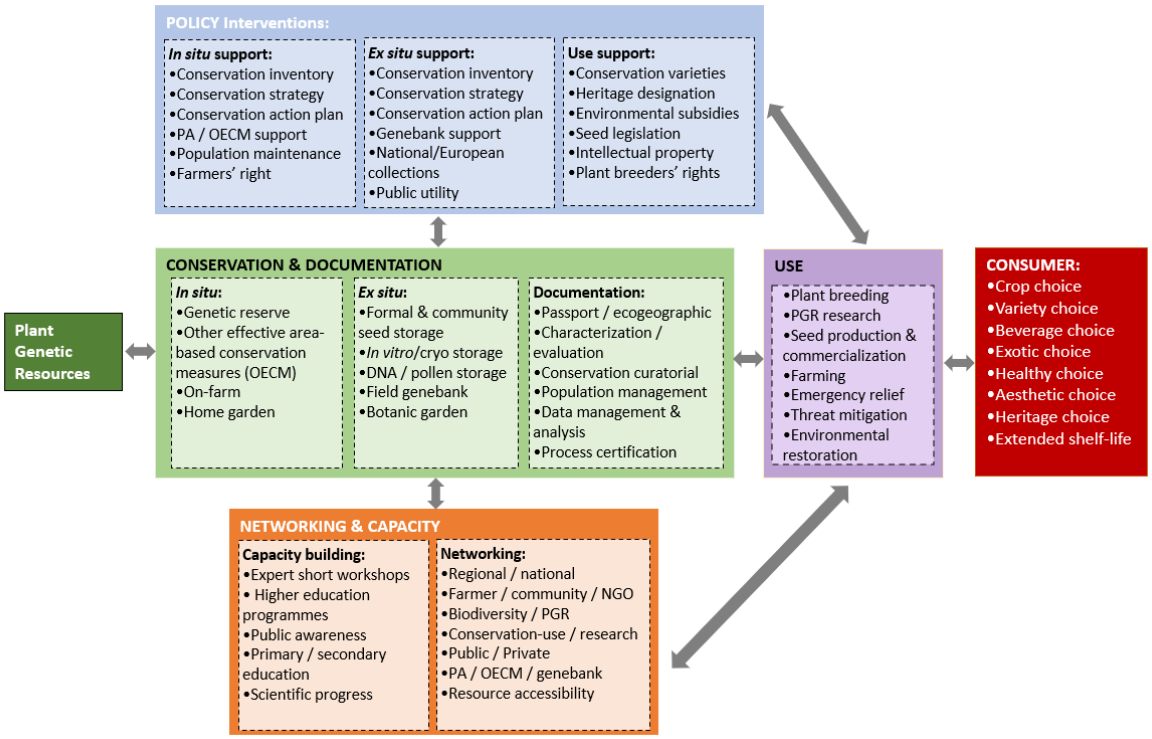

Figure 1. *Map of the four main categories of activities (Conservation & Documentation, Use, Policy, Networking & Capacity) that are used in this document to group stakeholders and services of the GRACE-RI.*

3. List and brief description of the main stakeholders of the proposed Research Infrastructure

In this chapter, the main stakeholder groups of the future GRACE-RI are listed (summarized in **Figure 2**).

- **Genetic resources centres.** Genetic resources centres (GRCs), primarily genebanks, will be the main stakeholders of this RI. In the stakeholder survey summarized in **Appendix I**, genebanks were listed as likely the main providers and users (together with researchers) of the services of the future GRACE-RI. A genebank's role is to oversee the *ex situ* conservation of PGR accessions for the medium and long term, using different methodologies (seed, field, *in vitro* conservation, cryopreservation). Genebanks are responsible for making germplasm accessible to users, internally (at the institutional level) as well as at the national and international levels. Access to PGR material from genebanks was listed as one of the main services that PGR stakeholders are currently using in the survey summarized in **Appendix I**.

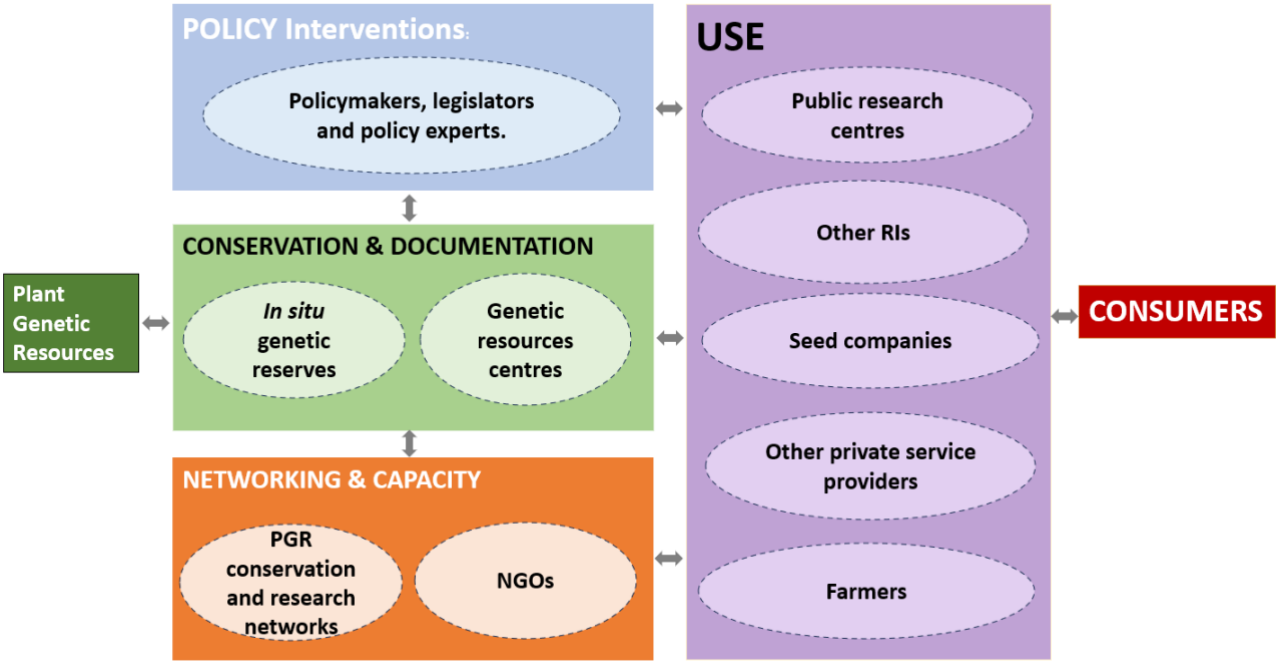

Figure 2. *Map of the GRACE-RI stakeholders. These are divided into four main categories (Conservation & Documentation, Use, Policy, Networking & Capacity) highlighted in* ***Figure 1*** *and based on their prevalent activities (keeping in mind that the same stakeholder could fit in more than one category).*

As part of the activities of a genebank, they also deal with the regeneration and characterization of the conserved accessions as well as with several other research activities. Increasingly, GRCs are also playing a more active role in *in situ*/on-farm conservation activities in collaboration with PGR population maintainers and are responsible for population back-up and providing the link between conserved populations and potential germplasm users. Genebanks also store and make available data related to the conserved accessions. As highlighted above, hundreds of genebanks operate in Europe, with great differences among institutions in their aims and operations. We can grossly divide European germplasm collections into two groups: 1) long-term collections that deal with the in-perpetuity conservation of the accessions as well as with their distribution (e.g. the Centre for Genetic Resources, the Netherlands (CGN), the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), and the Nordic Genetic Resource Center (NordGen)) and 2) short- and medium-term collections (sometimes also known as active or research collections), serving research or breeding projects without commitment for the long term. These two main groups of genebanks have different requirements and obligations, which should probably be reflected in different standards applied in the genebanks and thus in their quality management systems (QMS). As part of the RI, the European genebank network AEGIS (A European Genebank Integrated System, https://www.ecpgr.cgiar.org/aegis/about-aegis/overview) should be strengthened. In AEGIS, the genebank members conserve in perpetuity unique European accessions, following internationally agreed standards, making the material available under the standard material transfer agreement (SMTA) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR). A strengthened AEGIS structure will be a pillar of GRACE-RI, benefiting from and contributing to the services of the infrastructure with a special focus on quality management and genebank certification. Some genebanks can be identified for specialized services as part of the RI (e.g. regeneration, cryopreservation, safety duplication etc.). In addition, GRACE-RI will explore and agree on a more mutually beneficial relationship between *in situ* and *ex situ* conservation facilities, to ensure a more systematic and complementary conservation of PGR diversity for current and future utilization.

- ***In situ* genetic reserves.** In recent years there has been an increasing focus at the European level on the establishment of *in situ* genetic reserves for the conservation of populations of CWR and other wild PGR in their natural habitats, involving the designation, management and monitoring of wild populations at the location where they are currently found (Maxted *et al*, 1997; 2016). Complementing *ex situ* conservation in genebanks with *in situ* conservation is particularly important, since this allows populations to evolve in their original place, adapt to local changes in the environment and retain a higher genetic diversity compared to genebank accessions (Guzzon *et al*, 2021a). The implementation of genetic reserves varies among countries, with few countries in which networks of genetic reserves have already been established (GENRES, 2023; Maxted and Magos Brehm, 2023), while in many other countries, there are currently no genetic reserves specifically set up for CWR *in situ* conservation. Genetic reserve managers/authorities will be invited to participate in GRACE-RI and contribute to its governance and services. It will be important to work towards operational QMS and monitoring systems for genetic reserves, enhancing their integration with *ex situ* conservation and all the services of the RI.

- **Farmers**. Farmers will be vital stakeholders in the activities and services of GRACE-RI. The work of the infrastructure will make available new resilient and nutritious varieties by unlocking potentially useful traits stored in germplasm collections. GRACE-RI could also facilitate the reintroduction of landraces and old cultivars conserved in genebanks that can potentially command higher prices when sold to speciality markets due to their connection with traditional food products (Guzzon *et al*, 2021b). The RI will also facilitate the long-term conservation and future availability of landraces, old cultivars and neglected crops still cultivated as well as CWR populations inadvertently maintained by farmers that are not yet included in any germplasm collection (both *in situ* and *ex situ*). Farmers' organizations are often involved in projects dealing with on-farm conservation of landraces and old cultivars which consists in the cultivation by farmers of locally developed, domesticated varieties to prevent their genetic erosion (Guzzon *et al,* 2021a). In the context of the introduction of the concept of other effective area-based conservation measures (OECMs) – i.e. geographically defined areas other than protected areas, which are governed and managed in ways that achieve positive and sustained long-term outcomes for the *in situ* conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socioeconomic and other locally relevant values (CBD, 2018) – farmers' organizations will likely increase their involvement in the *in situ* conservation of CWR and landraces. The GRACE-RI has the opportunity to open a permanent channel of communication/information between PGR scientists and farmers' representatives at the European level. Farmers' organizations should be represented in the GRACE-RI governance. Moreover, PRO-GRACE should contact regional, national and subnational farmers' organizations to provide their input to the GRACE-RI vision as well as seek their interest in actively participating in some of the services (either as providers or utilizers).

- **Seed companies.** The seed sector plays a fundamental role in the European seed system, driving many crop improvement and research activities on PGR. There are around 7,000 seed companies located in the EU only, with a relatively high number of small and medium-sized enterprises (SMEs). At the same time, among the top ten global seed companies, five are based in Europe (Ragonnaud, 2013). Representatives of seed companies could be involved in the GRACE-RI governance to make sure that public–private partnerships are nurtured. The input of seed companies will be of key importance in fully implementing several of the services listed in Chapter 3 (e.g. genotyping and phenotyping services), for which they will be also important users.

- **Other private service providers.** In this group, we gathered service providers in the private sector other than seed companies. These can be for example genotyping companies, *in vitro* multiplication laboratories, nutritional analyses laboratories, seed testing laboratories and data analysis companies. While developing the services of the RI, it will be important to identify individual companies that can provide some of the services. A specific tool or directory could be

created as part of GRACE to foster the use of new technologies in PGR conservation, characterization and use. This could also create new business opportunities within Europe.

- **Other Research Infrastructures.** Other European Research Infrastructures are working on research topics that have some intersections with the PRO-GRACE proposed services. A gap analysis between existing RIs and the mission of GRACE-RI is part of Deliverable 5.1 of PRO-GRACE and further highlights potential interactions with existing RIs (Bucci *et al,* 2023). Some RIs included in the 2021 ESFRI roadmap deal with topics related to the GRACE-RI: handling and coordination of biological data for life sciences (ELIXIR), plant phenotyping (EMPHASIS), digitization of natural science collections (DISSCO), biodiversity and ecosystem research (LIFEWATCH), metrology services for the enhancement of food quality and safety (METROFOOD) and preservation, investigation and valorization of microbial resources (MIRRI). While the services of GRACE-RI are developed, it will be important to seek integration with relevant services that are being developed as part of other RIs. In particular:
  - DISSCO (https://www.dissco.eu/) is developing a series of tools to improve the access, curation and digitalization of natural sciences collections. The service that DISSCO is developing can provide integration opportunities with taxonomy and data services of PRO-GRACE.
  - ELIXIR (https://elixir-europe.org/) monitors global archives for genomic and metabolomic data (e.g. ENA: https://www.ebi.ac.uk/ena/browser/home and Metabolights: https://www.ebi.ac.uk/metabolights/) as well as international registries in support to FAIR data management (meeting principles of findability, accessibility, interoperability and reusability) and reproducible analytics in the domain of Life Sciences (e.g. FAIRsharing: https://fairsharing.org/, bio.tools: https://bio.tools/, WorkflowHub: https://workflowhub.eu/). In addition, a Plant Sciences Community was created to engage with the plant research community and develop resources and services supporting the integration and interoperability of different types of plant data, ranging from phenomics and genomics to transcriptomics, metabolomics, modelling and bibliographic data. This Community aims to promote tools, databases, standards and best practices for plant research. It will be important to seek integration between the ELIXIR Plant Sciences Community and the GRACE-RI services on data storage, completeness and availability as well as data analysis. The Plant Sciences Community will be a good entry point towards other working groups in ELIXIR (e.g. other communities or technical platforms).
  - EMPHASIS (https://emphasis.plant-phenotyping.eu/) is developing a series of services on plant phenotyping, including data analysis tools. These services should be integrated with the phenotyping activities of GRACE-RI.
  - LIFEWATCH (https://www.lifewatch.eu/) is developing several services which run taxonomic checks on taxonomic and common species names. This could be integrated as part of the taxonomic services of GRACE-RI, to avoid taxonomic errors in the passport data of conserved accessions.

- **Public research centres.** Numerous public research centres and universities in Europe deal with the conservation, characterization and use of PGR. Researchers were indicated as the most important users and the second most important providers (after genebanks) of the future GRACE-RI in the recent stakeholder survey (see **Appendix I**). Different centres have different research objectives (e.g. crops, CWR or trait-specific), using different –omics approaches and at different geographical scales (subnational, national, regional). GRACE-RI will be an opportunity to coordinate and consolidate the efforts of the different research centres in Europe on some key research questions as well as to exploit the results of theoretical research into applied research that serves humankind towards food and nutritional security. In the current PRO-GRACE phase, 31 partners are involved including national research centres and universities, allowing for integration of research efforts. Some of the key research objectives that the RI could address are: 1) increase the deployment of PGR in plant breeding to select the resilient and nutritious cultivars of the future, 2) develop and enhance the use of new technologies in PGR conservation (e.g. artificial

intelligence to monitor genetic integrity and seed quality) and evaluation (high-throughput phenotyping and genotyping), and, through the generated information, improve the services of genebanks, 3) seamlessly integrate *in situ* and *ex situ* conservation, and user application of the full breadth of PGR diversity for crop improvement, and 4) research on fundamental aspects of plant biology (plant physiology, genetics, evolution) that can contribute to improving conservation and composition of collections and to pre-breeding efforts. As part of GRACE-RI governance, a Scientific Advisory Board or a similar entity will collect feedback from partners and advise on GRACE's research priorities. Finally, some of the research centres and universities that participate in PRO-GRACE have ethical committees that can also assist in dealing with positioning on ethical issues related to PGR.

- **Non-governmental organizations.** Diverse non-governmental organizations (NGOs) working at regional, national and European levels are involved in the on-farm conservation of landraces, neglected crops and old cultivars often in collaboration with farmers' groups and other organizations. NGOs are also involved in participatory plant breeding programmes as well as in activities regarding the scientific, technical and legal aspects of seed production. Some NGOs manage community seedbanks (CSBs, also known as seed reserves, seed libraries or seed houses in different contexts) that conserve germplasm of landraces, neglected crops and old cultivars (Vernooy et al. 2015). Two recent Horizon 2020 European projects (DIVERSIFOOD: https://diversifood.eu/ and DYNAVERSITY: http://dynaversity.eu/) defined and described CSBs in the current European seed system, clarifying their role in the conservation of crop agrobiodiversity, public awareness and training activities on PGR conservation and use as well as participatory crop evaluation projects. NGOs are represented within PRO-GRACE and provide important input on their role in a future GRACE-RI. Relevant NGOs will be identified and invited to be members of the RI, since they are important recipients of PGR material and information, and they can be users and promoters of several of the services listed below (e.g. QMS, phenotyping, policy and regulatory aspects).

- **PGR conservation and research networks.** Several additional organizations, collaborative projects and networks are active at the European level in enhancing the conservation and use of PGR. It will be extremely important to also involve consortia that manage large data repositories on PGR. Here are a few notable examples of such collaborative institutions and projects (in alphabetical order):

    - AgBio: A consortium of agricultural biological databases aiming at consolidating standards and best practices for acquiring, displaying, and reusing genomic, genetic and breeding data (see here: https://www.agbiodata.org/). This consortium can be an important partner of GRACE-RI, especially advising on the standardization of practice and protocols for databases of PGR data.
    - BGCI: The Botanical Gardens Conservation International (BGCI) is a non-profit membership organization that aims to promote and develop a more efficient, cost-effective and rational approach to plant conservation in botanic gardens (https://www.bgci.org/). BGCI leads plants conservation strategic projects, including many CWR taxa. It works in seed supply, building capacity and providing funding for conservation activities. BGCI also provides membership to institutions working in plant conservation. This organization can be a strategic partner for the RI to enhance the *ex situ* conservation and availability of PGR.
    - CGIAR: CGIAR is a global research partnership for a food-secure future dedicated to transforming food, land and water systems in the current climate crisis. CGIAR genebanks manage collections of more than 20 staple crops in ten locations across five continents. The collections are made freely available upon request to thousands of users worldwide every year under the ITPGRFA, accounting for a large amount of the germplasm being exchanged under the multilateral system of access and benefit-sharing. The CGIAR Genebank Initiative aims to support the global system for the conservation and use of PGR

(https://www.cgiar.org/initiative/genebanks/). CGIAR will be a strategic partner for the future GRACE-RI, with several opportunities for collaborative activities on PGR conservation, research and use.

- DivSeek: The DivSeek International Network is a global community that connects, combines and communicates expertise among stakeholders engaged in the management and characterization of PGR. DivSeek's role is to facilitate and encourage the dissemination of information about PGR and to promote benefit-sharing derived from their use, while respecting international treaties and conventions established to protect them (https://divseekintl.org). This network could be an important partner in realizing GRACE-RI's mission especially when dealing with the services on data availability, tools for genomics and phenomics as well as capacity building on policy issues.
- ECPGR: The European Cooperative Programme for Plant Genetic Resources (ECPGR) is a collaborative programme among most European countries aimed at ensuring the long-term conservation and facilitating the increased utilization of PGR in Europe (https://www.ecpgr.cgiar.org/). ECPGR supports several projects and networks at continental level including: 1) Crop-specific and thematic working groups dealing with the conservation, characterization and evaluation of PGR, 2) the above-mentioned AEGIS, which established a European Collection that is maintained in a decentralized virtual genebank consisting of various associated genebanks across Europe. The accessions in the European Collection are maintained in accordance with agreed quality standards, and must be freely available in accordance with the terms and conditions set out in the ITPGRFA (https://www.ecpgr.cgiar.org/aegis/), 3) the European Genebank Managers Network aimed at building capacity of genebank curators and managers and providing a platform for networking and knowledge exchange (https://www.ecpgr.cgiar.org/about/genebank-managers-network), and 4) the ECPGR European Evaluation Network (EVA) for PGR, an international project involving public and private sector partners, aimed at increasing the use of crop genetic diversity conserved in European genebanks and the diversity of stakeholders in plant breeding (https://www.ecpgr.cgiar.org/eva). Being partner in PRO-GRACE, the Secretariat of ECPGR is strongly involved in the development of the concept of GRACE-RI and thus well-placed to exercise its brokering and coordinating role as part of the GRACE-RI governance and advisory boards.
- EUROSEEDS: A non-profit association representing national seed associations and seed companies, EUROSEEDS deals with research, breeding, production and marketing of seeds of agricultural, horticultural and ornamental plant species. It is a partner of PRO-GRACE and currently includes 30 national member associations from EU Member States and beyond, and represents several thousand seed businesses, including more than 70 direct seed company members (https://euroseeds.eu/). The role of EUROSEEDS in representing the interests of seed companies will be critical to connecting GRACE-RI with the private sector, informing on requirements of the end users of the RI as well as identifying service providers.
- EUCARPIA: The European Association for Research on Plant Breeding (EUCARPIA) is a non-profit association that aims to promote scientific and technical cooperation in the field of plant breeding in order to foster its further development. To achieve this purpose, the Association arranges and sponsors meetings throughout Europe, bringing together the public and private sector breeders to discuss general or specific problems from all fields of plant breeding and genetics research (https://www.eucarpia.eu/). This association will be a suitable forum for promoting the RI services and getting suggestions on the development of the infrastructure.
- EUROPARC: The EUROPARC Federation is the network for Europe's natural and cultural heritage. It works to improve the management of PA in Europe through international cooperation, exchange of ideas and experience, and by influencing policy. This organization can partner with the future GRACE-RI to find synergies for the improvement of the *in situ* conservation of CWR and other wild PGR (https://www.europarc.org/).
- European Coordination Let's Liberate Diversity: ECLLD is an international nonprofit organization dedicated to the dynamic management of PGR. It supports a network of 21

members and, in collaboration with approximately 15,000 farmers, is engaged in the conservation and management of PGR across Europe (https://liberatediversity.org/). ECLLD can be an important partner for GRACE-RI in particular on relevant services of on-farm conservation and education. It can also provide advice on legislative support to farmers, hobbyists and small seed companies on agricultural biodiversity.

- Eurosite: Eurosite, the European Land Conservation Network, provides networking, capacity building, training, information, advocacy and awareness-raising services for *in situ* conservation practitioners all over Europe. The members are organizations and individuals working on nature conservation in governmental and civic societies. These work across a broad range of topics and geographic levels, with a focus on practical aspects of natural site management, restoration and conservation as well as the implementation of nature conservation policies, both inside and outside protected areas (PA; https://www.eurosite.org). This organization can support the future GRACE-RI by finding strategies to enhance the *in situ* conservation of CWR and other wild PGR.
- Global Crop Diversity Trust: It is a non-profit international organization dedicated to conserving crop diversity and making it available for use globally, forever, for the benefit of everyone (https://www.croptrust.org/). It is a PRO-GRACE associated partner and was established in October 2004 by the Food and Agriculture Organization of the United Nations (FAO) and Bioversity International on behalf of CGIAR for the purpose of sustainably supporting a global system for the conservation and use of crop diversity through its Crop Diversity Endowment Fund.
- Horizon Europe projects: Horizon projects, supported by the European Union's Horizon 2020 or Europe research and innovation programmes, that deal with PGR in any form, are interested in interacting with GRACE-RI. Contacts with the majority of these projects (summarized in **Table 1**) have been established at the PRO-GRACE workshop on the sustainable management of PGRs held in Chania on 3-4 October 2023.

- **Policymakers, legislators and policy experts.** This group includes the stakeholders involved in the development and implementation of PGR policy and legislation. This includes the ratification of international agreements that govern access and use of PGR as well as the European directives on PGR conservation and cultivar registration (Spataro and Negri, 2013). The ECPGR National Coordinators and/or National Focal Points of the Commission on Genetic Resources for Food and Agriculture (CGRFA) and of the ITPGRFA of the UN Food and Agriculture Organization (FAO), might serve as contact points between GRACE-RI and the national legislators on PGR. They will be invited to get involved in the planning of the RI, for support and advice. A core group of policy experts will be also essential to accompany the establishment of the RI and subsequently to provide a permanent advisory and educational service on legal issues.

Table 1. *Horizon 2020 and Horizon EU projects on PGR interested in GRACE-RI*

Project and programme	Website
TRADITOM H2020	https://www.traditom.eu/
G2P-SOL H2020	http://www.g2p-sol.eu/
HARNESSTOM H2020	http://harnesstom.eu/en/index.htm
AGENT H2020	https://www.agent-project.eu/
INCREASE H2020	https://www.pulsesincrease.eu/
BREEDINGVALUE H2020	https://breedingvalue.eu/
FORGENIUS H2020	https://www.forgenius.eu/
GEN4OLIVE H2020	https://gen4olive.eu/
COUSIN H-EU	N/A

4. List and brief description of the proposed services of the GRACE-RI

In this chapter a list of the possible services of the future GRACE-RI is presented (summarized in **Figure 3**) including a list of utilizers and providers for each service, based on the stakeholder groups described in the previous section. It is important to highlight that GRACE-RI will be the main provider of the services, as providers we listed the stakeholders, as part of GRACE-RI, that will be able to provide or contribute to the services in the framework of the RI.

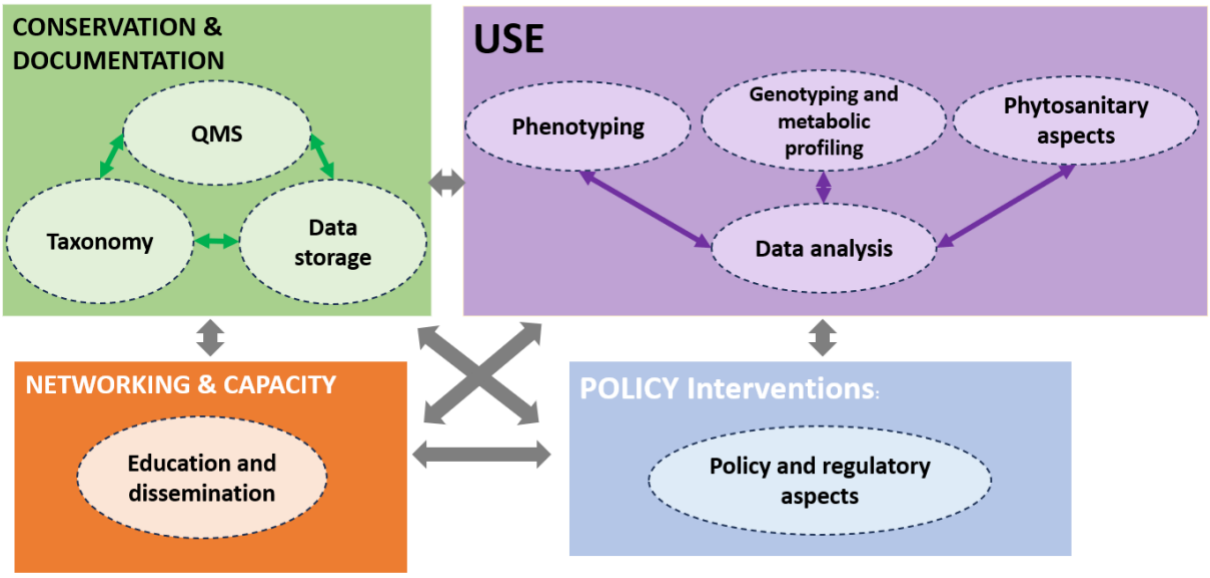

Figure 3. *Summary table of the proposed GRACE-RI services, grouped in the four categories (Conservation & Documentation, Use, Policy, Networking & Capacity) described in* ***Figure 1****.*

- **Quality management systems (QMS) for PGR conservation.** As mentioned in the introductory section, more than two million accessions of crops and their wild relatives are conserved *ex situ* in Europe by hundreds of institutes. To ensure that PGR are appropriately conserved and made available, which is a prerequisite for collaboration amongst genetic resources centres, quality standards should be harmonized, and quality management systems should be introduced in genebanks. To accomplish this, genebanks should have their protocols and procedures recorded in standard operating procedures (SOPs), and these SOPs should comply with agreed standards, based on the international FAO Genebank Standards (FAO, 2014). From the stakeholders' survey (see **Appendix I**), it emerged that standardization of procedures and protocols in all the different PGR activities should be one of the main goals for GRACE-RI, underlining the need for solid QMS. As highlighted by van Hintum et al. (2021), germplasm collections in Europe are very variable in terms of size, aims and compliance with FAO Genebank Standards. A certification and monitoring system should be established as a permanent service of the RI to enable the upgrade and harmonization of genebank operations in Europe. Different levels of QMS and certifications can be developed considering the different mandates and the type of services that the different genebanks operating in Europe provide. The AEGIS network has developed a QMS for AEGIS genebanks (AQUAS) that can serve as the basis for creating the QMS of the future RI (https://www.ecpgr.cgiar.org/aegis/).
  Ex situ conservation in genebanks is the predominant means of conserving and making PGR diversity available to users due to its reliability and efficiency. On the other hand, adopting a complementary approach that can conserve the great breadth of CWR and landrace diversity *in situ* and on-farm, while allowing the conserved resources to evolve in relationship to dynamic environmental changes, has the potential to at least double the diversity available to users (Maxted and Magos Brehm, 2023). Yet, although significant progress has been made in developing

methodologies for *in situ* genetic reserve and on-farm conservation, there are still few examples of their practical implementation and although a networking approach would seem logical, hardly any country has established national *in situ* or on-farm networks. GRACE-RI could support the establishment of national *in situ* and on-farm networks, the testing and refinement of methodologies (Maxted *et al,* 2002, Nilsen *et al,* 2017; FAO 2019; Magos Brehm *et al,* 2019) and *in situ* standards (Iriondo *et al,* 2012; Maxted *et al,* 2016) already proposed, and could investigate the potential for the establishment of a European network for *in situ* conservation and sustainable use of PGR. As part of this RI, it will be possible to have a board of experts that can establish a set of common rules for *in situ* conservation, and therefore apply a QMS system also to *in situ* and on-farm conservation programmes; this will include the safety duplication of unique accessions into *ex situ* repositories and guidance on the development of SOPs for *in situ* conservation.

As part of the QMS it is also important that genebanks and genetic reserves are regularly audited to ensure that all their SOPs are well documented and are being used in daily activities as well as being aligned to international standards. The RI will be able to provide this service of auditing among genebanks and *in situ* conservation sites, including capacity building on relevant aspects of the QMS (see also below the service on education and dissemination). As part of Horizon projects GenRes Bridge (http://www.genresbridge.eu/) and AGENT, the AEGIS network has prototyped a type of auditing (peer-reviews) among European genebanks (https://www.ecpgr.cgiar.org/aegis/aquas/peer-visits). These pilot reviews can help in establishing a certification system for European genebanks. Additionally, as part of the QMS, it will be important to enhance the safety duplication of germplasm materials across centres to avoid any loss of accessions. This is particularly relevant considering that a significant percentage of unique accessions at European level are conserved only in small genebanks and working collections. Recent incidents that affected large genebanks – such as the war in Ukraine (Global Crop Diversity Trust, 2022), the civil strife in Syria (Seed Vault, 2017) and typhoons in the Philippines (Grain, 2007) – highlighted the importance of safety duplication of PGR collections. The AEGIS safety-duplication policy recommends that identified safety duplicates be stored under the same or better conditions than the original at another AEGIS Associate Member genebank, possibly in a different country and/or at the Svalbard Global Seed Vault. Therefore, a natural candidate for the ultimate backup of orthodox seed accessions of PGR conserved in Europe is the Svalbard Global Seed Vault. The Seed Vault currently safeguards duplicates of more than 1 million samples, with room for millions more (Global Crop Diversity Trust, 2023). While duplicating orthodox seed accessions is relatively accessible and low-cost, the backup of field, *in vitro* and cryopreserved collections can be more expensive and technically and logistically challenging. The GRACE-RI will offer a good platform to find solutions for the safety duplication of these accessions (e.g. by identifying which European genebank can conserve these collections), making sure that unique collections are conserved for the long-term and that germplasm material conserved in genetic reserves is also duplicated in *ex situ* repositories.

As part of the proposed Infrastructure, it will also be possible to identify partners (private and public) that can provide fundamental services or offer capacity building to meet the minimum QMS requirements (e.g. seed drying, germination testing, *in vitro* subculturing, virus-indexing, field regeneration and multiplication, cryopreservation) to those genebanks that do not currently have appropriate facilities or capacities. The opportunity to delegate some of these services to specialized units will be elaborated during the development of the RI.

This service will aim to create a better-integrated network of 'certified genebanks'. Similarly, for *in situ* conservation, it will be possible to create a network of identified genetic reserves and on-farm programmes that conserve and keep available wild PGR and landrace collections, duplicated in *ex situ* collections.

Services in this category will be further refined based on output from Work Package 2 of PRO-GRACE, which is developing a vision for a QMS system for PGR conservation in Europe, considering both *ex situ* and *in situ* conservation, with planned deliverables outlining minimum quality standards for genebank operations (D2.1) and *in situ* management (D2.3), blueprints for a genebank quality certification system (D2.2), constructing national inventories of *in situ* PGR (D2.5,

these inventories can also guide in completing national FAO Agrobiodiversity Target Indicators) and capacity building programmes (D2.4), as well as a system for unique identification of PGR in *ex situ* and *in situ* collections (D2.6).
Utilizers: Genetic resources centres, *in situ* genetic reserves.
Providers: The provider of this service could be an independent entity within GRACE-RI in collaboration with the utilizers (genebanks and genetic reserves) and employing also the expertise and facilities of these stakeholders: other private services providers, PGR conservation and research networks, public research centres, seed companies.

- **Taxonomy.** Rapid advances in genetics have led to the revisions of the taxonomic treatments of many species of crops, CWR and other wild PGR. This can cause a high occurrence of taxonomic errors in the passport data of conserved accessions/populations that can prevent the clear establishment of the accessions' taxonomic identity, with consequences for their conservation and use (Guzzon and Ardenghi, 2018). Taxonomic authorities for each crop/family could be established as part of the RI, to prevent taxonomic misnaming issues from occurring as well as to update the taxonomic treatment of the target species in the relevant databases (while conserving and keeping available information on the previous taxonomic treatments). In order to achieve this, an important starting point would be to survey existing taxonomic treatments and databases to understand which ones could be adopted as part of GRACE-RI. Some examples of relevant databases are: GRIN Taxonomy (https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch), the Royal Botanic Gardens, Kew's Plant of the World Online (https://powo.science.kew.org/), World Flora Online (https://www.worldfloraonline.org/) and, at the European level, the Euro+Med PlantBase (https://www.emplantbase.org/home.html). This service will also offer the opportunity to identify herbaria that can host and/or duplicate herbarium vouchers of the conserved accessions/populations and whose expertise could be fundamental in validating the identity of the collected and conserved accessions. A similar approach can also be used to identify repositories for DNA samples. This taxonomic validation service will be particularly important for CWR and other wild PGR, whose species attribution in the field is sometimes complex for non-experts in that particular genus/species. This service will provide taxonomic validation in cases where genebank personnel or recipients of the germplasm material have doubts about the taxonomic identity of the material (e.g. during regeneration/seed multiplication stages). Besides more traditional methods, such as species identification via herbarium vouchers, the genotyping service highlighted below will also be useful to facilitate DNA fingerprinting analyses to validate the species identity and cultonomy of accessions with potential misnaming errors. The Lifewatch RI is developing several services that run taxonomic checks on taxonomic and common species names (https://www.lifewatch.eu/thematic-services/). Similarly, DiSSCo is working on aggregating taxonomic data (DiSSCo, 2017). These services provided by the other RIs could be integrated with the ones provided by GRACE-RI.
  Utilizers: Genetic resources centres, *in situ* genetic reserves, public research centres and seed companies (scientists and breeders).
  Providers: Other RIs (Lifewatch), PGR conservation and research networks, public research centres.

- **Data storage, completeness and availability.** The value of PGR accessions lies not only in the germplasm material itself but also in the associated passport, phenotypic and genomic data. GRCs across Europe use different documentation systems, either employed by several collections across the globe, e.g. Grin Global (https://www.grin-global.org/) or Brahms (https://herbaria.plants.ox.ac.uk/bol/brahms), or locally customized systems. From their documentation systems, more than 400 European genebanks contribute to EURISCO, which provides passport and phenotypic information for more than 2 million accessions of crop plants and their wild relatives, conserved *ex situ* (EURISCO, 2023). As noted above, however, passport data are not always consistently complete, and taxonomy may require reviews.

Phenotypic data are even more fragmented, being often generated in collaboration with external partners in different projects and stored as data sets linked to publications, sometimes in dedicated databases (e.g. ENA, European nucleotide archive, https://www.ebi.ac.uk/ena/browser/home) or in public repositories (e.g. Zenodo: https://zenodo.org, Dryad: https://datadryad.org, e!DAL: https://edal.ipk-gatersleben.de). Databases emerged as the most important service currently used by PGR stakeholders in the recent PRO-GRACE workshop. In the same framework, several issues on data availability and interoperability were highlighted (see **Appendix I**). These issues are perceived as important bottlenecks by PGR stakeholders and the need to create a centralized hub for information on PGR at European level was underlined. The GRACE-RI will therefore support FAIR data management and data quality control through validation procedures. It will develop and promote common guidelines and best practices for (meta)data collection, services to support data deposition in recommended databases and interoperability between these databases. It will promote EURISCO as a central hub for storing PGR data at European level, including *in situ* conservation. Actions to facilitate the reuse of data will include improving the procedures for data-capturing (e.g. by implementing automated data collecting systems and barcoding) as well as storage (promoting the utilization of multi-functional databases that allow data collection and reporting, e.g. Grin Global Community Edition) while strengthening EURISCO as a central hub for data of European PGR collections. This will help manage germplasm collections and the availability of accession data in public databases. Moreover, as part of GRACE-RI, there will be the opportunity to link collections' data with genotyping and phenotyping information from different data repositories. The RI will promote the use of Digital Object Identifiers (DOI) for any PGR as well as BioSamples IDs (https://www.ebi.ac.uk/biosamples/) for samples derived from these PGR for interoperability with genomic data. These tools can facilitate the accurate identification and provenance of germplasm material and the interoperability of information derived from its use. In PRO-GRACE, Work Package 1 is working on developing standards for PGR data collection, management and interoperability, producing standards for collecting and displaying phenotypic (D1.1) and genotypic (D1.2) data, developing a system for interfacing *in situ* information with EURISCO (D1.3) and a standard for minimum information about a biological collection (D1.4), as well as a strategy for interfacing of different information systems with EURISCO (D1.5). These outputs will inform the data services provided by the future GRACE-RI.

Utilizers: Genetic resources centres, *in situ* genetic reserves, public research centers, seed companies.

Providers: Genetic resources centres, other RIs (ELIXIR, DISSCO), PGR conservation and research networks, public research centres.

- **Phenotyping.** Novel alleles for breeding are often discovered through phenotyping activities (i.e. characterization and evaluation) performed by genebank staff, researchers or breeders, providing significant genetic gains for the selection of favourable traits. New technologies for high-throughput phenotyping are available for scientists allowing for time and cost-effective screening tools to obtain valuable phenotypic data for more traits on large germplasm collections. The utilization of these phenotyping tools, coupled with high-throughput genotyping, will accelerate the use of genetic resources and fast-track the development of more resilient food crops. Nevertheless, the application of high-throughput phenotyping is not a widespread practice in genebanks (Nguyen and Norton, 2020). GRACE-RI will provide a unique opportunity for strengthening the PRGFA phenomics at European level, including enhancing collaborations with universities, research institutes and industries ensuring that the resulting phenotypic data are comparable across institutions. Moreover, as part of this RI, standard characterization and evaluation protocols for different crops will be developed with the involvement of research institutes that have been working on these protocols and shared with the users. The aforementioned ECPGR initiative EVA, a collaborative project involving public and private sector partners, is already generating standardized evaluation data for numerous crop accessions available in European genebanks. It can provide a good model to deliver this service as part of the

GRACE-RI. Furthermore, the EMPHASIS RI is also working to develop high-throughput phenotyping services, including multi-site phenotyping, fostering innovation in plant phenotyping technologies, data analysis and mathematical modelling (https://emphasis.plant-phenotyping.eu/). It is therefore important to integrate these services across RIs and connect EMPHASIS with GRACE-RI. A workshop on the evaluation of *ex situ* and *in situ* PGR collections, co-organized with EMPHASIS, will be organized (D4.2) to strengthen the connection between the two RIs. Work Package 4 of PRO-GRACE is developing unified standards for crop phenotyping (D4.1 and D4.3) as well as strategies for the interconnection of the different phenotyping databases with the central EURISCO information system (D4.4). These deliverables will inform the specific services related to phenotyping provided by GRACE-RI.
Utilizers: Genetic resources centres, public research centres, seed companies.
Providers: Genetic resources centres, NGOs, other private services providers, other RIs (EMPHASIS), PGR conservation and research networks, public research centres, seed companies.

- **Genotyping, resequencing, cytogenetics and metabolic profiling.** In the current scenario of increasing utilization of PGR in plant breeding to expand the eroded genepool of elite varieties, several genebanks are in the process of genotyping or sequencing their entire collection of accessions (Bassi *et al,* 2023). It is envisioned that in the near future breeding programmes at risk of losing variation in a specific region or for a specific trait would become able to query international databases (e.g. Genesys, Germinate) to identify the needed variation and acquire it from the genebanks (Bassi *et al,* 2023). The genotypic data can also guide genebank management, in terms of identifying duplicated accessions and gaps of diversity within and across genebanks and contribute to quality control during regenerations. GRACE-RI could coordinate the genotyping effort of European genebanks (in collaboration also with the private sector), by identifying institutions that can provide this service and bridging (if needed) users and the providers. This will assist in making sure that genotyping, resequencing and cytogenetic services, as well as data analysis and interpretation services are accessible to genebank managers and researchers to identify unique crop diversity and mine the collections for potentially useful traits. The RI will also be able to centralize genotyping efforts to make them more cost-effective, making it possible to genotype larger sample sizes, combining samples from different genebanks. GRACE-RI will also promote the development of services for the identification of metabolites relevant to plant performance and food/feed quality in PGR collections. Work Package 3 of PRO-GRACE is working on the demonstration of genomic (D3.2) and metabolomic (D3.3) methods relevant to genebank management, developing also simplified sample collection protocols (D3.1) that will facilitate access to genotyping, phytosanitary and metaboloic profiling services.
  Utilizers: Genetic resources centres, *in situ* genetic reserves, public research centres, seed companies.
  Providers: Private services providers, public research centres.

- **Data analysis.** The above-mentioned advances in genotyping and phenotyping technologies as well as the strengthening of data repositories will make available a large amount of data, including fundamental passport data as well as data on the management and monitoring of *in situ* and *ex situ* collections. These data can guide the conservation and use of PGR at European level. They will allow the identification of 1) duplicates within and across germplasm collections, assisting with the rationalization of large collections (Singh *et al,* 2019), 2) unique, potentially uncollected accessions (e.g. from on-farm projects or *in situ* genetic reserves) that should be incorporated into *ex situ* repositories, and 3) priority populations of CWR and other wild PGR for active *in situ* conservation. Moreover, the exploitation of these data, through bioinformatic tools, will also dramatically increase the possibility of mining germplasm collections for potentially beneficial traits, and therefore enhance the use of germplasm material in breeding programmes. The availability of genotypic and phenotypic data will allow the use of genomic selection tools for the prediction of genetic values and therefore identify traits of interest for breeding in the conserved accessions (Burgueño *et al,* 2012). Core collections within or among genebanks could be established for

different crops, to carry out genome-wide association studies (GWAS). Finally, bi-parental mapping populations could be generated and used for QTL analyses. However, it is not always possible for genebanks to dedicate time and resources to these activities, as they require specific expertise and appropriate funding. Therefore, as part of GRACE-RI, it will be of great importance to identify research institutions (private and public) that, besides providing ad hoc bioinformatic pipelines, can regularly assist with the data analysis and interpretation of passport, phenotypic and genotypic data that can guide and optimize genebank operations and impacts. Several EU-funded projects have developed pipelines and bioinformatics tools that could be used by genebanks for data management and analysis. This service will also allow the compilation and development of tool sets for data analysis as well as capacity-building opportunities for the researchers who want to use them. Deliverable 3.5 of PRO-GRACE is dealing with the demonstration of bioinformatic methods and services for kinship/population structure/pedigree determination, gap analyses, GWAS and QTL analyses.
Utilizers: Genetic resources centres, *in situ* genetic reserves, public research centres, seed companies.
Providers: Public research centres, private services providers.

- **Phytosanitary aspects.** Genebanks must ensure that the germplasm that they distribute globally to farmers, researchers and breeders is free of pests and diseases of quarantine concern. To do so, germplasm health units (GHUs) such as the ones of the CGIAR Genebank Initiative are needed to characterize the health status of the accessions (Kumar *et al,* 2021). GHUs deal with the development and application of diagnostic tools for health testing as well as with the cleaning of contaminated seed and planting material for pest elimination. These actions prevent the spread of pests and diseases as part of germplasm distributions and allow genebanks to keep available the largest percentage possible of their collections for users. GHUs also have an important function in ensuring the compliance of each germplasm distribution and import from and to genebanks to national and international phytosanitary requirements. The mission of GHU includes a lot of research work, in order to optimize protocols for diagnostic and cleaning as well as provide surveillance for pests' risks. While some of the largest European genebanks have GHUs and provide material that is tested as free of pests and diseases of quarantine concern, many organizations do not have easy access to phytosanitary-related services. As part of this RI, it will be possible to establish a steering group and/or a community of practice at continental level (including public and private partners), ensuring that all germplasm distributed by genebanks is free of diseases of quarantine concerns as well as providing phytosanitary surveillance services. Deliverable 3.4 of PRO-GRACE is dealing with the demonstration of methods and services for *ex situ* and *in situ* phytosanitary surveillance and phytosanitation of contaminated unique material and will inform the shape of this service of the future GRACE-RI.
  Utilizers: Farmers, genetic resources centres, NGOs, public research centres, seed companies.
  Providers: GRACE-RI (including through a dedicated pan-European plant quarantine infrastructure), private service providers, public research centres.

- **Policy and regulatory aspects.** The rules contained in international treaties and national laws that govern access and benefit-sharing (ABS) of PGR are very complex and not always easily understandable for the intended PGR utilizers. Furthermore, even when researchers are aware of international agreements and laws, there is often a lack of understanding about how best to comply with potentially applicable requirements (Marden *et al,* 2023). The three key international agreements that govern access and use of PGR are 1) the Convention on Biological Diversity (CBD) (https://www.cbd.int/), 2) the ITPGRFA (https://www.fao.org/plant-treaty/en/); 3) the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (https://www.cbd.int/abs/about/). The level of ratification of these agreements varies across countries, increasing the complexity of potentially applicable regulations. GRACE-RI can guide stakeholders on navigating these rules (including relevant national laws) and how to comply with their requirements (see also the below

service on education and dissemination). In the results of the stakeholders' survey presented in **Appendix I**, policy and legal aspects of PGR availability emerged as a potential challenge for the activity of the future Infrastructure. This reinforces the need for strong guidance on policy and regulatory aspects in the framework of the new GRACE-RI. Moreover, the RI could provide expert advice to European legislators in the ratification and implementation of these international rules, solving current inconsistencies in their implementation with the aim of enhancing the access and use of PGR at national and European level (ECPGR, 2021). Additionally, the accessibility of germplasm material conserved *in situ* is not always clear from a legal point of view and might be subjected to different national and local legislations. The RI has the opportunity to clarify the legal status of *in situ* collections by promoting a European legal framework to facilitate the *in situ* and *ex situ* conservation, use and documentation of PGR (Marden *et al,* 2023). Another issue complicating PGR management and use is the Digital Sequence Information (DSI) concept. It originated in CBD and its Nagoya Protocol but immediately propagated to other fora such as the FAO ITPGRFA and the CGRFA. There is concern that uncertainty surrounding the use and regulation of DSI might hinder the exploitation of PGR, limiting the use of associated information such as sequencing data, which can foster PGR conservation and exploitation (Cowell *et al,* 2021). This service could advise PGR researchers on the international regulations on DSI. The RI can also provide guidance to stakeholders on intellectual property (IP) rights and cultivar registration. Finally, this service could guide researchers on ethical issues regarding PGR conservation and sustainable use and associated data (including traditional knowledge).
Deliverable 5.6 of PRO-GRACE is carrying out an analysis of the ethical, social and regulatory aspects of the transition of the present PGR system to an integrated pan-European Research Infrastructure. This is a very important preparatory work to fully implement the GRACE service on policy, ethical and regulatory aspects.
Utilizers: Farmers, genetic resources centres, *in situ* genetic reserves, NGOs, policymakers and legislators, public research centres, seed companies.
Providers: PGR conservation and research networks, policymakers and legislators, public research centres.

- **Education and dissemination.** Despite the relatively high number of scientists working in Europe in PGR conservation and use, few higher education courses exist that aim at developing the next generation of genebank and genetic reserve managers, and PGR researchers. From the results of the recent PRO-GRACE workshop, it emerged that training would be the service that stakeholders would like to access the most and that sharing of expertise across partners could be the greatest opportunity for GRACE-RI (**Appendix I**). This reinforces the importance of setting up solid capacity-building and knowledge-exchange programmes in the framework of GRACE-RI. Besides the MSc in Plant Science with a specialization in Plant Breeding and Genetic Resources at Wageningen University & Research, to the best of our knowledge, there is currently no university programme in Europe fully dedicated to PGR conservation and use. Nevertheless, there are 77 MSc programmes in Plant & Crop Sciences currently active in Europe that include PGR components and courses in their curricula (retrieved from: https://www.mastersportal.com/). As part of this service, it will be important to connect with existing courses and education programmes in order to develop capacity-building opportunities at all levels, covering all the different aspects of conservation and use of PGR, from collecting to breeding, including taxonomy, conservation planning, *in situ*/*ex situ* conservation, data management and analysis, applied genetics, characterization and evaluation, breeding, policy and management aspects. A panel of experts will be created to develop education modules for the different aspects of PGR conservation, characterization and use. The rapid development of learning management systemscan facilitate the use of e-learning and therefore allow the reach of a wider audience of interested students and professionals in Europe. Some relevant education modules on PGR already exist (e.g. at the Alliance of Bioversity International and CIAT and the University of Birmingham); the education services of GRACE-RI can build on these already existing modules. The ongoing PRO-GRACE project is realizing two training events on PGR, which can serve as the basis for developing a GRACE

training strategy. As part of the future RI, there will also be the opportunity to support the open-access publication of research findings, enhancing also the dissemination of scientific papers e.g. results of characterization, collecting missions and PGR inventories, which are important references to plan conservation and use of PGR. The diamond open-access journal *Genetic Resources* (https://www.genresj.org/), currently managed by ECPGR and conceived as part of the GenRes Bridge project, would represent a good platform for these dissemination activities and could be and important service provided by the RI for all PGR stakeholders. Moreover, GRACE-RI will need to coordinate internal communications across the partners of the RI and facilitate outreach activities related to research and conservation on PGR, making them more accessible to the general public. It will also be important to maintain and foster the relationship with other RIs on shared topics (e.g. phenotyping, data management and analysis). All these activities will create more awareness on PGR, highlighting their relevance for sustainability as well as food and nutritional security. This will also increase the attention of policymakers and funding agencies on PGR-related activities. Raising awareness will be particularly relevant considering that long-term germplasm conservation requires sustainable and stable funding, and that the contribution of PGR conserved in genebanks to breeding is predicted to increase in the current climate change scenario and thanks to the advances in breeding and genomics (Kilian *et al,* 2021, Bohra *et al,* 2022). A specific unit of the RI will work to ensure that outreach products on PGR research carried out across the infrastructure are widely available and accessible to the public. PRO-GRACE's Work Package 6 focuses on communication, dissemination, exploitation and training aspects, collaborating with other work packages to identify relevant topics that could become part of the GRACE-RI training and communications services.

Utilizers: Farmers, genetic resources centres, *in situ* genetic reserves, NGOs, policymakers and legislators.

Providers: *In situ* genetic reserves, genetic resources centres, NGOs, PGR conservation and research networks, public research centres.

5. Conclusions

Figure 4 maps the connections between different stakeholders and services identified in this document. As mentioned in the Introduction, this deliverable will be further developed in a second iteration (D5.5), which will refine the list of potential services that GRACE-RI will provide as well as the list of stakeholders. Here we list some points that deserve further discussion and that should be addressed as part of the second version of this document but also in other relevant deliverables (e.g. D5.3 'Financial plan for the proposed infrastructure' and D5.4 'Governance structure of the proposed infrastructure').

- Several deliverables of PRO-GRACE are under development; these will help to clarify the vision for the future GRACE-RI. In particular, different aspects of data management, structure of the services as well as governance and financial aspects of the future Research Infrastructure will be outlined in these deliverables. These findings should be integrated into the second iteration of this document (D5.5).
- As highlighted in **Appendix I**, the feedback of stakeholders is very informative and important in understanding the needs of the users and providers in terms of access to data and services as well as their vision for the future GRACE-RI. In the preparation of the second iteration of this document, it will be important to carry out a wider survey of potential stakeholders of GRACE-RI, to assist in refining the map of stakeholders and services as well as provide useful information when setting up the governance structure.
- Several stakeholders and services are considered as part of the future GRACE-RI. In particular, service providers have often been identified as broad potential categories. In the next

iteration, it will be useful to pinpoint how the responsibility of providing services can be assigned to and shared by the appropriate stakeholders.

- The types of services that GRACE-RI will ultimately provide, and its main users will need to be considered when developing the financial plan for the proposed infrastructure (D5.3), in order to define the appropriate business plan that can secure institutional support to sustainably implement GRACE-RI.
- It will also be of great importance to have a well-defined governance structure that will enable the provision of GRACE-RI services and facilitate the interaction between providers and utilizers of the RI (D5.4). In particular, it will be key to define coordination between 1) the transnational technical development of services, 2) the national implementation of services, 3) transnational/sometimes centralized implementation of services, 4) opportunities of integrating services with other RIs, and 5) the mission and role of ECPGR and GRACE-RI: how they will support each other and what tasks would be specific of each organization; this could be included as part of the governance structure and will require consultation with the ECPGR Steering Committee.

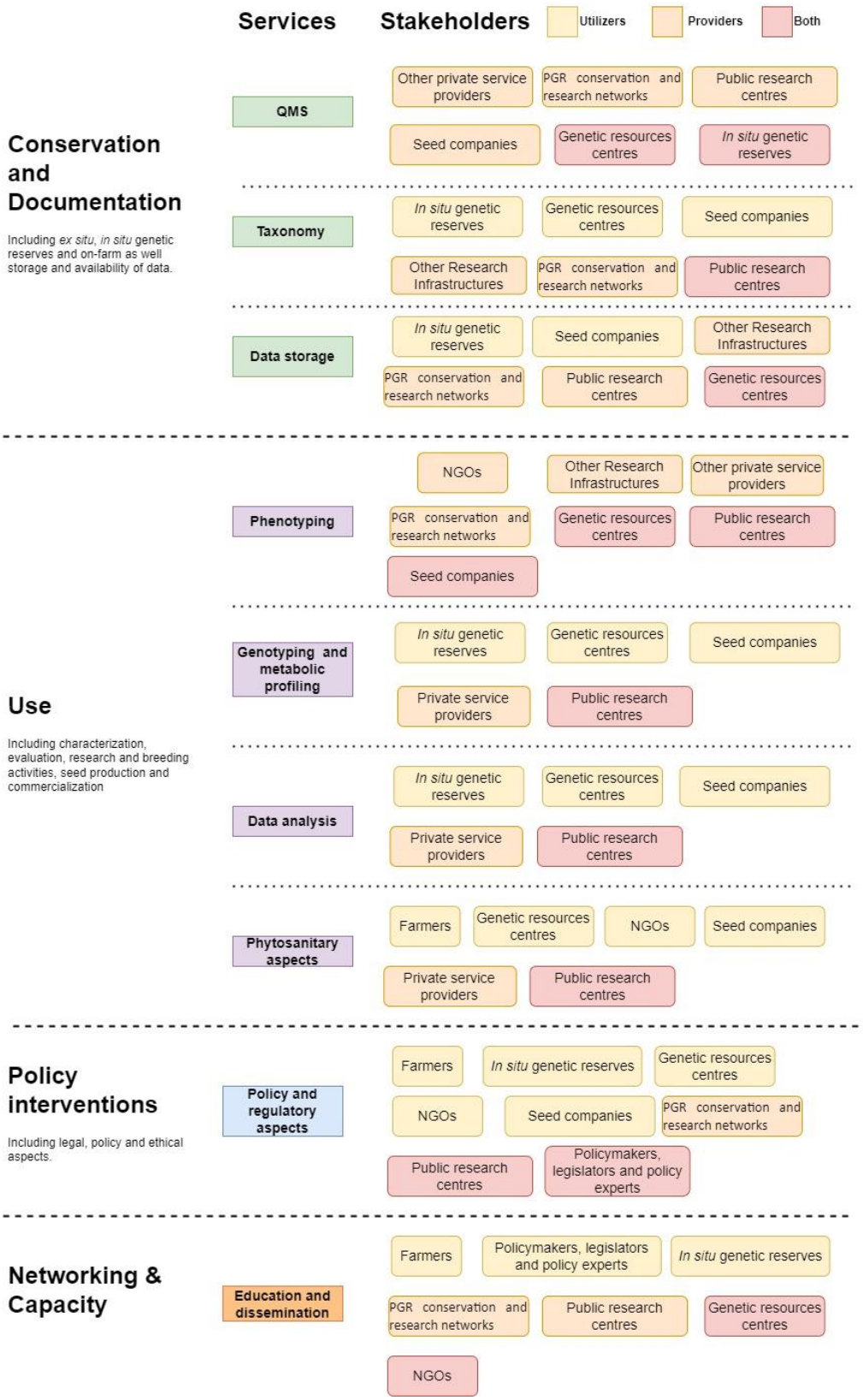

Figure 4. *Map of the proposed services of GRACE-RI, divided into the four main categories (Conservation & Documentation, Use, Policy, Networking & Capacity). Stakeholders are identified as utilizers (in yellow), providers (in orange) or utilizers and providers (in red) of the service.*

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Appendix I

Results of the session 'Stakeholders, services, sustainability – Visions for the future GRACE-RI' held in Chania on 4 October 2023.

Filippo Guzzon, Sandra Goritschnig (ECPGR)

Summary

During the first international workshop on "Sustainable Management of Plant Genetic Resources (PGR)", held in Chania (Greece), which was organized in the framework of the PRO-GRACE project, an interactive session on 4 October 2023 engaged project partners and stakeholders in a discussion on central issues for the development of a future European research infrastructure (RI) for PGR (GRACE). This session was organized by pro-GRACE work package 5 partners in order to collect input for the development of deliverables related to the structure and governance of the GRACE-RI.

More than 50 participants engaged in groupwork both online and in person to identify: 1) the most likely stakeholders of the future RI (both as users and providers), 2) the main services that they currently use in their work on plant genetic resources for food and agriculture (PGR) and that they would like to see provided by the future RI, 3) which elements need to be considered when developing a governance structure and financial plan of the future GRACE-RI and 4) the future RI's main opportunities and challenges.

Participants expressed a clear need for establishment of a dedicated RI for PGR, which would serve mainly genebanks and researchers, but also breeders and farmers as a one-stop shop for their needs in conservation and utilization of PGR. The main services currently used on PGR are related to conservation (both *ex situ* and *in situ*) and data generation, management and analysis. In the future, participants would also like to be able to access training, standardized protocols and support for legal and policy issues through the GRACE-RI. Current bottlenecks, such as lack of harmonized standards and protocols, issues with data accessibility and interoperability as well as lack of staff, capacity and facilities could be addressed through the development of a GRACE-RI that would provide access to dedicated PGR services. Stakeholder representation, effective communication and dissemination of service outputs and the need for agile, coordinated leadership were considered important elements for the governance of GRACE-RI with political support from host countries highlighted as essential. This is reflected also in the observed need to gain governments' and the EU's commitment to supporting GRACE financially, which together with support from third party users of the services will contribute to the RI's financial sustainability.

Establishing the GRACE-RI will contribute to connecting the European PGR community, improving PGR conservation, access and use, implementing quality standards in conservation and data collection and management, and through provision of complementary services connect with and fill gaps in the current European RI system. The main challenges that the GRACE-RI will face in its development and implementation are funding, the diversity of stakeholders and their visions as well as legal and political issues related to PGR availability.

Taken together, the interactive session highlighted important aspects that will be considered during the development of the GRACE-RI. This process will continue engaging more stakeholders of the future RI in dedicated surveys to collect information that will feed into proposed services, governance structures and financial planning.

Introduction

Work package 5 of the Pro-GRACE project is tasked with developing the concept of a future European Research infrastructure (RI) specifically dedicated to PGR: GRACE, A Plant Genetic Resources

Community for Europe. This includes positioning the proposed GRACE within the European RI ecosystem, identifying main stakeholders and services and developing a governance structure and financial plan for GRACE-RI.

To gather input from partners and stakeholders, an interactive, hybrid workshop session: "Stakeholders, services, sustainability – Visions for the future GRACE-RI" was carried out 4 October 2023. This was part of the PRO-GRACE workshop: "Sustainable Management of Plant Genetic Resources (PGR)", held in Chania (Greece) at the Mediterranean Agronomic Institute of Chania (MAICH), on the 3-4 October 2023. Questions were asked to the participants through SLIDO, an anonymous surveying tool, then the participants were split into groups (in person or through Zoom breakout rooms) to discuss different topics on the current PGR scenario in Europe and visions for the future GRACE-RI.

Here below the results of the workshop are presented. The responses were summarized in standardized categories, where possible. The categories that were mentioned by just one response were grouped as "others".

Results of the SLIDO survey

The question "Do we need a dedicated PGR RI in Europe?" was asked at the beginning and at the end of the workshop session. There was a wide consensus among the respondents that a future RI dedicated to PGR is needed in Europe (**Figure 5**).

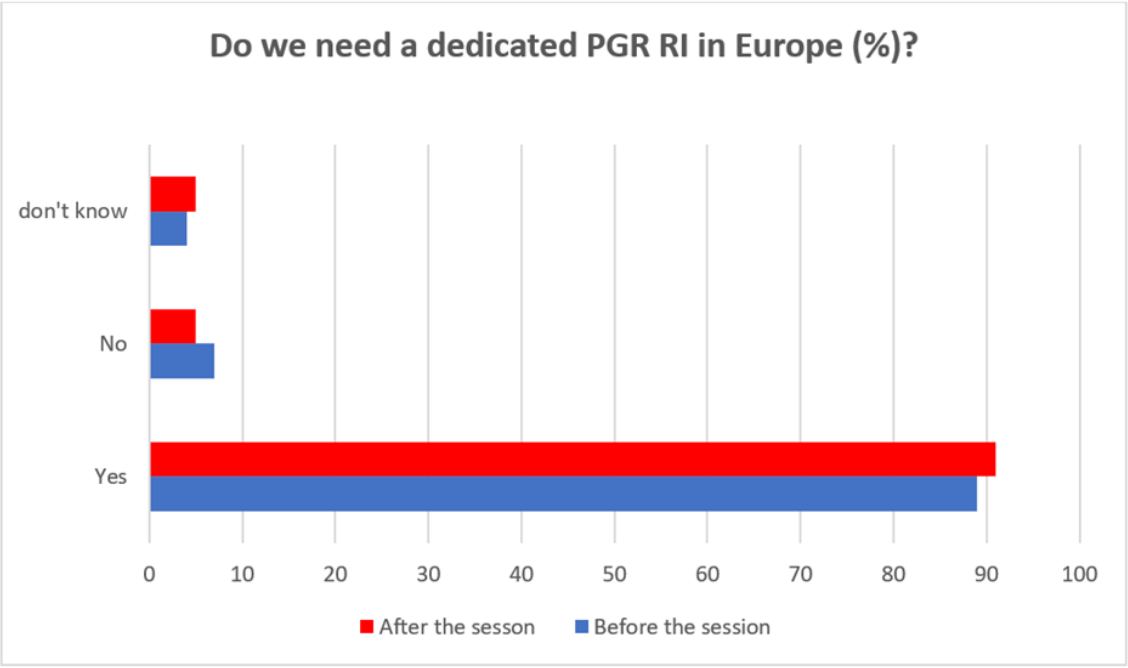

Figure 5. *Results of the first SLIDO survey: "Do we need a dedicated PGR RI in Europe" (45 and 44 responses at the beginning and at the end of the workshop session respectively)*

Through the second and third questions ("Who will be the main users and providers of GRACE-RI?"), it emerged that the participants believed that genebanks and researchers will be the main users and providers of GRACE-RI (see **Figure 6**). Breeders and farmers are also important users of a future GRACE-RI. Other users could be the EU Commission, gardeners, our (grand-)children and the PGR community more in general. Workshop participants identified data scientists and repositories, governments, *in situ* conservers, industries, lawyers, the PGR community, seed companies, start-ups and universities as potential other service providers.

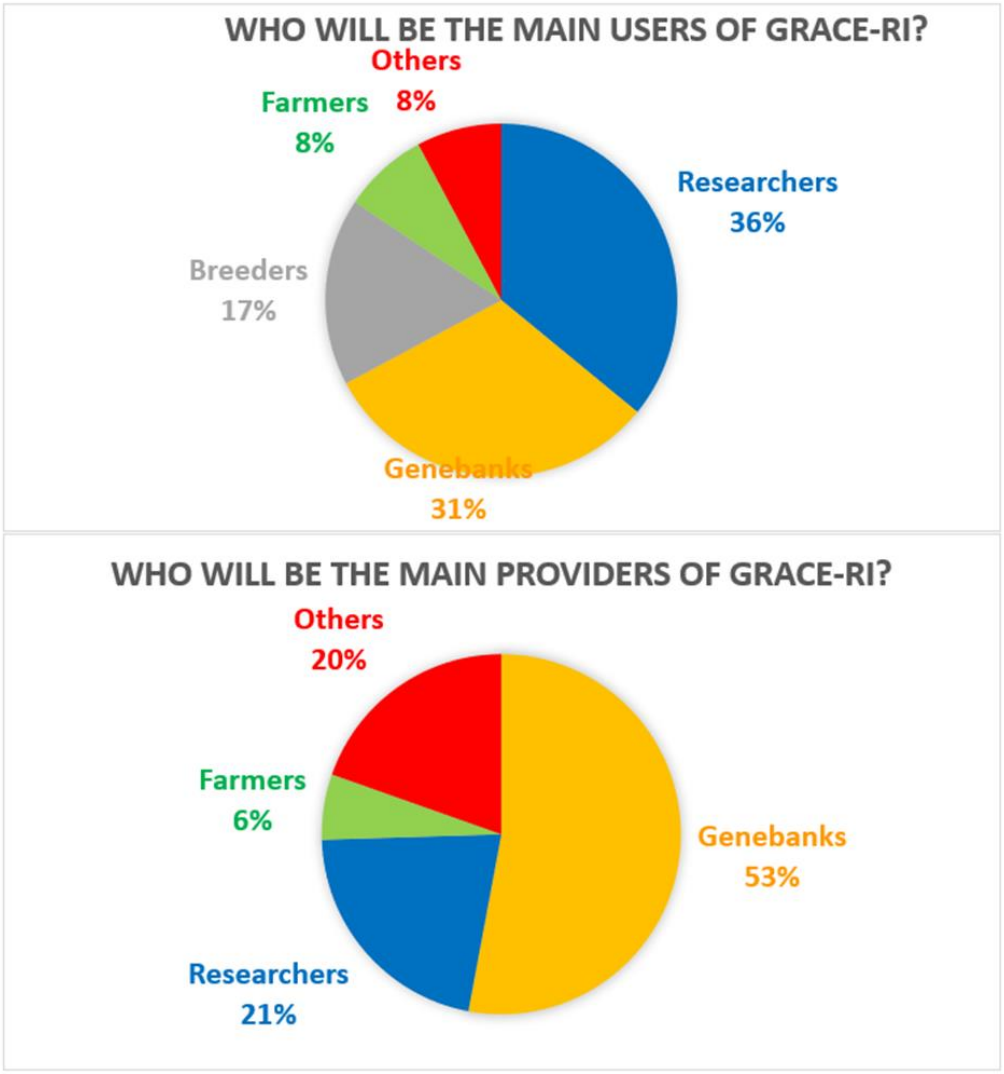

Figure 6. *Results of the SLIDO surveys: "Who will be the main users and providers of GRACE-RI?" (56 and 53 responses respectively).*

It also emerged that data-related services and training are the services that the participants would like to use the most, followed by need for standard protocols and a common platform for PGR as well as legal and policy support (**Figure 7**).

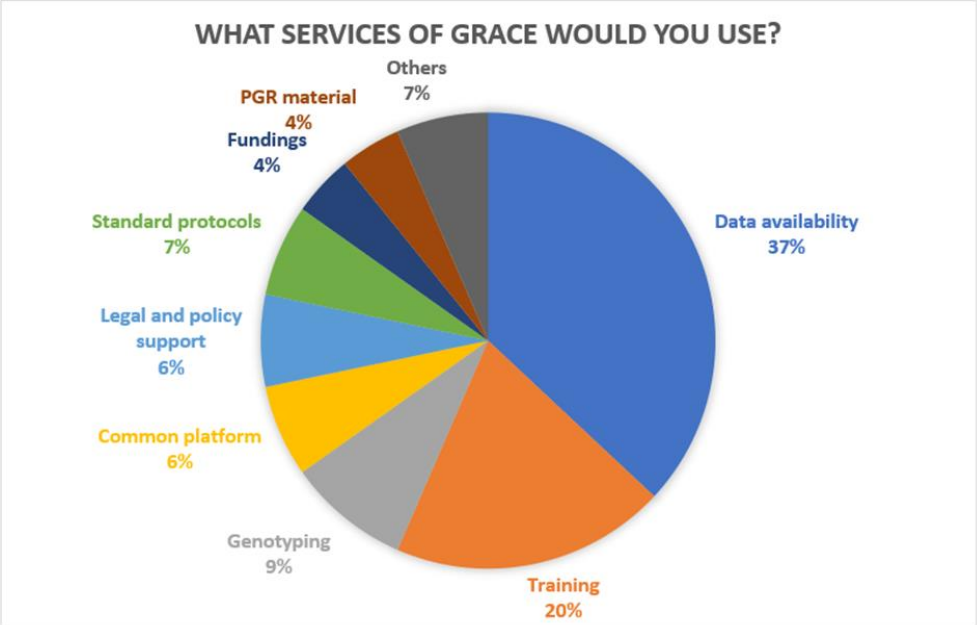

Figure 7. *Results of the SLIDO survey: "What service of GRACE-RI would you use" (48 responses).*

Results of the groupwork

As mentioned, after the SLIDO surveys, the audience was divided into groups (using Zoom breakout rooms for online participants) and two groupwork sessions were organized, with 40 minutes in total for the groups to work on questions on the current PGR services in Europe and a future vision for GRACE-RI.

Results of 13 groups (9 in person and 4 online, 48 and 18 participants respectively), were collected by pre-assigned rapporteurs for further analysis. Text responses were summarized in standardized categories and presented as pie charts (% of the total responses) or funnel charts (% of the groups that gave the same answer). Again, categories that were mentioned by just one response were grouped as "others" for this analysis, but may be useful input for further development of the deliverables related to services, structure and governance of GRACE-RI.

PGR Services

Databases and genebank services (including access to PGR material but also to other conservation services, e.g. *in situ*, cryopreservation, *in vitro* conservation) are the services that are currently most used, followed by genomics and phenomics services (**Figure 8**).

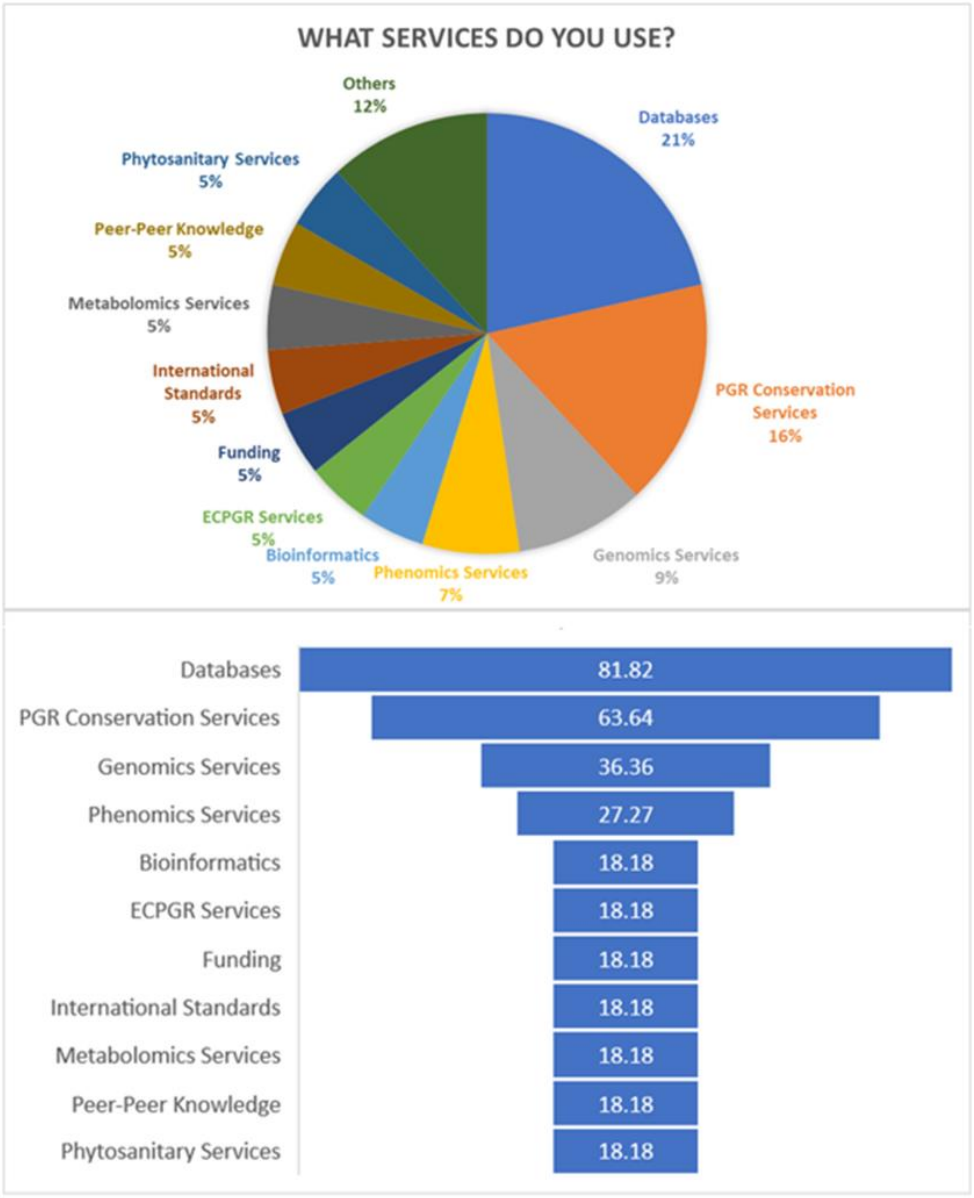

Figure 8. *Results of the first question of the groupwork: "what services do you use/have access to?" The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=11).*

Lack of funding as well as data-related issues (access to data, interoperability and inconsistent standards) are listed as main bottlenecks to access PGR-related services at the moment. Lack of capacity, difficulties in accessing PGR material, as well as issues related to policy regulations on PGR were also mentioned (**Figure 9**).

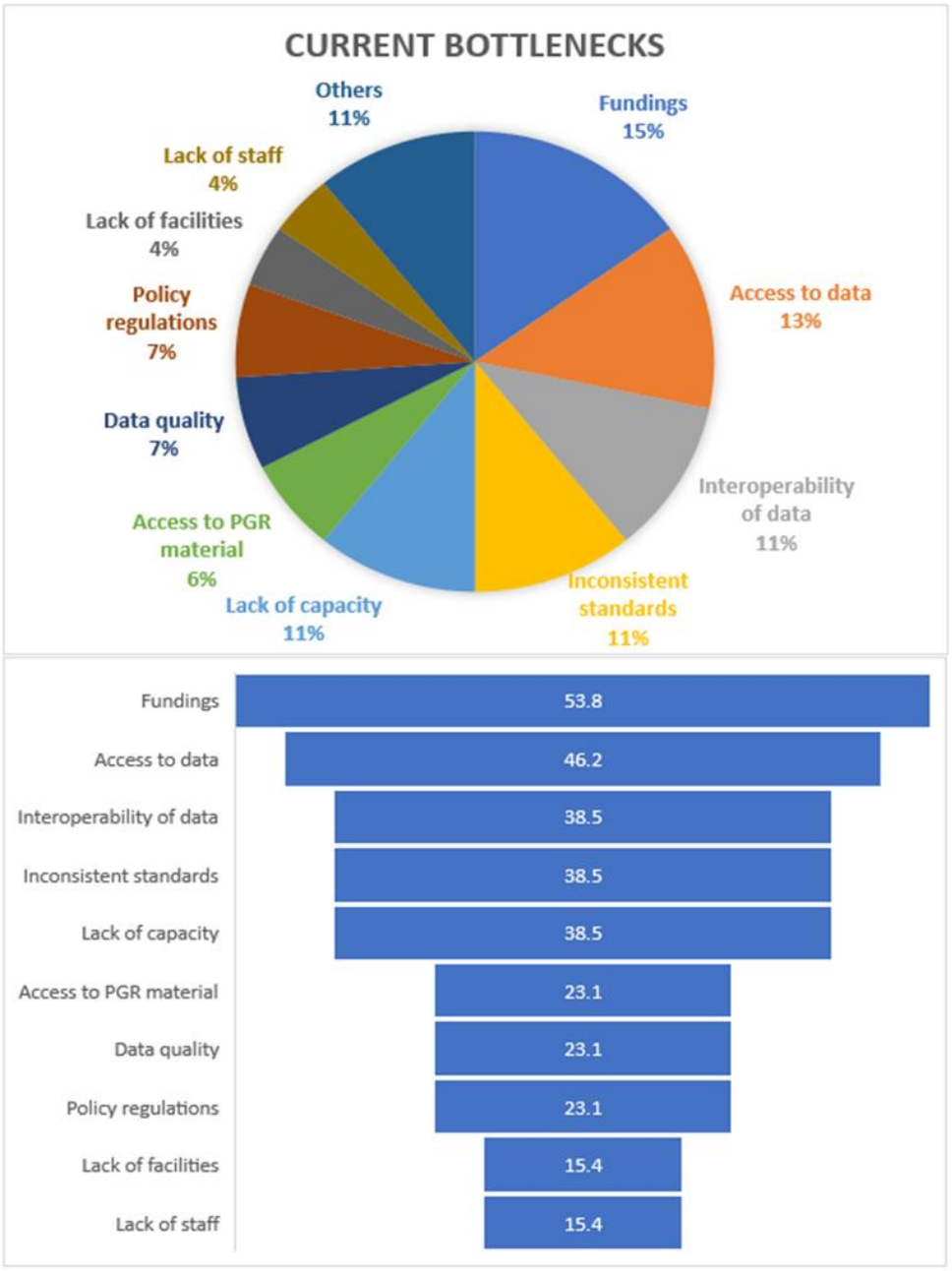

Figure 9. *Results of the question of the groupwork: "What are the bottlenecks in accessing them?". The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=13).*

Training, the creation of a centralized hub for PGR-related services and information as well as the standardization of procedures are the main services that the participants would like to have access to. Awareness on PGR, genomic services, QMS on PGR conservation and use as well as access to research visits were also mentioned as important future services (**Figure 10**). Among other services that could be interesting for individual users of the GRACE-RI are: CWR-related information, legal and policy advice, phytosanitary services, support for smaller genebanks and support for *in situ* conservation.

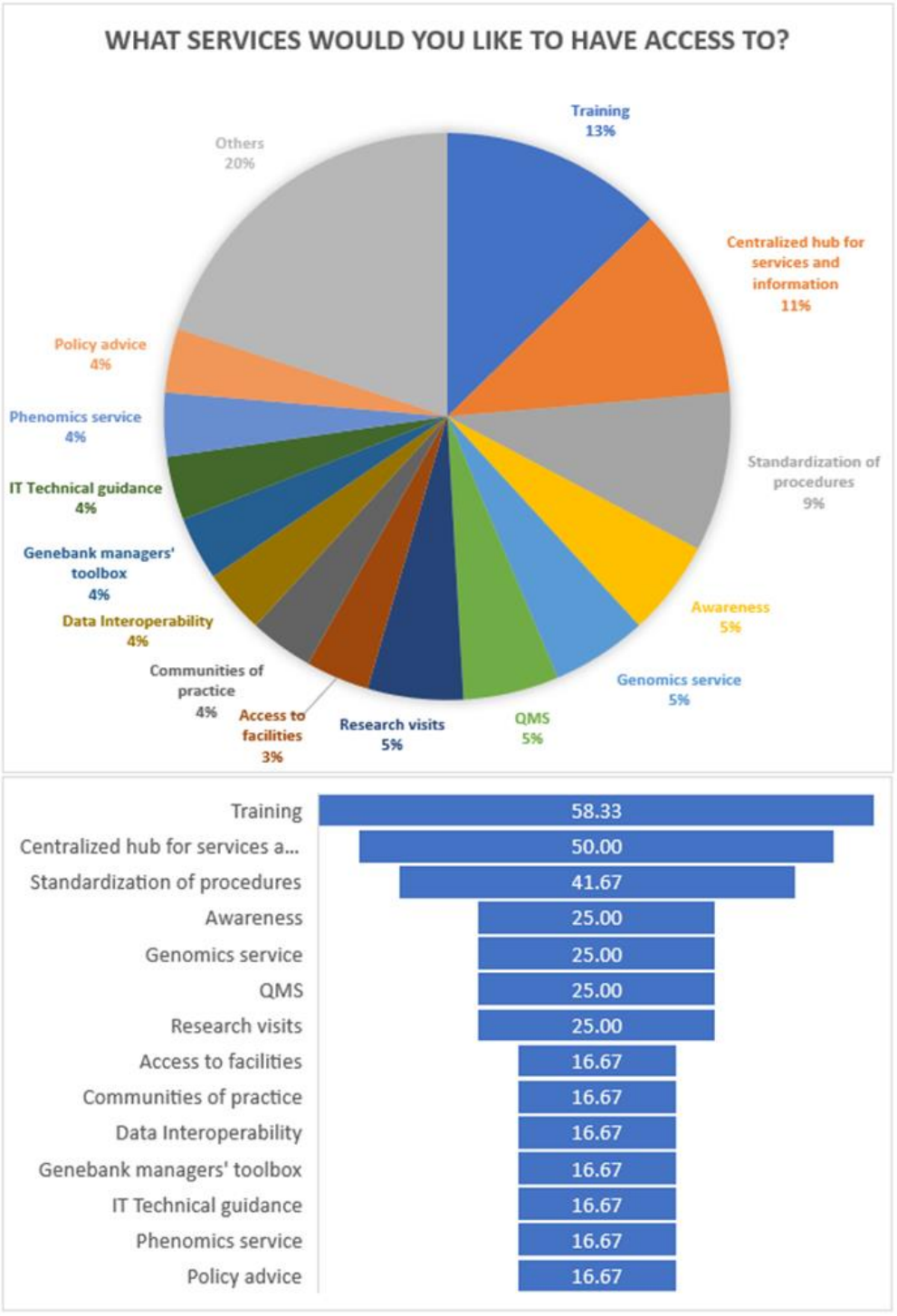

Figure 10. *Results of the groupwork question: "What services would you like to have access to?" The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=12).*

Governance and financial plan of GRACE-RI

The most important elements for the governance of the future RI, according to the workshop participants, are that the different stakeholders are well represented, that knowledge and information exchange is guaranteed, as well as a good coordination and political support. It will also be important to define the mission of the future RI, have a good dissemination strategy, have guidance on PGR-related legal issues as well as a strong leadership of the RI (**Figure 11**). Three in-person groups drew a

schematic proposal for GRACE-RI governance (**Figure 12**), which could inform development of a governance structure for the RI.

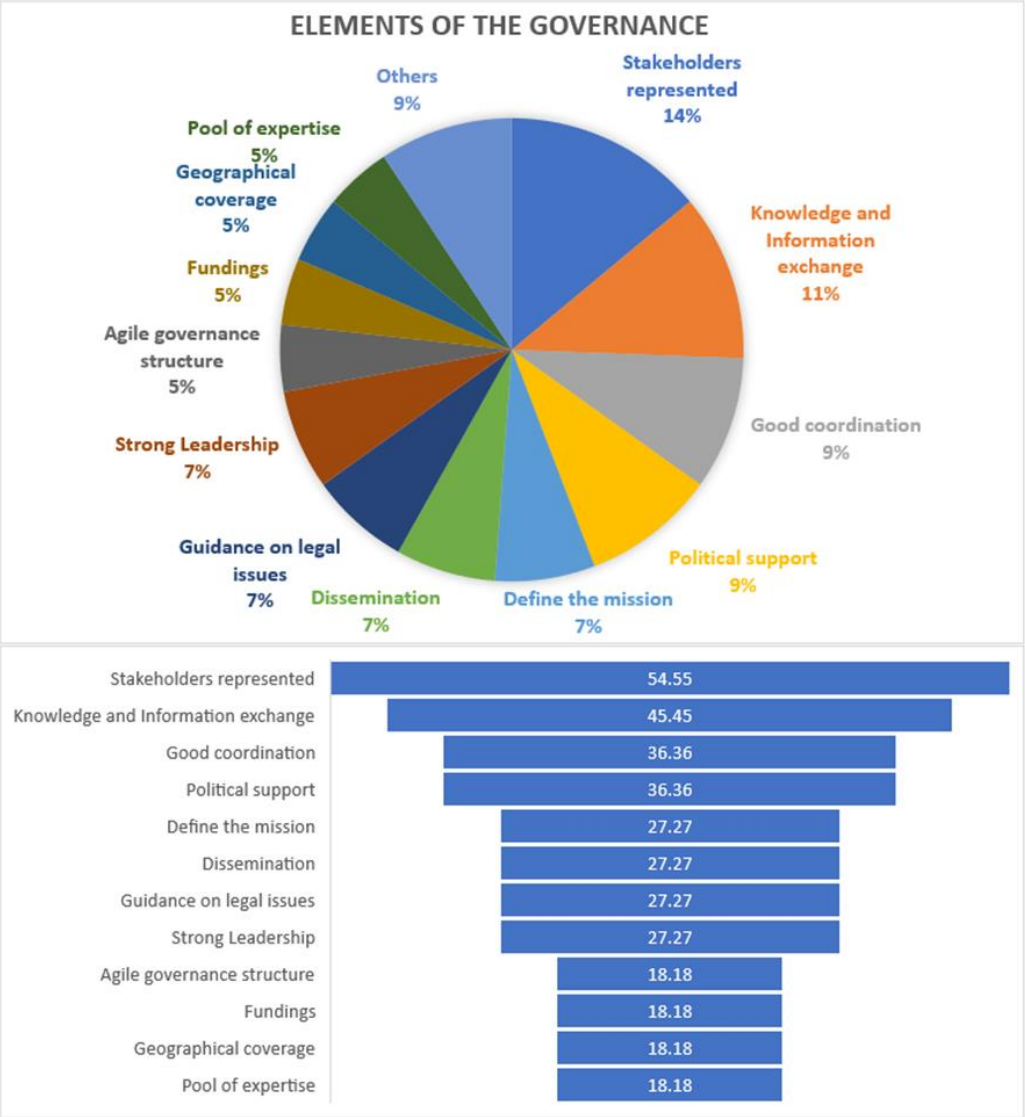

Figure 11. *Results of the groupwork question: "Which elements are important for governance of GRACE-RI?". The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=12).*

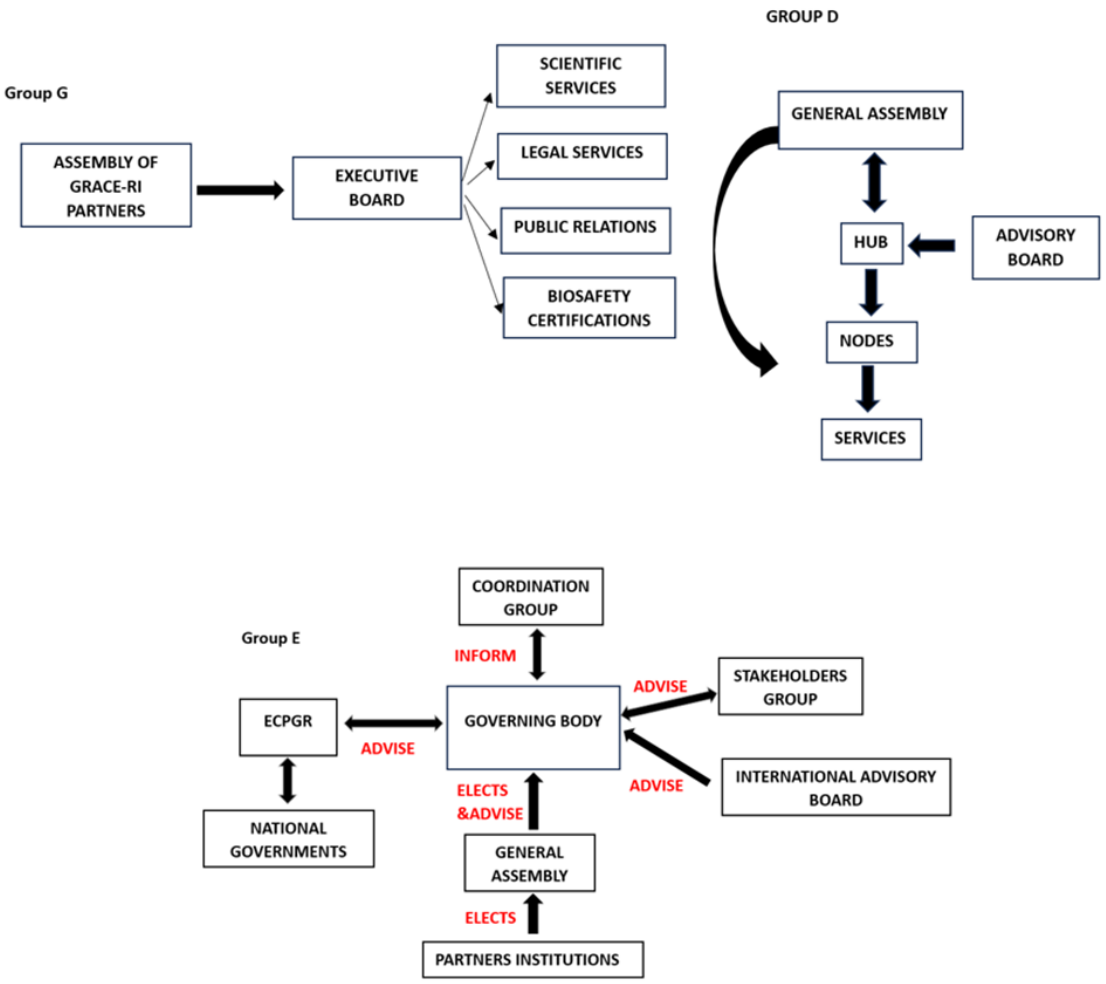

Figure 12. *Schematic proposals for GRACE-RI governance as drawn by three groups during the workshop.*

The main elements needed to make GRACE financially sustainable will be the support from private companies as well as the commitment of national governments. The commitment of the EU, obtaining long-term funding and a solid and transparent financial plan were also considered as important elements (**Figure 13**).

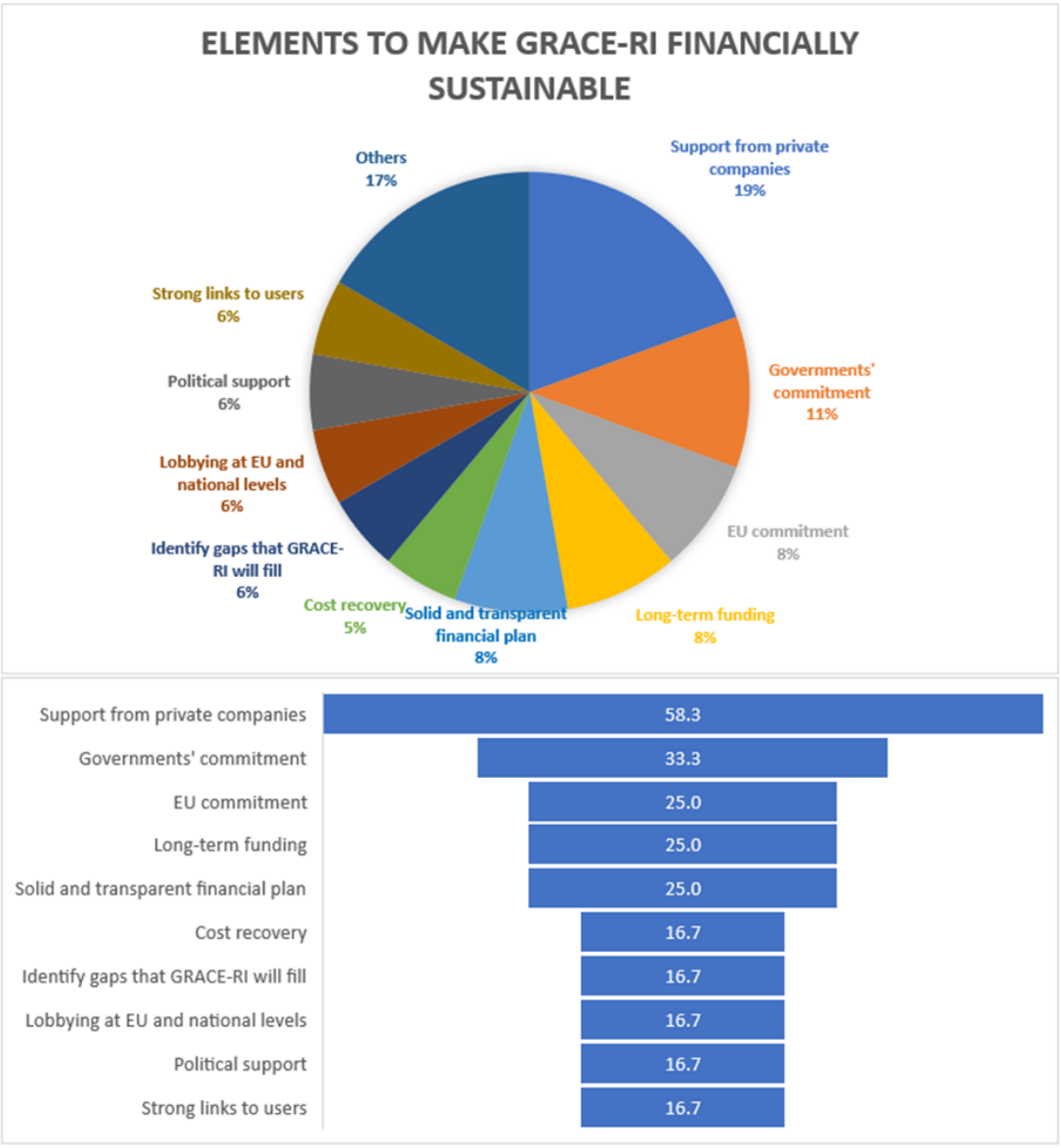

Figure 13. *Results of the groupwork question: "What elements are needed to make GRACE-RI financially sustainable?" The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=12).*

Opportunities and Challenges

The participants perceived that the greatest opportunities for GRACE are the possibility of sharing expertise, the creation of a common platform for PGR data and information and the possibility of improving the accessibility and use of PGR. Other significant opportunities listed were the possibility of connecting with other RIs, dissemination and visibility on PGR activities and research, the implementation of unified standards and the access to quality services (**Figure 14**). On the other hand, the greatest challenges for GRACE will be the availability of funding, the inclusion of different stakeholders and visions, policy and legal issues on PGR, garnering government's political support and the successful integration of quality information and services (**Figure 15**).

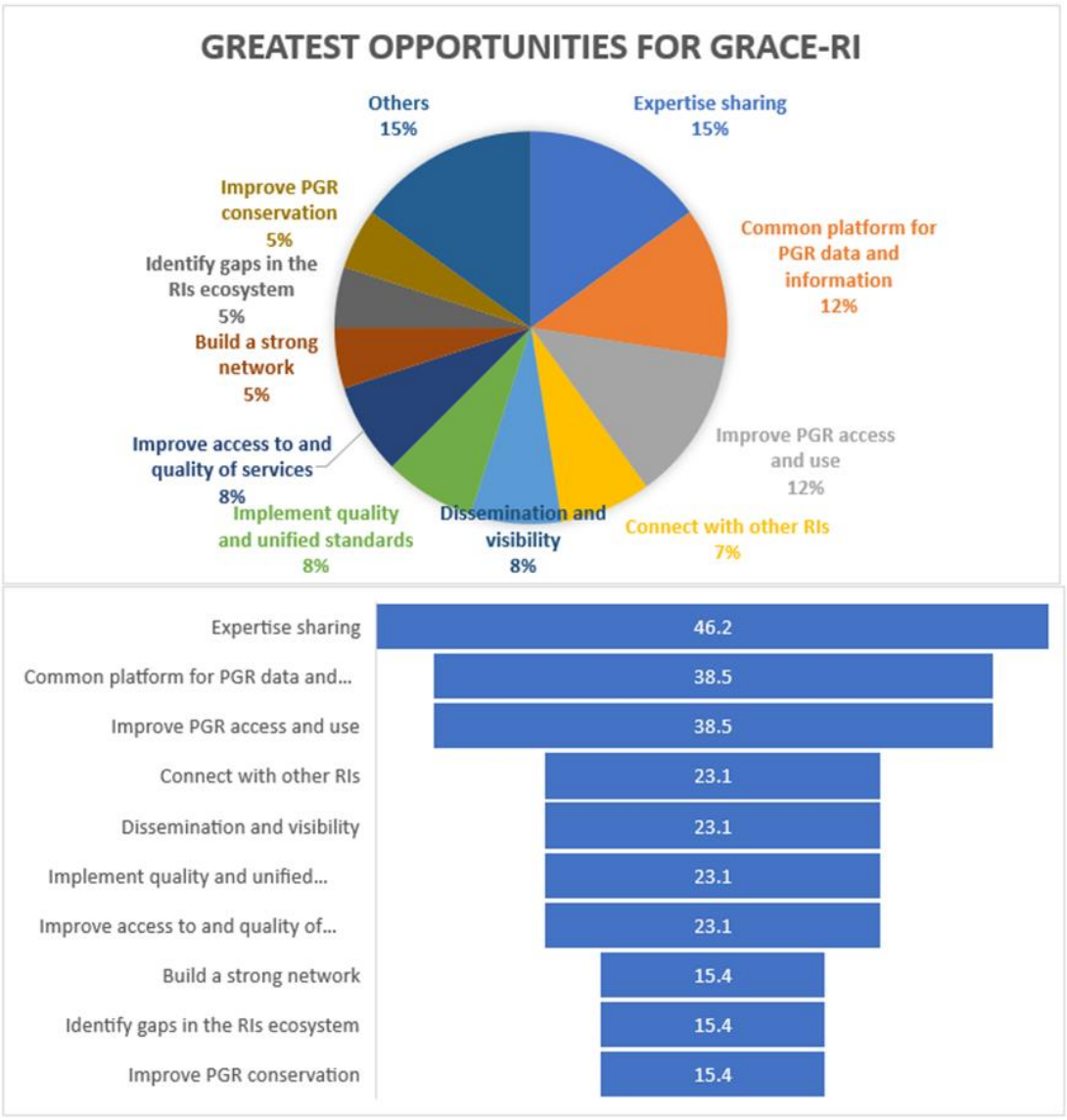

Figure 14. *Results of the groupwork question: "what are the greatest opportunities for GRACE-RI?" The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=13).*

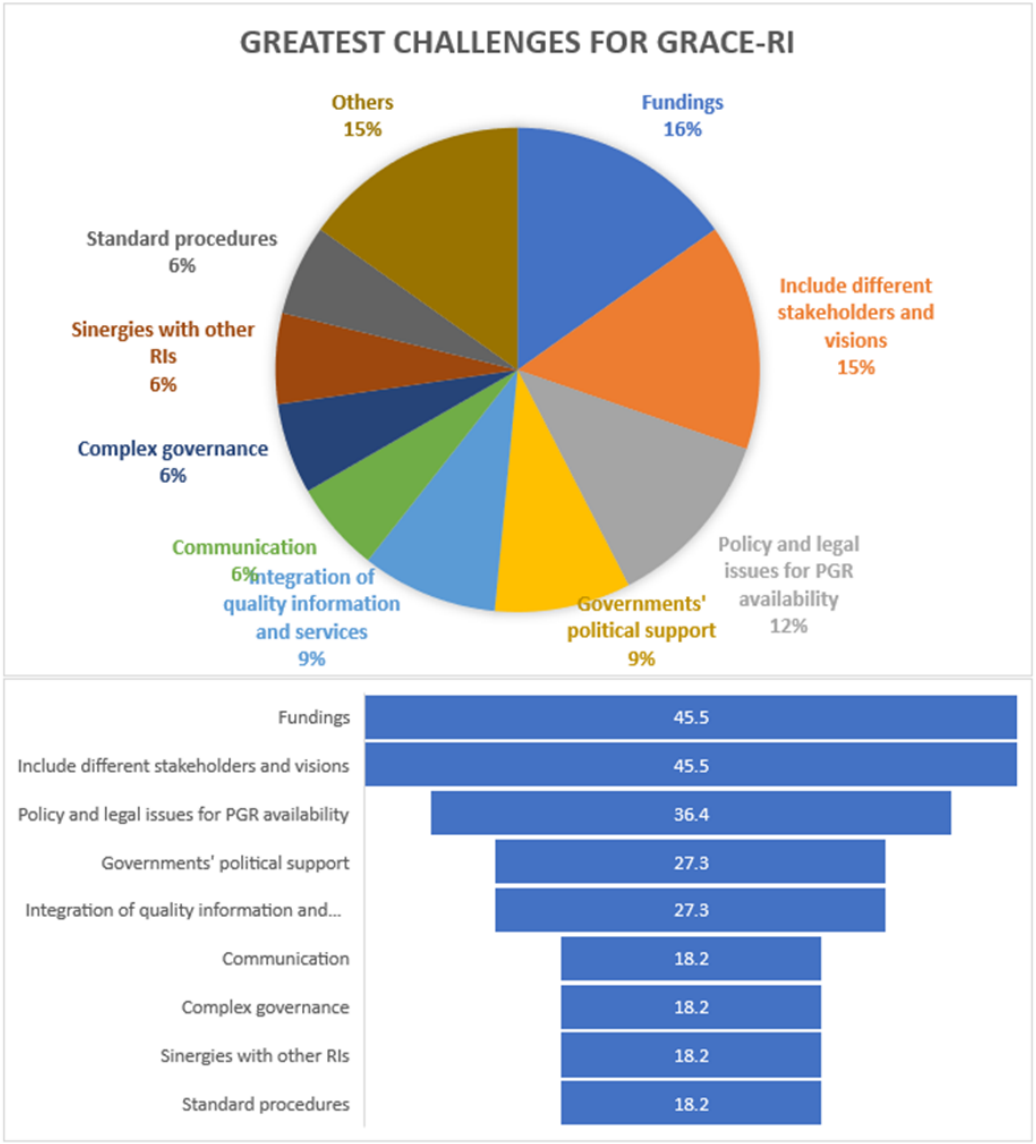

Figure 15. *Results of the groupwork question: "What are the greatest challenges for GRACE-RI?" The pie chart represents % of the total responses, grouped in standardized categories. Funnel charts show the % of the groups that gave the same answer (N=11).*

Conclusions and Outlook

The active engagement of project partners and stakeholders provided important input from different viewpoints and will inform development of the concept of the GRACE-RI. Additional surveys and workshops, involving wider stakeholder groups, will be conducted to complete the picture of the available or missing services that could be provided to PGR stakeholders through GRACE-RI. Engaging all relevant actors in discussions about the governance and financial sustainability of the future GRACE-RI will also be important to ensure the buy-in of the policymakers, providers and end-users who will work together on the implementation of the new PGR research infrastructure GRACE.