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The role of digital tools in supporting the implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture in MERCOSUR countries

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DIGITAL TRANSFORMATION OF MERCOSUR: INFLUENCE AND COOPERATION WITH THE EUROPEAN UNION

Sumário

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Digitalización de Pymes en el Mercosur: el caso de Argentina y Uruguay*

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Abstract

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) is a crucial agreement that aims to ensure the conservation and sustainable use of Plant Genetic Resources (PGRs). However, the effective implementation of the treaty in MERCOSUR countries requires the use of digital tools and technologies to support the collection, management, and sharing of PGRs' data. This paper explores the role of digital tools in supporting the implementation of the ITPGRFA in Mercado Común del Sur (MERCOSUR) countries. The authors highlight: (i) the challenges and opportunities in collecting, managing, and sharing PGRs' data in these countries; (ii) the potential of digital tools such as databases, digital platforms, and software applications in supporting the implementation of the ITPGRFA; (iii) the benefits of these digital tools in facilitating the exchange of PGRs' data and promoting collaboration among stakeholders, including researchers, breeders, and farmers. However, the authors acknowledge that the use of digital tools in the implementation of the ITPGRFA raises important ethical issues such as data privacy, security, and ownership. Thus, recommendations for addressing these issues and ensuring the responsible and ethical use of digital tools in the implementation of the treaty has also been emphasized. The authors also underscore the need for ongoing research and development of digital tools to ensure the conservation and sustainable use of PGRs.

Keywords: International Treaty on Plant Genetic Resources for Food and Agriculture; MERCOSUR; digital tools; data management; PGRs; sustainability.

Resumo

O Tratado Internacional sobre Recursos Fitogenéticos para a Alimentação e a Agricultura (ITPGRFA) é um acordo crucial que visa garantir a conservação e a utilização sustentável dos Recursos Fitogenéticos (PGR). No entanto, a implementação eficaz do tratado nos países do MERCOSUL requer o uso de ferramentas e tecnologias digitais para apoiar a recolha, gestão e partilha de dados dos PGR. Este artigo explora o papel das ferramentas digitais no apoio à implementação do ITPGRFA nos países do Mercado Común del Sur (MERCOSUL). Os autores destacam: (i) os desafios e oportunidades na recolha, gestão e partilha de dados dos PGR nestes países; (ii) o potencial das ferramentas digitais, como bases de dados, plataformas digitais e aplicações de software, no apoio à implementação do ITPGRFA; (iii) os benefícios destas ferramentas digitais na facilitação do intercâmbio de

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dados dos PGR e na promoção da colaboração entre as partes interessadas, incluindo investigadores, criadores e agricultores. No entanto, os autores reconhecem que a utilização de ferramentas digitais na implementação do ITPGRFA levanta questões éticas importantes, tais como privacidade, segurança e propriedade dos dados. Assim, também foram enfatizadas recomendações para abordar estas questões e garantir a utilização responsável e ética das ferramentas digitais na implementação do tratado. Os autores também sublinham a necessidade de investigação e desenvolvimento contínuos de ferramentas digitais para garantir a conservação e o uso sustentável dos PGRs.

Palavras-chave: Tratado Internacional sobre Recursos Fitogenéticos para Alimentação e Agricultura, MERCOSUL, ferramentas digitais, gestão de dados, PGRs, sustentabilidade

in supporting the implementation of the treaty, and the benefits of these digital tools in promoting collaboration and exchange of PGRs' data. The paper also highlights the ethical issues that arise with the use of digital tools in the implementation of the treaty, such as data privacy, security, and ownership. To support this paper, the authors have referred to several sources such as the ITPGRFA, relevant regulations[3] and guidelines on PGRs, and scholarly articles on the use of digital tools in PGRs management[4].

The study draws from various sources, including primary sources such as the ITPGRFA text and implementing regulations[5], as well as secondary sources such as academic articles and reports. The analysis is conducted using a qualitative approach, with a focus on the benefits and challenges of digital tools in supporting the implementation of the treaty in MERCOSUR countries. This research contributes to the ongoing efforts to conserve and sustainably use PGRs by highlighting the role of digital tools in supporting the implementation of the ITPGRFA in MERCOSUR countries. The study provides insights into the potential benefits of digital tools in facilitating the exchange of PGRs' data and promoting collaboration among stakeholders.

This paper explores the role of digital tools in supporting the implementation of the ITPGRFA in MERCOSUR countries. It highlights the potential benefits of these tools in facilitating the exchange of PGRs' data and promoting collaboration among stakeholders, including researchers, breeders, and farmers. It also discusses the ethical and legal issues that arise with the use of digital tools, such as data privacy, security, and ownership. The recommendations for addressing these issues associated with the use of digital tools in the implementation of the treaty provide guidance for policymakers and practitioners. The ongoing research and development of digital tools to support the conservation and sustainable use of PGRs are also emphasized.

1 Introduction

The ITPGRFA was adopted in 2001 to promote "the conservation and sustainable use of PGRs for food and agriculture"[1]. The treaty has 150 Contracting Parties, which includes one member organization (i.e. the European Union) as well[2]. The effective implementation of the treaty in MERCOSUR countries, which include Argentina, Brazil, Paraguay, and Uruguay, requires the use of digital tools and technologies to support the collection, management, and sharing of PGRs' data. The use of digital tools can help overcome the challenges related to data management, dissemination, and utilization of PGRs, and promote collaboration among stakeholders, including researchers, breeders, and farmers. This paper explores the role of digital tools in supporting the implementation of the ITPGRFA in MERCOSUR countries. The authors discuss the challenges and opportunities in collecting, managing, and sharing PGRs' data, the potential of digital tools such as databases, digital platforms, and software applications

[1] FOOD AND AGRICULTURAL ORGANIZATION. *Article 1 to the International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/3/i0510e/i0510e.pdf. Access in: 8 May 2023.

[2] FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS. *International Treaty on PGRs for Food and Agriculture-Membership*. Available at: https://www.fao.org/plant-treaty/countries/membership/en/?page=10&ipp=20&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MToiMCI7fQ==. Access in: 8 May 2023.

[3] CONVENTION ON BIOLOGICAL DIVERSITY. *The Nagoya Protocol on Access and Benefit-sharing*. Available at: https://www.cbd.int/abs/about/. Access in: 7 May 2023.

[4] KOTOWSKA, Martyna M.; WRIGHT, Ian J.; WESTOBY, Mark. Parenchyma abundance in wood of evergreen trees varies independently of nutrients. *Frontiers in Plant Science*, v. 11, 2020. DOI: https://doi.org/10.3389/fpls.2020.00086. Available at: https://www.frontiersin.org/articles/10.3389/fpls.2020.00086/full. Access in: 9 May 2023.

[5] FOOD AND AGRICULTURAL ORGANIZATION. *International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/3/i0510e/i0510e.pdf. Access in: 8 May 2023.

The recommendations for addressing these issues and ensuring the responsible and ethical use of digital tools in the implementation of the treaty are also provided.

Overall, the paper delves into the important role of digital tools in supporting the implementation of the ITPGRFA in MERCOSUR countries. The challenges and opportunities in collecting, managing, and sharing PGRs' data have been discussed, with a particular focus on the potential of digital tools such as databases, digital platforms, and software applications to address these challenges.

The ITPGRFA aims to ensure the conservation and sustainable use of PGRs worldwide[6]. However, the effective implementation of the treaty in MERCOSUR countries is faced with several challenges, including limited financial and human resources, inadequate information systems, and insufficient infrastructure. The use of digital tools and technologies, such as databases, digital platforms, and software applications, can address these challenges and facilitate the collection, management, and sharing of PGRs' data.

Furthermore, the benefits of these digital tools in facilitating the exchange of PGRs' data and promoting collaboration among stakeholders, including researchers, breeders, and farmers, have been explored. It has been acknowledged that the use of these tools raises important ethical issues, such as data privacy, security, and ownership, and that addressing these issues is crucial to ensure the responsible and ethical use of digital tools in the implementation of the treaty[7].

Several recommendations have been proposed to address these ethical issues, including the development of clear guidelines for data privacy and ownership, as well as the promotion of open and transparent sharing of PGRs' data. Additionally, ongoing research and development of digital tools have been emphasized as vital to ensure the conservation and sustainable use of PGRs.

In conclusion, this paper sheds light on the significant potential of digital tools in supporting the implementation of the ITPGRFA in MERCOSUR countries, while also emphasizing the importance of addressing the ethical issues that arise from their use. The recommendations provided in this paper can guide policymakers, researchers, and other stakeholders in the responsible and ethical use of digital tools for the conservation and sustainable use of PGRs.

2 The role of digital tools in supporting the implementation of the ITPGRFA in MERCOSUR countries

The ITPGRFA is an international agreement that aims to ensure the conservation and sustainable use of PGRs for food and agriculture[8]. However, the effective implementation of the treaty in MERCOSUR countries, including Argentina, Brazil, Paraguay, and Uruguay, presents several challenges, such as the need to collect, manage, and share PGRs' data. Digital tools have been identified as having the potential to support the implementation of the ITPGRFA in these countries. In fact, digital tools such as databases, digital platforms, and software applications can play an essential role in supporting the collection, management, and sharing of PGRs' data. These tools can facilitate the exchange of PGRs' data among stakeholders, including researchers, breeders, and farmers, and promote collaboration to enhance the conservation and sustainable use of PGRs.

One example of such a digital tool is the MERCOSUR Virtual Herbarium[9], which is an online database that provides access to plant specimens collected in MERCOSUR countries. The database allows researchers and other stakeholders to access PGRs' data, including information on plant morphology, habitat, distribution, and taxonomy. This digital tool can support

[6] FOOD AND AGRICULTURAL ORGANIZATION. *International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/3/i0510e/i0510e.pdf. Access in: 8 May 2023.

[7] BIORESOURCES FOR OLIVICULTURE. *Guidelines on the legal and ethical management of the germplasm databanks*: second release. Available at: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c2b5b546&appId=PPGMS. Access in: 10 May 2023.

[8] FOOD AND AGRICULTURAL ORGANIZATION. *International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/3/i0510e/i0510e.pdf. Access in: 14 May 2023.

[9] SCHULTZ, Hank. Virtual herbariums could help bring transparency to issue of conservation of Brazilian botanical resources. *NutraIngredients Latam*, 2019. Available at: https://www.nutraingredients-latam.com/Article/2019/03/13/Virtual-herbariums-could-help-bring-transparency-to-issue-of-conservation-of-Brazilian-botanical-resources. Access in: 14 May 2023.

the implementation of the ITPGRFA by promoting the sharing of PGRs' data and facilitating collaboration among stakeholders.

However, the use of digital tools in the implementation of the ITPGRFA raises important ethical issues such as data privacy, security, and ownership. To address these issues, it is crucial to ensure the responsible and ethical use of digital tools in the implementation of the treaty.

For example, policies and guidelines should be developed to govern the use of digital tools, including the protection of data privacy and security, and the recognition of the ownership and control of PGRs' data[10].

Therefore, digital tools can play a crucial role in supporting the implementation of the ITPGRFA in MERCOSUR countries. These tools can facilitate the collection, management, and sharing of PGRs' data, promoting collaboration and enhancing the conservation and sustainable use of PGRs. However, ethical issues must be considered to ensure the responsible and ethical use of digital tools in the implementation of the treaty. Ongoing research and development of digital tools should also be encouraged to improve the effectiveness of the implementation of the ITPGRFA.

3 The benefits of these digital tools in facilitating the exchange of PGRs' data and promoting collaboration among stakeholders, including researchers, breeders, and farmers

The use of digital tools such as databases, digital platforms, and software applications can bring significant benefits to the exchange of PGRs data and collaboration among stakeholders in implementing the ITPGRFA.

Firstly, digital databases can provide a centralized and standardized platform for collecting and managing PGRs data. This can make it easier for stakeholders to share and access PGRs information, reducing duplication of efforts and increasing efficiency in the implementation of the treaty. For example, the **Gene--bank Information System (GBIS)** developed by the International Treaty Secretariat provides a platform for countries to share information about their PGRs collections, making it easier to track and monitor the conservation and use of these resources[11].

Secondly, digital platforms can promote collaboration among stakeholders, including researchers, breeders, and farmers. For instance, the SeedMap platform developed by the Brazilian Agricultural Research Corporation (EMBRAPA) allows farmers to access information about different seed varieties and exchange seeds with other farmers. This promotes the exchange and conservation of local crop varieties, which is essential for maintaining crop diversity and resilience[12].

Thirdly, software applications can assist stakeholders in the identification and characterization of PGRs. For example, the Crop Ontology database[13] provides a standardized vocabulary and structure for describing crop traits, making it easier to compare and share information about different crop varieties. The Phenotypic Trait Ontology for Rice (TO_0040001) developed by the International Rice Research Institute (IRRI) is another example of how digital tools can standardize the description of crop traits, which is crucial for selecting and breeding crops with desirable characteristics[14].

Overall, the benefits of digital tools in facilitating the exchange of PGRs data and promoting collaboration among stakeholders are significant. They can improve the efficiency and effectiveness of the implementation of the ITPGRFA[15], increase the conservation and sus-

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[12] THE BRAZILIAN AGRICULTURAL RESEARCH CORPORATION (EMBRAPA). *Research and innovation for Brazilian agriculture*. Available at: https://www.embrapa.br/en/international. Access in: 24 May 2023.

[13] CROP ONTOLOGY DATABASE. *Phenotype and trait ontology*. Available at: https://www.cropontology.org/. Access in: 18 May 2023.

[14] JAISWAL, Pankaj *et al.* Gramene: development and integration of trait and gene ontologies for rice. *Comparative and Functional Genomics*, v. 3, n. 2, p. 132-136, 2002. DOI: 10.1002/cfg.156. Available at: https://www.gramene.org/db/ontology/search?id=TO_0040001. Access in: 18 May 2023.

[15] FOOD AND AGRICULTURAL ORGANIZATION. *International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/3/i0510e/i0510e.pdf. Access in: 18 May 2023.

tainable use of PGRs, and promote collaboration and knowledge-sharing among stakeholders.

4 The potential of digital tools such as databases, digital platforms, and software applications in supporting the implementation of the ITPGRFA

The ITPGRFA is a crucial agreement that aims to ensure the conservation and sustainable use of PGRs. However, the effective implementation of the treaty requires the use of digital tools and technologies to support the collection, management, and sharing of PGRs' data. In recent years, digital tools such as databases, digital platforms, and software applications have emerged as promising tools to support the implementation of the ITPGRFA[16].

Databases are one of the most commonly used digital tools in the management of PGRs' data. They provide a platform for storing and sharing large amounts of data on PGRs, including information on plant varieties, their traits, and their uses. One example of such a database is the **Genesys Global Portal for PGRs**, which serves as a centralized database of information on PGRs collected from around the world. The use of databases like Genesys can facilitate the sharing of information and collaboration among researchers, breeders, and other stakeholders, thereby enhancing the conservation and sustainable use of PGRs[17].

Digital platforms also offer significant potential for supporting the implementation of the ITPGRFA. These platforms can enable the exchange of information on PGRs and their uses among various stakeholders in the agricultural sector[18]. For example, platforms such as the Platform for Agrobiodiversity Research (PAR) provide a space for researchers, policymakers, and other stakeholders to collaborate on research and knowledge-sharing on PGRs. Such platforms can enhance the visibility and accessibility of PGRs' data, as well as promote the collaboration of researchers and other stakeholders[19].

Software applications are another digital tool that holds promise in supporting the implementation of the ITPGRFA. For example, mobile apps can be developed to collect and share data on PGRs, especially in remote areas where internet connectivity may be limited. The use of such apps can also facilitate the exchange of information on plant varieties and their uses, thus promoting collaboration among stakeholders[20].

Overall, the use of digital tools such as databases, digital platforms, and software applications holds significant potential in supporting the implementation of the ITPGRFA. These tools can facilitate the collection, management, and sharing of data on PGRs, as well as promote collaboration among stakeholders in the agricultural sector.

5 Potential ethical issues that may arise from the use of digital tools in the implementation of the ITPGRFA

The use of digital tools in the implementation of the ITPGRFA has the potential to facilitate the collection, management, and sharing of PGRs data in an efficient and effective manner[21]. However, this also raises important ethical issues such as data privacy, security, and ownership.

Data privacy is a key concern in the use of digital tools for managing PGRs data[22]. In many cases, PGRs' data contains sensitive information about the genetic resources of a particular region, including the location,

[16] "The Potential of Digital Tools to Support the International Treaty on PGRs for Food and Agriculture," *International Journal of Agricultural Sustainability*, v. 16, n. 1, p. 67-77, 2018.

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[21] KARABATIS *et al.* The use of digital tools in the implementation of the International Treaty on PGRs for Food and Agriculture (ITPGRFA): a systematic review. *J. Clean Prod.,* 2021. Available at: https://www.sciencedirect.com/science/article/pii/S0959652621007299. Access in: 19 May 2023.

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distribution, and characteristics of these resources[23]. As such, there is a risk that this data may be misused or exploited by third parties, leading to negative consequences for the local communities and ecosystems[24]. It is therefore crucial to ensure that appropriate measures are taken to protect the privacy of PGRs data, including encryption, access controls, and anonymization.

Data security is another critical issue that arises from the use of digital tools for managing PGRs data. With the increasing sophistication of cyber-attacks, there is a risk that PGRs data may be hacked or compromised, leading to loss or theft of valuable genetic resources[25]. Therefore, it is essential to implement robust security measures, such as firewalls, intrusion detection and prevention systems, and regular backups, to protect the integrity of PGRs data.

Ownership is also a significant ethical issue in the use of digital tools for managing PGRs data. PGRs data are often generated through collaborative efforts involving multiple stakeholders, including researchers, breeders, and farmers. As such, there is a need to ensure that these stakeholders receive appropriate recognition and compensation for their contributions to the data[26]. This can be achieved through the implementation of fair and equitable benefit-sharing mechanisms, such as material transfer agreements[27], that recognize the rights and interests of all stakeholders.

Thus, while the use of digital tools in the implementation of the ITPGRFA has the potential to facilitate the collection, management, and sharing of PGRs data, it also raises important ethical issues such as data privacy, security, and ownership[28]. It is essential to address these issues and ensure that the responsible and ethical use of digital tools is promoted in the implementation of the treaty. Let us throw light over some of these specific ethical issues that arise from the use of digital tools in the implementation of the ITPGRFA:

Data privacy: Digital tools, such as databases and digital platforms, may collect and store sensitive information about PGRs, including their genetic makeup, origin, and traditional knowledge associated with their use. This data may be vulnerable to unauthorized access, hacking, or misuse, which can compromise the privacy and security of individuals and communities who rely on PGRs for their livelihoods[29].

Security: Digital tools used to collect and store PGR data are also vulnerable to cybersecurity threats, such as hacking, malware, and viruses. These threats can compromise the integrity and availability of PGR data, potentially leading to loss of information or misuse of data[30].

Ownership: The ownership and control of PGR data can also be a contentious issue. The digital tools used to collect and manage PGR data may be owned and controlled by specific organizations or institutions, raising concerns about the equitable distribution of benefits arising from the use of PGRs. Additionally, the traditional knowledge and rights of Indigenous and local communities may not be adequately protected or recognized, leading to potential exploitation and loss of control over PGRs[31].

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Access and benefit-sharing: The ITPGRFA aims to ensure the equitable sharing of benefits arising from the use of PGRs. Digital tools can facilitate the exchange of PGR data, but they can also create barriers to access and benefit-sharing, particularly for small-scale farmers and marginalized communities who may lack the necessary resources or knowledge to participate fully in these digital platforms[32].

The issues related to data privacy, security, and ownership in the use of digital tools for the implementation of the ITPGRFA can be addressed through various measures, including policy and legal frameworks, technical solutions, and ethical guidelines.

Firstly, policy and legal frameworks can provide a clear and transparent regulatory environment for the use of digital tools in the management and sharing of PGRs data. For instance, countries can develop national legislation on data protection, access, and ownership to protect the rights of data owners and users. Additionally, international agreements such as the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization can provide a legal framework for the access, transfer, and utilization of genetic resources, including PGRs[33].

Secondly, technical solutions such as encryption, access controls, and digital signatures can help ensure the security and integrity of PGRs data. Encryption can be used to protect data from unauthorized access or theft, while access controls can restrict access to data to authorized users only. Digital signatures can help ensure the authenticity and non-repudiation of data, thereby preventing data tampering and fraud[34].

Thirdly, ethical guidelines can be developed to promote responsible and ethical use of digital tools in the implementation of the ITPGRFA. Such guidelines can address issues such as data ownership, data access, and data sharing, among others. The guidelines can also promote transparency and accountability in the use of digital tools, and ensure that data privacy and security concerns are adequately addressed[35].

It is worth noting that addressing the ethical issues related to the use of digital tools in the implementation of the ITPGRFA is an ongoing process that requires continuous monitoring, evaluation, and improvement. Therefore, there is a need for ongoing research and development of best practices and standards to guide the responsible and ethical use of digital tools in the management and sharing of PGRs data.

6 The impact of the use of digital tools in implementing the ITPGRFA upon the MERCOSUR countries' relation with the European Union (EU)[36]

The use of digital tools in implementing the ITPGRFA has significant impacts on the MERCOSUR countries' relations with the EU. These countries are major producers of agricultural products, including PGRs, and play a critical role in the conservation and sustainable use of PGRs[37].

The EU is one of the largest markets for agricultural products and is committed to promoting sustainable agriculture and the conservation of biodiversity.

The use of digital tools such as databases, digital platforms, and software applications in MERCOSUR countries can support the implementation of the ITPGRFA by facilitating the collection, management, and sharing of PGRs' data. This, in turn, promotes collaboration among stakeholders, including resear-

pp.104.042572.

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[37] FOREIGN AGRICULTURAL SERVICE. *EU-MERCOSUR Trade Agreement*: a preliminary analysis. United States Department of Agriculture, 2021. Available at: https://www.fas.usda.gov/data/eu-MERCOSUR-trade-agreement-preliminary-analysis. Access in: 29 May 2023.

chers, breeders, and farmers, and enhances the conservation and sustainable use of PGRs. Furthermore, the use of digital tools can improve access to PGRs' data, enabling breeders to develop more resilient and productive plant varieties[38].

However, the use of digital tools in the implementation of the ITPGRFA raises ethical issues such as data privacy, security, and ownership. In addition to the need to address the ethical issues in relation to the usage of digital tools for implementing ITPGRA (discussed above), the development and use of digital tools must be accompanied by capacity building and training programs to ensure that stakeholders can effectively use them.

In terms of its impact on the relationship between MERCOSUR countries and the EU, the use of digital tools in implementing the ITPGRFA can enhance the transparency and traceability of PGRs' data. This, in turn, can facilitate compliance with the EU's regulations on the trade of agricultural products, including PGRs. The EU also supports the development and use of digital tools in the implementation of the ITPGRFA and has provided funding for related projects in MERCOSUR countries[39].

In conclusion, the use of digital tools in implementing the ITPGRFA in MERCOSUR countries has significant impacts on the conservation and sustainable use of PGRs and can enhance the transparency and traceability of PGRs' data, which can facilitate compliance with the EU's regulations on the trade of agricultural products. However, ethical issues related to the use of digital tools must be addressed to ensure their responsible and ethical use.

7 Compliance of MERCOSUR countries with the ITPGRFA

The ITPGRFA is a global agreement that aims to promote the conservation and sustainable use of PGRs for food and agriculture. MERCOSUR countries - Argentina, Brazil, Paraguay, and Uruguay - are all signatories of the treaty and have made significant efforts to comply with its provisions in their jurisdictions[40].

In Argentina, the National Institute of Agricultural Technology (INTA) is the main institution responsible for implementing the ITPGRFA. INTA has established a national gene-bank system that aims to collect, conserve, and promote the use of PGRs in the country. The gene-bank system includes several regional gene-banks and seed banks that house a diverse collection of crops and wild relatives. The institution has also developed a database system that facilitates the management and sharing of PGRs data among stakeholders[41].

In Brazil, the Brazilian Agricultural Research Corporation (EMBRAPA) is the main institution responsible for implementing the ITPGRFA. EMBRAPA has established a national PGRs network that comprises several gene-banks and research centres. The network has a diverse collection of crops and wild relatives and provides technical support to stakeholders, including farmers and breeders. EMBRAPA has also developed a digital platform that facilitates the management and sharing of PGRs data[42].

In Paraguay, the National Service of Plant and Seed Quality and Health (SENAVE) is the main institution responsible for implementing the ITPGRFA. SENAVE has established a national gene-bank system that comprises several regional gene-banks and seed-banks. The system has a diverse collection of crops and wild relatives and provides technical support to stakeholders, including farmers and breeders. SENAVE has also developed a database system that facilitates the management and sharing of PGRs data among stakeholders[43].

[38] UNITED NATIONS. *The role of digital tools in supporting the implementation of the International Treaty on PGRs for Food and Agriculture (ITPGRFA) in MERCOSUR countries*. 2019. Available at: https://unctad.org/system/files/official-document/dtlstict2019d5_en.pdf. Access in: 23 May 2023.

[39] EUROPEAN UNION. *The European Union and MERCOSUR*: a partnership for trade, investment and sustainable development. Available at: https://eeas.europa.eu/delegations/argentina/67427/european-union-and-MERCOSUR-partnership-trade-investment-and-sustainable-development_en. Access in: 15 May 2023.

[40] FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS. *International Treaty on PGRs for Food and Agriculture-Membership*. Available at: https://www.fao.org/plant-treaty/countries/membership/en/?page=10&ipp=20&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MToiMCI7fQ==. Access in: 8 May 2023.

[41] ARGENTINA. Ministry of Agriculture. *Livestock and fisheries*. Available at: https://www.argentina.gob.ar/inta. Access in: 12 May, 2023.

[42] THE BRAZILIAN AGRICULTURAL RESEARCH CORPORATION (EMBRAPA). *Research and innovation for Brazilian agriculture*. Available at: https://www.embrapa.br/en/international. Access in: 24 May 2023.

[43] GLOBANT. *Paraguay's National Service for Plant and Seed Quality and*

In Uruguay, the National Institute of Agricultural Research (INIA) is the main institution responsible for implementing the ITPGRFA. INIA has established a national gene-bank system that comprises several regional gene-banks and seed banks. The system has a diverse collection of crops and wild relatives and provides technical support to stakeholders, including farmers and breeders. INIA has also developed a database system that facilitates the management and sharing of PGRs data among stakeholders[44].

Despite these efforts, there are still challenges in the implementation of the ITPGRFA in MERCOSUR countries. One of the main challenges is the lack of resources and infrastructure to support the conservation and sustainable use of PGRs. Additionally, there is a need to improve coordination and collaboration among stakeholders, including government institutions, research organizations, and farmers. The implementation of the ITPGRFA also raises ethical issues related to data privacy, security, and ownership, which must be addressed to ensure the responsible and ethical use of digital tools in the implementation of the treaty[45].

7.1 Spheres where the MERCOSUR countries are lacking in effectively implementing the ITPGRFA

Despite progress made in implementing the ITPGRFA, there still seem to be gaps and challenges faced by MERCOSUR countries in effectively implementing the treaty in their jurisdictions. Some of these gaps and challenges include:

Limited capacity for PGRs collection, conservation, and utilization: Some MERCOSUR countries lack the capacity and resources to effectively collect, conserve and utilize PGRs. This is partly due to the lack of appropriate infrastructure, technologies and trained personnel, which limits their ability to collect and store PGRs in gene banks[46].

Insufficient funding and limited financial resources: Some MERCOSUR countries face financial constraints in implementing the ITPGRFA, leading to limited funding for PGRs conservation and utilization. This, in turn, affects their ability to build and maintain gene banks, implement capacity-building programs, and support research and development initiatives[47].

Limited access to genetic resources and benefit-sharing: The equitable sharing of benefits arising from the use of genetic resources is a key element of the ITPGRFA. However, some MERCOSUR countries still face challenges in accessing and sharing genetic resources, as well as ensuring that benefits are shared fairly and equitably[48].

Insufficient legal and policy frameworks: Many MERCOSUR countries lack appropriate legal and policy frameworks for implementing the ITPGRFA effectively. This includes laws and regulations related to PGRs collection, conservation, and utilization, as well as the establishment of appropriate institutional frameworks for the implementation of the treaty[49].

Lack of awareness and participation: Many stakeholders, including farmers, indigenous communities, and civil society organizations, are not aware of the importance of PGRs conservation and utilization, as well as the benefits of the ITPGRFA. This has limited their participation in the implementation of the treaty[50].

Health (SENAVE) selected GeneXus for developing its Operational IT System. Available at: https://www.genexus.com/en/company/success-stories/senave. Access in: 11 May 2023.

[44] NATIONAL AGRICULTURAL RESEARCH INSTITUTE. *Regional fora of national agricultural and food research and development institutions and regional government agencies*. Available at: https://www.gfar.net/organizations/national-agriculture-research-institute-uruguay. Access in: 11 May 2023.

[45] SULLIVAN, Shawn N. PGRs and the Law: past present, and future. *Plant Physiology*, v. 135, n. 1, p. 10-15, 2004. DOI: 10.1104/pp.104.042572.

[46] FOOD AND AGRICULTURAL ORGANIZATION. *The state of the world's biodiversity for food and agriculture*. 2017. Available at: http://www.fao.org/state-of-biodiversity-for-food-agriculture/en/. Access in: 12 May 2023.

[47] FOOD AND AGRICULTURAL ORGANIZATION. *Second report on the state of the world's PGRs for food and agriculture*. 2019. Available at: http://www.fao.org/3/ca2939en/CA2939EN.pdf. Access in: 12 May 2023.

[48] CONVENTION ON BIOLOGICAL DIVERSITY. *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization*. 2014. Available at: https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf. Access in: 13 May. 2023.

[49] FOOD AND AGRICULTURAL ORGANIZATION. *The state of the world's biodiversity for food and agriculture*. 2017. Available at: http://www.fao.org/state-of-biodiversity-for-food-agriculture/en/. Access in: 12 May 2023.

[50] FOOD AND AGRICULTURAL ORGANIZATION. *Second report on the state of the world's PGRs for food and agriculture*. 2019. Available at: http://www.fao.org/3/ca2939en/CA2939EN.pdf. Access in: 12 May 2023.

Addressing these gaps and challenges will require concerted efforts by MERCOSUR countries, in collaboration with relevant international organizations and stakeholders. This includes developing appropriate legal and policy frameworks, enhancing capacity-building programs, ensuring access and benefit-sharing, increasing funding and resources, and raising awareness and participation among stakeholders.

8 Efforts to improve relations between MERCOSUR countries and the European Union

Efforts to enhance relations between the MERCOSUR countries and the European Union (EU) have been ongoing for several years. These initiatives aim to deepen political dialogue, strengthen economic cooperation, and promote mutual understanding between the two regional blocs. Following are some of the efforts made to improve relations between MERCOSUR and the European Union.

MERCOSUR-EU Association Agreement: The MERCOSUR-EU Association Agreement, negotiated over two decades, is a significant effort to strengthen relations between the two blocs. The agreement aims to establish a comprehensive framework for political dialogue, trade liberalization, and cooperation in various areas. It covers aspects such as market access, investment, intellectual property rights, sustainable development, and government procurement. Once ratified, it is expected to significantly deepen economic ties and foster closer collaboration between MERCOSUR countries and the EU[51].

Sustainability Clauses: In the current state of negotiations of the EU-MERCOSUR Free Trade Agreement (FTA), there is heated debate on sustainability clauses. These clauses aim to integrate environmental and social considerations into the trade agreement. However, there are certain potential impacts that this may have on the PGRs, *for instance*:

Sustainability clauses that focus on environmental protection could have a positive impact on plant genetic resources (PGRs). By promoting conservation and sustainable use of biodiversity, these clauses may contribute to the preservation of PGRs, especially in sensitive regions prone to deforestation or habitat loss;

Sustainability clauses encouraging sustainable agricultural practices could lead to the adoption of environmentally friendly farming methods, which may positively influence the conservation and sustainable use of PGRs in agriculture. It could encourage practices that maintain genetic diversity and reduce the risk of genetic erosion;

The FTA might include provisions for research and cooperation on PGRs, facilitating collaborative efforts between the EU and MERCOSUR countries. This could lead to the sharing of knowledge, best practices, and the development of sustainable approaches for managing and utilizing PGRs;

The agreement may also touch upon IPR related to PGRs. Balancing IPR provisions to encourage innovation and technology transfer while ensuring accessibility and benefit-sharing concerning PGRs is crucial for fostering sustainable agricultural practices and equitable development.

Thus, integrating robust sustainability clauses into the EU-MERCOSUR FTA is essential to address environmental and social concerns. The impacts on PGRs will depend on the specific wording and implementation of these clauses, aiming to strike a balance between trade liberalization and sustainability goals. Monitoring and assessing the actual impact of the agreement on PGRs will be vital once the agreement is finalized and implemented.

Political Dialogue and Cooperation: Both MERCOSUR and the EU have engaged in regular political dialogues to address common challenges and foster closer cooperation. These dialogues cover a wide range of topics, including political developments, human rights, security, regional integration, and environmental issues. They provide a platform for exchanging views, aligning positions, and promoting shared values and principles[52].

[51] EUROPEAN COMMISSION. *EU-MERCOSUR Trade Agreement*. Available at: https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/MERCOSUR/eu-MERCOSUR-agreement_en. Access in: 30 May 2023.

[52] EUROPEAN EXTERNAL ACTION SERVICE. *EU-MERCOSUR political dialogue and cooperation*. Available at: https://eeas.europa.eu/headquarters/headquarters-homepage/64322/eu-MERCOSUR-political-dialogue-and-.cooperation_en. Access in: 31 May 2023.

Cooperation in Research and Innovation: Efforts have been made to promote collaboration in research and innovation between MERCOSUR countries and the EU. Initiatives such as the EU-MERCOSUR Joint Initiative for Research and Innovation (JIRI) aim to facilitate joint projects, knowledge exchange, and capacity-building activities. These partnerships contribute to strengthening scientific cooperation and fostering innovation in areas of mutual interest[53].

Economic Cooperation and Trade: Enhancing trade and economic cooperation is a key focus of efforts between MERCOSUR and the EU. The EU is a major trading partner for MERCOSUR countries, and there is a shared interest in deepening economic integration. Efforts have been made to reduce trade barriers, improve market access, and promote investment flows between the two regions[54].

Efforts to improve relations between MERCOSUR countries and the European Union encompass a broad range of areas, including political dialogue, trade, cooperation in research and innovation, and economic integration. The MERCOSUR-EU Association Agreement, once ratified, is expected to play a pivotal role in strengthening these relations. Continued collaboration and dialogue between the two blocs will be crucial in addressing common challenges and promoting shared prosperity.

8.1 The EU-MERCOSUR Agreement and its Implications for the Effective Implementation of the ITPGRFA

The European Union-MERCOSUR Agreement is a comprehensive trade deal between the EU and the MERCOSUR, a regional integration initiative consisting of Argentina, Brazil, Paraguay, and Uruguay. Negotiations for the agreement began in 1999 and concluded in 2019[55]. The agreement aims to establish a free trade area between the two blocs, covering various economic sectors, including agriculture. The ITPGRFA is an international legal framework that addresses the conservation, exchange, and sustainable use of PGRs. Let us examine the potential impact of the EU-MERCOSUR Agreement on the effective implementation of the ITPGRFA.

8.1.1 Scope and Objectives of the Agreement

The EU-MERCOSUR Agreement aims to enhance trade and economic cooperation between the two regions. It covers numerous areas, such as trade in goods and services, government procurement, intellectual property rights, sustainable development, and agricultural products.

8.1.2 Agriculture and PGRs

A significant component of the agreement relates to agriculture and agri-food products. The agreement addresses issues such as market access, tariffs, quotas, sanitary and phytosanitary measures, and technical barriers to trade[56]. These provisions have the potential to impact the production, trade, and access to PGRs.

8.1.3 Impact on the Implementation of the ITPGRFA

Access and Benefit-Sharing (ABS): The ITPGRFA recognizes the rights of farmers and countries to access and share the benefits arising from the use of PGRs. It encourages fair and equitable sharing of benefits through measures such as access agreements and the creation of a multilateral system[57]. The EU-MERCOSUR Agreement may influence the implementation of ABS

[53] EUROPEAN COMMISSION. *EU-MERCOSUR Joint Initiative for Research and Innovation*. Available at: https://ec.europa.eu/info/news/eu-and-MERCOSUR-join-forces-research-and-innovation-2019-mar-11_en. Access in: 29 May 2023.

[54] EUROPEAN COMMISSION. *Trade*. Available at: https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/MERCOSUR_en#:~:text=The%20EU%20is%20MERCOSUR's%20second,EU%20were%20%E2%82%AC43%20billion. Access in: 28 May 2023.

[55] EUROPEAN COMMISSION. *EU-MERCOSUR Trade Agreement*. Available at: https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/MERCOSUR/eu-MERCOSUR-agreement_en. Access in: 30 May 2023.

[56] EUROPEAN COMMISSION. *EU-MERCOSUR Trade Agreement*. Available at: https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/MERCOSUR/eu-MERCOSUR-agreement_en. Access in: 30 May 2023.

[57] FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS. *International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/plant-treaty/countries/membership/en/?page=10&ipp=20&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MToiMCI7fQ==. Access in: 28 May 2023.

provisions by potentially altering the terms of access to genetic resources and associated traditional knowledge.

Intellectual Property Rights (IPRs): The EU-MERCOSUR Agreement includes provisions on intellectual property rights, including patents and plant variety protection[58]. Stronger IPR protections could potentially limit the free exchange of genetic resources and hinder the implementation of the ITPGRFA's open-access approach[59]. It may also create challenges for farmers in accessing and using PGRs for breeding and innovation.

Sustainable Agriculture and Conservation: The ITPGRFA promotes the conservation and sustainable use of PGRs, recognizing their importance for food security and agriculture. The EU-MERCOSUR Agreement includes provisions related to sustainable development and environmental protection[60]. However, concerns have been raised regarding the potential negative impacts of increased agricultural trade on deforestation, biodiversity loss, and the sustainability of agriculture in the MERCOSUR countries.

The researchers believe that in order to address the ethical issues surrounding the use of digital tools in the implementation of ITPGRFA, it is essential to establish clear guidelines and policies for data privacy, security, and ownership. Governments and relevant institutions must ensure that data is collected and managed in a responsible and ethical manner, and that the rights of data providers, including farmers and indigenous communities, are respected. Additionally, capacity-building programs can be developed to train stakeholders on how to use digital tools effectively and responsibly, and to raise awareness about the importance of data privacy and security.

To improve the relationship between MERCOSUR countries and the European Union, there should be a collaborative effort to establish common standards and protocols for the use of digital tools in the implementation of the ITPGRFA. This can be achieved through joint research and development initiatives, as well as information sharing and exchange programs. Additionally, regulatory frameworks and international agreements should be developed to promote responsible and ethical use of digital tools in the exchange of PGRs data, ensuring that they are not used for commercial gain or to the detriment of farmers' and indigenous communities' rights.

Ultimately, the adoption of responsible and ethical practices in the use of digital tools can help build trust between MERCOSUR countries and the European Union, as well as enhance the conservation and sustainable use of PGRs. By working together, these countries can establish a more robust and resilient global food system, which is essential to meet the challenges posed by climate change and population growth.

9 Gaps in the current model of digital tool usage in MERCOSUR countries and the EU

There are several gaps in the current model of digital tool usage in MERCOSUR countries and the EU concerning the implementation of the ITPGRFA[61].To bridge the existing gaps in the utilization of digital tools for implementing the ITPGRFA in MERCOSUR countries and the EU, several measures can be taken:

Firstly, it is crucial to establish common standards and protocols for the application of digital tools. These standards would ensure consistency in data collection and enable comparative analysis.

Secondly, capacity-building programs should be implemented to educate and empower relevant stakeholders on the responsible and ethical use of digital tools. By doing so, the rights of data providers, including farmers and indigenous communities, would be respected,

[58] EUROPEAN COMMISSION. *EU-MERCOSUR Trade Agreement*. Available at: https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/MERCOSUR/eu-MERCOSUR-agreement_en. Access in: 30 May 2023.

[59] FOOD AND AGRICULTURAL ORGANIZATION. The Multilateral System of Access and Benefit-sharing. *International Treaty on PGRs for Food and Agriculture*. Available at: https://www.fao.org/plant-treaty/countries/membership/en/?page=10&ipp=20&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MToiMCI7fQ==. Access in: 28 May 2023.

[60] BELÉN GRACIA, María. The EU-MERCOSUR Agreement is not a threat to EU Environmental Policy. *Trade Experettes*. Available at: https://www.tradeexperettes.org/blog/articles/the-european-union-MERCOSUR-agreement-is-not-a-threat-to-eu-environmental-policy. Access in: 28 May 2023.

[61] EUROPEAN PARLIAMENT. Regulation n. 511/2014 on Compliance measures for users from Nagoya Protocol. *Official Journal of European Union,* 2014. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0511. Access in: 30 May 2023.

and the collected data would be utilized in an ethical manner.

Thirdly, emphasis should be placed on data privacy and security to safeguard the collected data from unauthorized access and misuse. Adequate attention must be given to privacy and security measures to protect the sensitive information gathered through digital tools.

Furthermore, enhancing collaboration between MERCOSUR countries and the EU is essential for the development and utilization of digital tools in implementing the ITPGRFA. Collaborative efforts would ensure that the tools created are suitable for local contexts and capable of addressing specific challenges effectively.

To promote responsible and ethical use of digital tools, it is imperative to establish regulatory frameworks and international agreements. These frameworks should safeguard against the commercial exploitation of PGRs data and protect the rights of farmers and indigenous communities.

In addition to the aforementioned steps, several challenges also need to be addressed. *For instance,* insufficient access to digital tools is a prevalent issue, particularly due to limited infrastructure, inadequate training, and lack of funding. Tackling these challenges necessitates increased investment in digital infrastructure, training programs, and financial support for smallholder farmers and local communities.

Another obstacle is the limited interoperability among existing systems used in MERCOSUR countries and the EU. Incompatibility between databases and platforms hampers the exchange of PGRs data and collaboration among stakeholders. Overcoming this hurdle requires the development of common data standards and protocols to facilitate seamless data exchange.

The issue of intellectual property rights also arises when employing digital tools in ITPGRFA implementation. Some platforms and databases may require users to relinquish their intellectual property rights when uploading data, discouraging data sharing and hindering collaboration. Addressing this challenge involves establishing ethical guidelines that ensure stakeholders retain their intellectual property rights and receive fair compensation for their contributions.

Furthermore, effective stakeholder engagement is crucial for the successful adoption of digital tools in implementing the ITPGRFA. This includes actively involving smallholder farmers and indigenous communities in the design and implementation of digital tools, as well as incorporating their perspectives in decision-making processes. Through meaningful stakeholder engagement, ownership of digital tools can be promoted, leading to increased adoption and sustainability.

Another major concern is the likelihood of these digital tools to be affected by Artificial Intelligence (AI). Though the impacts can be both positive and negative, depending on the strategy of its integration in the utilization of the digital tools.

AI-integration into the utilization of digital tools for implementing the ITPGRFA) has the potential to significantly enhance agricultural practices and biodiversity conservation. AI algorithms can process vast amounts of data swiftly and accurately, leading to precise analysis of PGRs), optimizing resource allocation, and improving agricultural practices[62]. Predictive analytics driven by AI can forecast crop yields, disease outbreaks, and climate patterns, allowing farmers to plan their activities accordingly and ensure better yields[63]. AI can also facilitate sustainable resource management by suggesting precise amounts of water, fertilizers, and pesticides based on real-time data analysis, contributing to sustainable agriculture and reduced environmental impact[64]. Additionally, AI's ability to customize digital tools to specific local contexts ensures the tools are effective and suitable for different agricultural systems, addressing unique challenges in various regions[65]. Furthermore, AI accelerates research by analyzing vast amounts of scientific literature and genetic data, potentially leading to breakthroughs in breeding and genomics, ultimately improving agricultural productivity and resilience[66].

[62] BALASKA, V. *et al*. Sustainable crop protection via robotics and artificial intelligence solutions. *Machines*, v. 11, 2023. DOI: https://doi.org/10.3390/machines11080774.

[63] MEHAR, Arpit. *AI in agriculture*: the revolutionary technology for farmers. 2023. Available at: https://almabetter.com/bytes/articles/ai-in-agriculture.

[64] TALAVIYA, Tanha *et al. Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides*. 2020. v. 4. p. 58-73.

[65] SUBEESH, A.; MEHTA, C. R. Automation and digitalization of agriculture using artificial intelligence and internet of things. 2021. *Artificial Intelligence in Agriculture*, v. 5. p. 278-291, 2021. DOI: https://doi.org/10.1016/j.aiia.2021.11.004.

[66] MUHAMMAD, H. Shoudong Wang *et al*. Applications of artificial intelligence in climate-resilient smart-crop breeding. *International Journal of Molecular Sciences,* v. 23, n. 19, 2022. DOI: 10.3390/ijms231911156.

However, the integration of AI into digital tools raises several concerns that must be addressed. Firstly, biases present in the data used to train AI algorithms can be perpetuated, resulting in discriminatory outcomes in decision-making[67]. Additionally, the increased reliance on AI and digital tools raises concerns about data privacy and security, risking unauthorized access, misuse, or data breaches, compromising sensitive information, including genetic data and farmers' data[68]. Over-reliance on AI can potentially lead to a decline in traditional agricultural skills and knowledge, creating dependency and exacerbating skill gaps[69]. Moreover, the computational requirements of AI technologies contribute to a larger environmental footprint due to energy-intensive data centers and high computational needs, partially negating the sustainability benefits achieved through optimized resource usage[70].

To mitigate the negative impacts of AI integration into digital tools, ethical AI development and adherence to transparency and bias-free algorithms are crucial[71]. Stringent data privacy regulations and security protocols should be implemented to safeguard sensitive information[72]. Comprehensive capacity-building programs should be instituted to enhance understanding and skills related to AI and digital tools, focusing on responsible AI use, data privacy, and security measures[73]. Encouraging the development and adoption of energy-efficient AI algorithms and computing infrastructure is essential to minimize the environmental footprint of AI technologies[74]. Collaborative efforts and informed policies are imperative to ensure the responsible and sustainable implementation of AI in digital tools for agriculture.

Generally, keeping in view all these possibilities, the researchers believe that in order to tackle these gaps comprehensively, it is pertinent to implement strategies such as investing in digital infrastructure and training programs to improve access to digital tools, developing common data standards and protocols to enhance interoperability, establishing ethical guidelines to safeguard intellectual property rights, and ensuring active engagement of stakeholders, particularly smallholder farmers and indigenous communities, in the design and implementation of digital tools. By implementing these measures, the utilization of digital tools in MERCOSUR countries and the EU for applying the ITPGRFA can be significantly enhanced.

To address the gaps in the utilization of digital tools for implementing the ITPGRFA in MERCOSUR countries and the EU, several additional strategies can also be employed.

Firstly, it is crucial to focus on the development of open-source and interoperable digital tools that can be easily adapted and adopted by different stakeholders. By embracing open-source solutions, collaboration can be enhanced, ensuring efficient management and sharing of PGRs data while fostering a cooperative environment. Improving access to digital tools in rural areas is essential to empower farmers and rural communities to actively contribute to the ITPGRFA implementation.

Initiatives such as establishing community seed banks and providing tailored training and capacity-building programs can bridge the digital divide, enabling effective participation and harnessing local knowledge for PGRs conservation and utilization.

Strengthening data privacy and security policies is paramount, as clear guidelines and measures such as data encryption, user authentication, and access controls are necessary to ensure responsible and ethical use of digital tools. By prioritizing data protection, stakeholders can have confidence in the confidentiality

[67] MUHAMMAD, H. Shoudong Wang *et al.* Applications of artificial intelligence in climate-resilient smart-crop breeding. *International Journal of Molecular Sciences,* v. 23, n. 19, 2022. DOI: 10.3390/ijms231911156.

[68] PEARCE, Guy. Beware the privacy violations in artificial intelligence applications. *ISACA,* 2023. Available at: https://www.isaca.org/resources/news-and-trends/isaca-now-blog/2021/beware-the-privacy-violations-in-artificial-intelligence-applications.

[69] PRICEWATERHOUSECOOPERS. The potential impact of artificial intelligence on UK employment and the demand for skills. *BEIS Research Report*, n. 42, 2021. Available at: https://assets.publishing.service.gov.uk/media/615d9a1ad3bf7f55fa92694a/impact-of-ai-on-jobs.pdf.

[70] VINUESA, Ricardo; AZIZPOUR, Hossein. The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications*, v. 11, p. 1-10, 2020. Available at: https://doi.org/10.1038/s41467-019-14108-y.

[71] MADHAV, Jeyaraman *et al.* Unraveling the ethical enigma: artificial intelligence in healthcare. *Cureus,* v. 15, n. 8, 2023. DOI: 10.7759/cureus.43262.

[72] MADHAV, Jeyaraman *et al.* Unraveling the ethical enigma: artificial intelligence in healthcare. *Cureus,* v. 15, n. 8, 2023. DOI: 10.7759/cureus.43262.

[73] UNESCO. *Ethics of artificial intelligence*. Available at: https://www.unesco.org/en/artificial-intelligence/recommendation-ethics.

[74] CHEN, Lin *et al.* Artificial intelligence-based solutions for climate change: a review. *Environmental Chemistry Letters*, v. 21, p. 2525-2557, 2023. DOI: https://doi.org/10.1007/s10311-023-01617-y.

and integrity of their data, fostering trust and facilitating collaboration.

Promoting a culture of responsible and ethical data sharing through capacity-building and awareness-raising programs is vital. These initiatives can educate stakeholders on responsible data sharing practices, including proper data attribution, respect for intellectual property rights, and privacy considerations. Cultivating such a culture enhances trust and collaboration, resulting in the effective implementation of the ITPGRFA.

The development of international agreements and frameworks is crucial to guide the responsible and ethical use of digital tools in implementing the ITPGRFA. These agreements should address areas such as data sharing and ownership, ensuring that PGRs data is not exploited for commercial gain without consent or fair compensation. Establishing international regulations and standards creates a harmonized approach, promoting cooperation among countries.

Lastly, promoting South-South cooperation among MERCOSUR countries and other developing nations plays a significant role in addressing the gaps in digital tools utilization.

Sharing experiences and best practices enables mutual learning and facilitates the development of more effective digital tools and policies. This cooperation fosters collaboration, enhances technical capacities, and advances the implementation of the ITPGRFA on a broader scale. By incorporating these strategies along with the previously mentioned measures, the gaps in the current model of digital tools usage in MERCOSUR countries and the EU can be effectively addressed. This comprehensive approach ensures the responsible and ethical use of digital tools, enhances collaboration, and promotes the conservation and sustainable utilization of PGRs for food and agriculture.

10 Conclusion

The ITPGRFA is a significant agreement aimed at promoting the conservation and sustainable utilization of PGRs. However, effectively implementing this treaty in MERCOSUR countries requires the use of digital tools and technologies to support the collection, management, and sharing of PGR data. Digital tools, including databases, digital platforms, and software applications, play a vital role in facilitating the exchange of PGR data and promoting collaboration among various stakeholders such as researchers, breeders, and farmers[75]. Nevertheless, the utilization of digital tools in implementing the ITPGRFA raises ethical concerns surrounding data privacy, security, and ownership. These issues can be addressed by implementing appropriate legal frameworks and guidelines, developing secure and transparent data-sharing mechanisms, and establishing clear protocols for data ownership and control.

Furthermore, continuous research and development of digital tools are crucial to ensure the conservation and sustainable utilization of PGRs. Collaborative efforts between researchers, policymakers, and other stakeholders are necessary to identify and address the technical, legal, and ethical challenges associated with the use of digital tools in implementing the ITPGRFA. Overall, the utilization of digital tools in ITPGRFA implementation presents both opportunities and challenges. However, with adequate measures in place, digital tools can play a pivotal role in promoting the conservation and sustainable use of PGRs, thereby contributing to global food security and agricultural sustainability.

Emphasizing the significance of ongoing research and development of digital tools is necessary to ensure the conservation and sustainable use of PGRs. While digital tools have the potential to support the implementation of the ITPGRFA, there is always room for improvement and innovation. Continuous research and development can ensure that digital tools evolve and adapt to meet the changing needs of stakeholders involved in the conservation and sustainable use of PGRs. For example, research can focus on developing more user-friendly and accessible digital tools for various stakeholders, including smallholder farmers. Additionally, research can aim to enhance the accuracy and reliability of digital databases and platforms to ensure the collection and sharing of high-quality data.

Moreover, research efforts should focus on addressing the ethical and legal concerns associated with the use of digital tools in implementing the ITPGRFA. Striking a balance between the need for open access to data

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and the protection of intellectual property rights of different stakeholders can be explored through research[76]. Overall, continuous research and development can guarantee that digital tools remain a valuable resource for stakeholders involved in the conservation and sustainable use of PGRs.

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