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Agrobiodiversity-Oriented Food Systems between Public Policies and Private Action: A Socio-Ecological Model for Sustainable Territorial Development

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Abstract: The international and European literature and institutional contexts are fostering agrobiodiversity as the foundation of a new paradigm for localized agri-food system development and sustainability. Accordingly, new systemic and holistic theoretical approaches and conceptual models are needed. This paper aims to identify and apply a new conceptual framework contributing to the understanding of how the restoring and valorization of underutilized or neglected landraces can act as a trigger for sustainable territorial development. A new holistic model was designed for the characterization and analysis of agrobiodiversity-oriented food systems. We consider the model innovative in enhancing the conceptualization of the adoption of a socio-ecological systems approach. We applied the model to a representative case study involving the localized agri-food system of the Valtiberina Red Onion, a threatened plant landrace cultivated in Tuscany, Italy. A participatory action–research approach was followed, involving both public and private stakeholders. As the main outcome of the paper, we demonstrated the capability of our new SES model by identifying and describing the assets, drivers, human action processes and generated beneficial effects concerning the development and reproduction of landrace-based quality valorization virtuous circles. Our research findings highlighted the model as an innovative tool for the analysis of agrobiodiversity-oriented food systems sustainability. Significantly, the model was designed to identify the combined role of public policy and private action in supporting the implementation of coherent management mechanisms and effective governance settings.

Keywords: agricultural biodiversity; localized agri-food systems; sustainability transition; socio-ecological systems; origin-linked quality valorization virtuous circles; multi-stakeholder governance models; hybrid management mechanisms



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1. Introduction

The exploration of the role of agrobiodiversity in fostering sustainable transition processes is among the key research issues in the field of agri-food systems and territorial development studies [1–4].

Agrobiodiversity can be described as the evident outcome of a long-lasting human-nature relationship, conceivable as the continuous use, conservation, enhancement and renewal of a variety of crops and animal breeding which results in a biological as well as cultural diversity of seeds and breeds [5].

The involvement of local farming systems and agri-food chains for the conservation and enhancement of underutilized or neglected landraces is therefore essential, on the one hand, as a contribution to preserving local biodiversity and its natural functionality for farming activities and, on the other hand, for supporting and enhancing the joint provision

of differentiated quality products and services together with social and environmental benefits [6–12].

Understanding the complexity of the values and processes underlying the management of local genetic resources and related traditions is a fundamental step for both private and public stakeholders to take for agrobiodiversity resource conservation and sustainable valorization [13–18].

In particular, preserving endangered local genetic resources and related human cultural values should not only be intended as a social and environmental goal, but also as a way to trigger rural territorial development on the basis of common territorial assets to be collectively activated and valorized [19–25].

Consequently, the current status of agrobiodiversity and related actions evidences the need for an increased research effort to support understanding of the role of agrobiodiversity in agri-food systems and territorial paths [26–28].

The literature on this topic discusses how agrobiodiversity, particularly threatened landraces, can form the foundation of a new paradigm for agricultural systems and sustainable food chain transformation [29–31].

To that end, the coherent and collective organization of endangered landrace protection and valorization can contribute to the creation of landrace-based localized agri-food systems and the enhancement of their competitiveness as well as a multifunctional role in the environment and for human well-being [15,32–36]. Accordingly, important changes are required at the governance level, through the involvement of both public and private stakeholders.

In light of this, both the international literature and the evolving institutional context are fostering the design and implementation of polycentric multi-actor governance models [37] and participatory strategies [38,39]. The latter should enable and boost the conservation and collective use of agrobiodiversity as a set of genetic–cultural common territorial assets [28,40,41] and adopt coherent policies and action favoring an equitable sharing and fair distribution of generated benefits [2,13–16].

Particularly, specific policy goals and legal measures have been established at both the international and EU level in order to direct and stimulate the evolution of national and local policies and legislations on the protection and sustainable valorization of agrobiodiversity resources, with particular attention to the recovery of threatened landraces [30,42–45]. The integration of policies towards a consistent framework is of outstanding importance in seeking to address both the transition to sustainability and territorial development based on agrobiodiversity [46–48].

In this regard, policy makers show a growing interest in the restoring of knowledge and cultivation of underutilized or neglected landraces and their qualification and valorization through the marketing of landrace-based agrobiodiversity products [11,13,28,49–51].

At the same time, the recent literature emphasizes the adoption of new holistic and systemic approaches to the conceptualization and analysis of agri-food systems, the preservation and valorization of endangered landraces, and the promotion of related culture and traditions [52,53].

The intent of the debate on these topics is to foster interdisciplinary action, research and participatory methodologies towards the development of sustainable and multifunctional agrobiodiversity-based systems [54–56]. The debate also aims at favoring the design of new conceptual frameworks in order to characterize and analyze underlying human and natural factors, related interactions and generated outcomes [57].

Despite the importance of innovative theories and models, the debate is still in its infancy. This paper aims to present and apply a new conceptual framework to support the understanding of how the restoration and valorization of underutilized or neglected landraces can act as a lever of territorial development and sustainability. Specifically, our aim is to characterize and analyze from an innovative theoretical perspective the assets, drivers, human action processes and beneficial effects related to public–private

initiatives for the protection and valorization of threatened local genetic resources and related traditions involving local farming systems and agri-food chains.

On a conceptual level, we make further reflections on and provide a contribution to the notion of biodiversity-oriented food systems [30] following the SES theoretical approach, and design a new holistic model for the characterization and analysis of agrobiodiversity-oriented food systems.

From a methodological point of view, we adopt a case study approach. A relevant case study was selected to apply the new SES framework and evaluate its potential. Specifically, we considered the initiatives implemented for the identification, protection and valorization of a threatened plant landrace in Tuscany, Italy: the Valtiberina Red Onion (Cipolla Rossa della Valtiberina). A participatory action–research approach was followed, with the involvement of both public and private stakeholders.

In Sections 2 and 3 we illustrate the identified conceptual framework and the participatory methodology. Section 4 presents the case study analysis and results. Lastly, Sections 5 and 6 are dedicated to the case study discussion and conclusions.

2. The Conceptual Framework

2.1. *Agrobiodiversity-Oriented Food Systems: A Reviewed Integrated Definition*

Restoring and promoting the knowledge and use of agrobiodiversity resources, particularly endangered landraces, can support the resilience of localized agri-food systems and contribute to local development and sustainable territorial growth [10,40]. Here, we refer to localized agri-food systems as production and service organizations (e.g., agricultural and agri-food production units, marketing, services and gastronomic enterprises, etc.) linked to a specific territory by their characteristics and operational methods [58,59].

Building on Brunori et al. (2018) [30], we identified the concept of agrobiodiversity-oriented food systems as localized agri-food systems based on: (i). The identification and preservation of underutilized, neglected and in particular threatened landraces and related traditions [21,24,60]; (ii). The collective use of the identified and protected local genetic and cultural resources for the creation of landrace-based agrobiodiversity products, both goods (e.g., fresh food, food preparations, by-products, etc.) and services (e.g., visits, didactic activities, etc.) [61,62]; and (iii). The participatory qualification, marketing and territorial valorization of landrace-based agrobiodiversity products [32,33,63].

Achieving resilient and sustainable agrobiodiversity-oriented food systems depends on increased levels of social learning and cognition about agrobiodiversity assets, involving both public and private stakeholders, and consequent improved collective action to structure adequate multi-actor governance and hybrid management mechanisms [27,54,55,57,62,64]. These processes can be seen within the frame of a quality valorization virtuous circle of endangered landraces and related traditions, considering the integration of relevant public policies and strategies of private actors [65,66]. In particular, the creation and enhancement of competitive and multifunctional landrace-based localized agri-food systems can be the result of a greater awareness and responsibility on the part of both public and private stakeholders on the multiple values (economic, social and environmental) of local genetic and cultural resources and the commitment of these stakeholders to coherent and collective valorization paths intended to guarantee the equitable sharing and distribution of the resulting public and private benefits [22,30,35,67].

The analysis of agrobiodiversity as a new lever for sustainable rural development requires the adoption of different theoretical perspectives. In light of that, we have considered the framing of agrobiodiversity-oriented food systems according to an interdisciplinary approach that identifies them as evolving socio-ecological systems (SES).

2.2. *Agrobiodiversity-Oriented Food Systems Analysis and Characterization: A New Socio-Ecological Model*

Despite the lack of a unifying definition of socio-ecological systems (SES), the evolving debate in the literature contributes to enhancing the added value of the SES approach

in analyzing and sustaining the resilience of local resource management systems [68–70]. The SES approach emphasizes that a delineation between social and ecological systems is artificial and arbitrary in understanding and supporting the development and sustainability of local farming systems and agri-food chains [71]. In particular, the SES approach favors the identification of systemic and interdisciplinary frameworks, which are suitable for the analysis of both human–natural assets and can process dynamic interplay within different territories and general socioeconomic and biophysical contexts [72–75]. SES frameworks can explain such important localized agri-food system properties as resilience and sustainability, and permit the identification of effective governance settings supporting local specific resources, socio-ecological understanding and coherent management [75,76].

To improve the validity and applicability of such findings, current research on agrobiodiversity increasingly places value on the contribution of holistic approaches [30,57,77], particularly socio-ecological theories and conceptual frameworks [2,78–84].

The SES approach can be retained as one of the most effective in interpreting the nature and value of the diversity of landraces and traditions characterizing a specific territory and affecting localized agri-food system potential, as well as in supporting agrobiodiversity-based sustainable growth and territorial development [85].

In light of this, our paper considers the SES theoretical framework by Maréchal et al. (2016) [71] and Dwyer et al. (2015) [86], designed on the basis of the SES conceptual model by McGinnis and Ostrom (2014) [75].

Drawing on Maréchal et al. (2016) [71] and Dwyer et al. (2015) [86], we identified a new conceptual framework by innovatively combining and adapting the aforementioned SES framework with the origin-linked quality valorization virtuous circle by Vandecastelaere et al. (2010) [65] and Belletti et al. (2017) [66].

This innovative SES conceptual framework represents a holistic tool for the analysis and characterization of agrobiodiversity-oriented food systems (Figure 1). Thus, it provides a systemic analysis of the complex of assets, actors, processes and effects characterizing the mutually evolving relations between localized agri-food systems and the surrounding natural and sociocultural contexts.

The presented SES conceptual framework (Figure 1) is intended to highlight the structural elements and dynamic relationships that characterize agrobiodiversity-oriented food systems.

As shown in Figure 1, the SES framework structure outlines the components and interactions of the following basic conceptual categories:

1. The assets (*territorial capital including agrobiodiversity and other local specific assets*). They are constituted by the (natural, human, social, manufactured and cultural) components of the specific territorial capital, feeding natural ecosystem processes, and managed by humans for conservation and agricultural or market use. As part of that capital, agrobiodiversity assets include local genetic resources and the related traditional knowledge and practices that originated and/or evolved in the territory;
2. The drivers (*socioeconomic and biophysical drivers*). They include the factors, inherent to the general and specific social and ecological contexts, that trigger the evolution of processes in farming systems and agri-food chains. On the socioeconomic side, most influential drivers can be identified as the set of public policies (at international, national and local level), market dynamics, socio-cultural values, organizational culture, etc., affecting the natural evolution, the acknowledgement and management of agrobiodiversity genetic and cultural resources in the localized agri-food system. Similarly, on the biophysical side, they include the set of most critical natural influences, as for example, geomorphology, soil, water, climate and weather, etc.;
3. Human action and natural ecosystem processes (*hybrid management mechanisms of agrobiodiversity and other territorial assets and natural processes affecting local biodiversity and the agro-ecosystem*). They include public and private action combinations, intended as complexes of decisions and practices affecting agrobiodiversity and natural processes within agro-ecosystems. The category focuses on the hybrid management mechanisms implemented to pursue the restoring and valorization of underutilized

- or neglected landraces knowledge and use in localized agri-food systems. To illustrate, these mechanisms include local genetic resources and traditions protection systems and valorization paths, enabling a collective and coherent qualification and remuneration of the complexity of agrobiodiversity values. In that regard, we open this category to a wider perspective and consideration of the role such mechanisms could play in the activation and support of a quality valorization virtuous circle of agrobiodiversity resources, that will be described in detail below;
4. The effects category (*generation of private and public goods and services that benefit the society and the ecosystem*). This category aims at evidencing how the development of landrace-based localized agri-food systems characterized by quality valorization virtuous circles can combine the production of private goods and services (e.g., local farmers access to threatened landraces genetic material and other provisioning ecosystem services, landrace-based food products and services supply, reusable waste, etc.) with the one of public goods and services (e.g., biodiversity and rural culture preservation, provision for food security and safe nutrition, contribution to social education and leisure, enhancement of rural landscape and other social and environmental goods and services, etc.) and generate benefits for both the society and the ecosystem. The latter can be identified as the beneficial effects stemming from the several stages of the virtuous circle and sustaining the agrobiodiversity-oriented food system reproduction and sustainability. They could be analyzed considering the changes induced by the system development in economic, social and environmental dimensions at a local and territorial level and even in a wider global perspective (e.g., higher income and competitiveness of local farmers and agri-food chains, growth of local economies, protection of the environment and the ecosystem, enhancement of social and cultural capital and human well-being, etc.).

Lastly, the SES framework considers the characteristics and fundamental role of multi-level institutions and *governance settings* to be analyzed as an overridden cross-category which transversely affects the structure and functionality of all the other identified categories. Therefore, this class is not graphically represented in Figure 1. Nonetheless, the model identifies it as the specific systems of formal or informal rules, institutions and principles (e.g., property rights) underlying and determining the structure and beneficial effects of the interactions between agrobiodiversity resources and human action in the quality valorization virtuous circle. Public policies, legal regimes and market institutions are also taken into consideration. How governance is shaped is a key determinant for the production, equitable distribution and sustainable use of the private and public goods and services generable from the restoration and valorization of underutilized and neglected landraces in localized agri-food systems. At the same time, the interaction between actors and the functioning of the virtuous circle can modify existing institutions and governance settings, and/or generate new ones, based on a long-lasting participative process of acknowledgement and actualization of the values of agrobiodiversity [66].

Regarding point 3 of the SES model description, we adapted the origin-linked quality virtuous circle model by Vandecandelaere et al. (2010) [65] and Belletti et al. (2017) [66] to permit a detailed characterization of the human action processes underlying agrobiodiversity-oriented food system development and sustainability. The elaboration of a quality valorization virtuous circle of agrobiodiversity resources (Figure 1) aims to frame and analyze the possible combinations of public and private action throughout the evolving stages of a collective process of value recognition and coherent management of local genetic resources and traditions, with the latter leading to the effective protection as well as the market and territorial valorization of underutilized or neglected landraces.

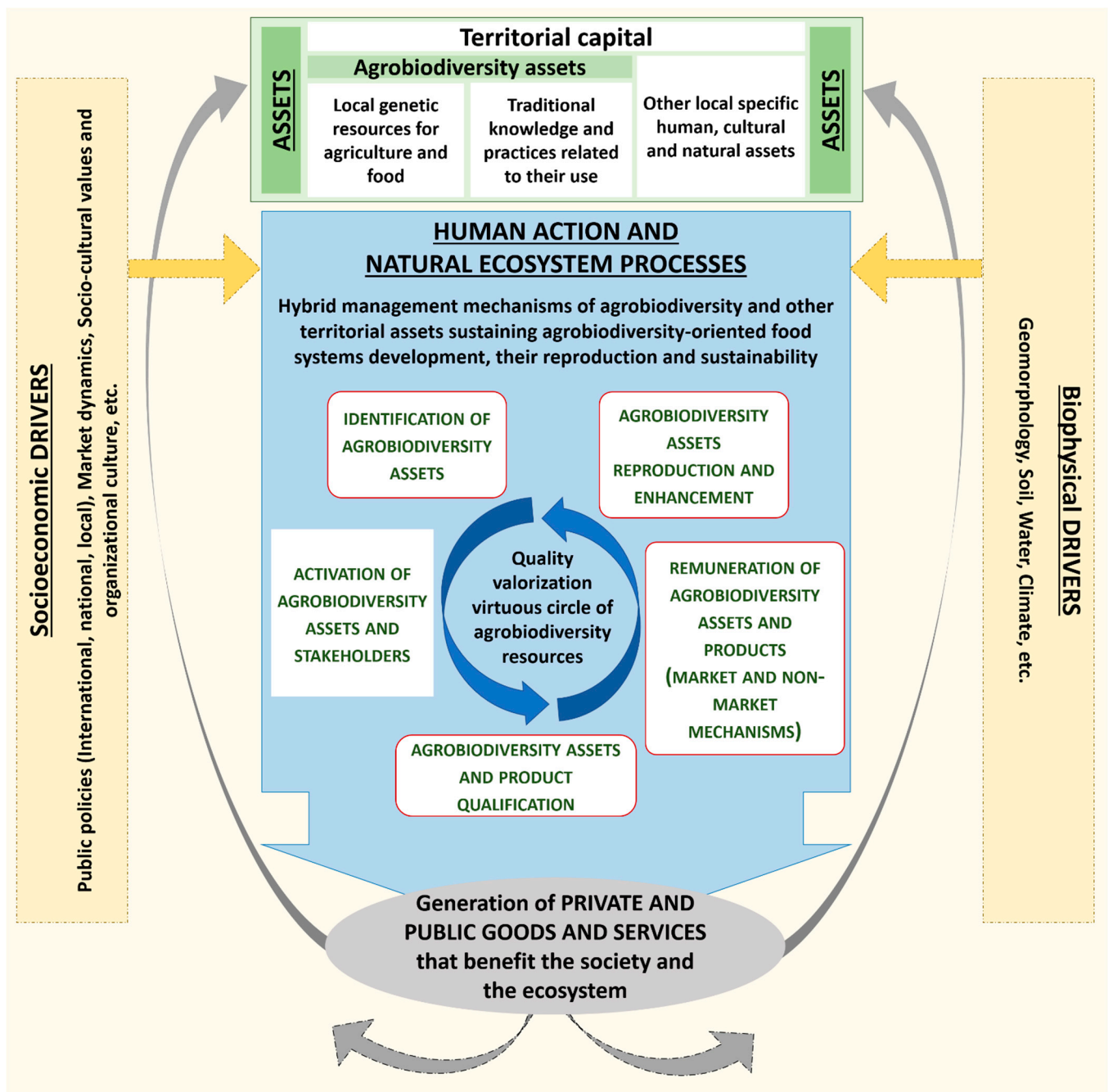


Figure 1. A Socio-ecological systems framework for the analysis and characterization of agrobiodiversity-oriented food systems. Source: our elaboration on [65,66,71,86].

As shown in Figure 1, the identified quality valorization virtuous circle includes the following stages:

1. *Identification of agrobiodiversity assets*: identification of underutilized or neglected local genetic resources (i.e., mapping, preliminary studies), their distinctive qualities (e.g., agronomic, morphological, organoleptic, nutraceutical, etc.) and reputation, their extinction risk and their relations with the territory and the other territorial assets (e.g., history, traditional knowledge and practices, etc.). As a result, local actors become aware of landraces and their specific identity and multiple value potential, and take action leading to public recognition, conservation and product qualification;

2. The *activation of agrobiodiversity assets and stakeholders* considers the commitment of local farmers, supply chain operators and other interested parties (e.g., custodian farmers, conservation and food security networks, etc.) whether local or non-local, public or private, towards the registration of local genetic resource names, qualities and territorial linkages in dedicated public repertories, as well as the conservation of the genetic material of threatened landraces and the restoring of landrace knowledge and cultivation/breeding in localized agricultural systems;
3. *Agrobiodiversity assets and product qualification*: private and sometimes public stakeholders work for the unanimous characterization and social recognition of the value of agrobiodiversity assets and products. For instance, they make special efforts to identify effective signaling tools to qualify landraces and landrace-based agrobiodiversity products (e.g., collective marks, denominations of origin, inscription in public registries of seeds, propagation material commercialization, etc.);
4. *Remuneration of agrobiodiversity assets and products*: local farmers realize individual and/or collaborative marketing strategies for the valorization and protection of landrace-based goods and services, with the collaboration of agri-food chains actors and the support of other local or non-local stakeholders (e.g., universities, associations, territorial bodies, etc.). These strategies can refer to product and placement policies, price setting, and promotional initiatives. Sometimes, when products cannot find a specific market, non-market mechanisms may be adopted. The latter are government interventions (e.g., assistance, training, payments, etc.), implemented to remunerate the farmers' efforts for the conservation of non-marketable landraces or to integrate the inadequate compensatory role of the market for the agrobiodiversity products' public and private functions [34,61,62,87]. The scope of this stage is that of leading society to pay for the total value of public and private goods and services produced by farmers and other stakeholders involved in initiatives for the protection and valorization of agrobiodiversity resources;
5. *Reproduction of agrobiodiversity assets*: this phase aims at the preservation, enhancement and renewal of agrobiodiversity and the other territorial assets around the landrace-based localized agri-food system. The goal of sustainability must be realized in terms of the production, equitable sharing and reproduction of the economic, social and environmental beneficial effects generated by the virtuous valorization circle in the evolving agrobiodiversity-oriented food system.

Lastly, horizontal results and further impacts can be reached through the implementation of extended territorial strategies based on the collective valorization (collective action and tools) of landraces and related traditions and of the products (goods and services) derived from them [54]. The scope of these strategies is the increase in social demand for agrobiodiversity in order to favor local genetic resource conservation and sustainable use in farming systems and agri-food chains, and resulting potential contributions to local territorial development.

3. Methodology

The methodology of this paper is based on a case study analysis [88,89]. We identified a case study concerning an agrobiodiversity-oriented food system structure and its evolving dynamics. Specifically, we focused on the triggers, actions and beneficial effects related to the combination of public and private initiatives implemented for the identification, protection and valorization of a threatened plant landrace typical of a small territory in Tuscany, Italy: the Valtiberina Red Onion. We chose the genetic resource from among the ones registered in the Tuscan Regional Repertories of local breeds and varieties (Regional law 64/2004) [90] and also included in the Italian National Registry of biodiversity for agriculture and food (National law 194/2015) [91].

The case study selection was the result of a documentary analysis of national and local policies and legislations in the EU concerning agrobiodiversity protection and valorization. To that end, we identified Italy as a virtuous country case. As a matter of fact, Italy is one of the few EU countries committed to the establishment of a specific national policy and legal

framework on agrobiodiversity with the aim of functionally interlinking the environmental goal of local genetic resource and ecosystem conservation with that of the economic and socio-cultural realization of local and rural territorial development paths [42,44,48,63].

Furthermore, we evaluated the fundamental role of the Tuscany Region as a reference model for the design and ongoing implementation of the new national system of agrobiodiversity. Tuscany was among the first Italian Regional Administrations to design and implement a specific regional law concerning the protection and valorization of Tuscan-specific agrobiodiversity assets, regarded as the capital of local breeds and varieties as well as related cultural and human aspects [90,92].

With reference to the Tuscan background, we selected the Valtiberina Red Onion for our case study based on the following criteria: (i). The case focuses on a threatened landrace that underwent a participatory process of characterization, protection and valorization involving local genetic resource registration and conservation and the development of a structured landrace-based localized agri-food system; (ii). We had access to suitable and reliable secondary and primary data and information; and (iii). there was sufficient availability of key informants willing and able to actively participate in the research process.

We adopted a participatory action–research approach. Representatives of the main public and private local stakeholders were actively involved in the research process. Participatory approaches are consistent with the analytical SES framework requirements [75,86,93]. Furthermore, active stakeholder participation is promoted as a new methodological paradigm within the debate on agrobiodiversity and socio-ecological transformation. Indeed, it gives support to both transdisciplinary research and the co-production of agro-ecological knowledge [28,40,94–98]. Specifically, the dialogue between theoretical and local practical understandings can strengthen endogenous potential and combine scientific production [99–101] with applicable solutions to the problems identified in the analyzed agri-food systems.

We applied qualitative methods for data collection and analysis [98,102]. A case study protocol was designed and discussed among the researchers involved [88,103]. We combined participatory field research activities with a prior detailed desk research process on literature, regulations, grey institutional sources and case-specific documents (Table 1). Secondary data collection contributed to the identification of the research institutional and theoretical contexts together with the main structural components characterizing the selected landrace-based localized agri-food system. Finally, primary data were collected by the means of 19 in-depth interviews with a series of key informants (Table 1) [104,105].

We employed purposeful snowball sampling for the recruitment of key informants. They were identified among private and public stakeholders involved in either characterization and conservation activities or promotional initiatives involving the selected landrace [106,107]. The interview structure was open ended. Five research topics were identified as guidelines for the interviews. Interviews were performed in person from October 2018 to April 2019 [108,109]. Interviews took between 60 and 240 min.

Qualitative text analysis followed data collection, aiming to triangulate the interview results with documentary analysis and literature review in order to enhance the validity of the results [105]. Both primary information and secondary qualitative and quantitative data and literature were integrated, elaborated and synthesized based on the innovative SES analytical framework conceptual categories (Section 2.2) which created the basis for discussion.

Ultimately, a focus group was organized in April 2019 thanks to the collaboration of the Tuscany Regional Offices tasked with the governance and management of agrobiodiversity resource protection and valorization. All interviewees took part in the meeting, together with other key actors as representatives of all local stakeholder categories (i.e., local farmers and supply chain actors, key experts, local associations and territorial groups, and other committed local authorities). The aim was a participatory discussion to enrich and validate the research findings and to evaluate any major limitations as well as desirable future action–research goals [110].

Table 1. The Valtiberina Red Onion case study data sources.

Primary Data Sources	Affiliation	No. of Interviewees
	Ministry of Agricultural, Food and Forestry Policies (Italy)	2
	Tuscany Region Offices	4
	Custodian farmers	6

4. Results: A Socio-Ecological Analysis and Characterization of the Valtiberina Red Onion Localized Agri-Food System

4.1. The Valtiberina Red Onion Genetic Resource and Related Territorial Capital

The Valtiberina Red Onion (Cipolla Rossa della Valtiberina) originated in the Tuscan Valtiberina area and co-evolved in time with the specific natural, cultural and human components of the local agro-ecosystem capital.

The origins of the Valtiberina Red Onion date back to the beginning of the 19th century. The landrace was widely cultivated in the territory, concentrated especially in the area of Sansepolcro (Arezzo). During this period, local farmers took the name of *onioners* (cipollari) in the community and nearby markets, testifying to the prevailing role and territorial rootedness of the knowledge and cultivation of this landrace. In time, farming extended from the Sansepolcro zone to the whole Tuscan Valtiberina territory, thanks to the distinctive territorial pedoclimatic (soil composition, climate, etc.) and socioeconomic characteristics (the central role of agriculture and horticultural products), which were particularly suitable for the introduction and enhancement of the local crop variety.

During the 19th century, the landrace significantly characterized the economic and socio-cultural history of the Valtiberina rural area and represented one of the main sources of livelihood for local farmers and families. Indeed, onion seedlings were produced for self-consumption both on farms and in family gardens. Moreover, farmers usually sold onion bunches in villages either in the local markets of the Arezzo area or in the more distant markets of the nearby regions of Marche, Upper Romagna and Umbria.

Over the course of the 20th century, while horticultural crops and even onions still counted for the major share of the Tuscan Valtiberina agricultural production, the knowledge and use of the traditional onion crop variety declined greatly in the area, until it almost disappeared from local farms and the minds of local consumers. This was a consequence of both global and local socioeconomic changes that increased the preference of local farmers for conventional crop varieties which better responded to the intensification of farming, the processes of mechanization, and market standardization. Despite this, the local genetic resource survived, thanks to the action of a few local farmers and families that preserved the landrace in their small farms or gardens, reproducing and cultivating the seed and handing down their knowledge of the crop and related traditions.

Eventually, in 2010, the initiative of a small group of local farmers and hobbyists led to the recovery of the landrace and activated the process of its characterization and registration. Our interviews provided evidence of the enabling role played by local actors' specific knowledge and participation. In particular, the investigation pointed out as determinant factors the level of knowledge of local farmers concerning the Valtiberina's territory, history and local agrobiodiversity resources; the commitment of some old Valtiberina farmers in preserving and passing on traditional crop breeding and cultivation; local farmers' widespread and growing awareness of landraces and landrace-based products and their market potential; their understanding and skill level concerning the recovery and cultivation of threatened local genetic resources (including public support, acknowledgement and training); and their collaborative attitude, willingness and responsibility towards local specific resource valorization for the benefit of local economies and communities.

For registration purposes, the provision of public financial and technical assistance supported the commitment of local actors to the naming of the landrace and the characterization of its extinction risk, identity qualities (e.g., historical, morphological, organoleptic, agronomic, culinary, etc.) and territorial linkage. Successively, other participatory research projects contributed to improving knowledge of the landrace's characteristics and its versatility [111]. The identification of the Valtiberina Red Onion's specific origin and distinctive attributes (Table 2) provided a basis for landrace protection and market differentiation.

Through inscription in the Regional Repertories (L.R. 64/2004) [90] and lately the National Registry (L. 194/2015) [91], the Valtiberina Red Onion received public recognition as a well-identifiable threatened local genetic resource, part of Tuscany's specific common agrobiodiversity assets and territorial capital. Its typical production area was identified

as the seven municipalities constituting the Tuscan Valtiberina. Currently, this area works as a boundary identifying the legally-established territorial limit for controlled in situ conservation, circulation and use of the seed (Section 4.3).

Table 2. The Valtiberina Red Onion's identity qualities.

Valtiberina Red Onion: Herbaceous Landrace at Risk of Genetic Erosion Pertaining to Tuscany-Specific Plant Agrobiodiversity			
Morphological Characteristics	Agronomic Characteristics	Nutraceutical Characteristics	Organoleptic Characteristics and Versatility
<ul style="list-style-type: none"> • Medium to large bulb size with high variability; reduced attractiveness and marketability of very large bulbs, with difficulty in standardization of packaging • Typical flattened, elliptical bulb shape and deep red outer tunics; immediate recognition of the variety by the consumer • Fleshy bulb with few layers, very delicate; needs manual harvesting or ad hoc soft mechanization 	<ul style="list-style-type: none"> • Sowing of the seed in seedbed with organic fertilizer from previous year • Transplantation of the seedlings between April and May, with spacing adjusted to control the growth of the bulbs • A four-year crop rotation cycle is necessary to avoid weeds and diseases • The crop is watered three or four times a year (the loamy Valtiberina soil absorbs water slowly) • Harvesting occurs between August and September; manual harvesting use of soft mechanization avoids trauma and weed drag 	<ul style="list-style-type: none"> • Significant and distinctive antioxidant properties of the landrace (high bioactive power) with respect to conventional varieties, due to: <ul style="list-style-type: none"> ◦ high content of total antioxidants and total polyphenols ◦ high content of total flavonoids (more than twice as high as conventional varieties) ◦ high content of specific flavonoids such as campferol ◦ high content of total anthocyanins and, in particular, of the anthocyanidins peonidin and petunidina 	<ul style="list-style-type: none"> • High sugar content of the landrace (glucose, fructose and sucrose) with respect to conventional varieties • Landrace characteristic intensity of smell, between sweet and spicy (easily recognizable by the consumer) • No perceived lacrimatory effect when smelling or cutting the bulbs • Bulbs have a taste that is neither garlicky or herbaceous, nor particularly sweet or flavorful, with average crunchiness

Table 2. *Cont.*

Valtiberina Red Onion: Herbaceous Landrace at Risk of Genetic Erosion Pertaining to Tuscany-Specific Plant Agrobiodiversity			
Morphological Characteristics	Agronomic Characteristics	Nutraceutical Characteristics	Organoleptic Characteristics and Versatility
<ul style="list-style-type: none"> • Strong resistance of the bulb to germination during the storage period, even if untreated, permitting organic cultivation and conservation; harvested bulbs are sold over a period of seven months from August to March 	<ul style="list-style-type: none"> • Harvested bulbs are stored in well-ventilated, dry places protected from frost, previously in canopies, today in specially designed net boxes. The latter are good for small quantities of bulbs; properly storing large quantities remains an issue 	<ul style="list-style-type: none"> • Consumption of the landrace has more beneficial effects on health than conventional varieties; the detected compounds, when consumed, can inhibit the action of free radicals and counteract oxidative phenomena, reducing the occurrence of inflammations, cancer and cardiovascular diseases 	<ul style="list-style-type: none"> • Bulbs can be eaten cooked or raw, used fresh or in a variety of more or less traditional preparations (e.g., baked in foil, as an accompaniment to stewed or roasted meats, in jam or soup, etc.)

Source: our elaboration on primary and secondary data.

4.2. The Socioeconomic and Biophysical Drivers

This case study investigation highlights the main contextual factors triggering the participatory recovery and characterization of the Valtiberina Red Onion crop variety and the restoration and valorization of its knowledge and use in the landrace-based localized agri-food system. Interviews and desk analysis showed these drivers as having different social, political, economic or ecological roots. We classified them according to the SES framework's conceptual categories of socioeconomic and biophysical drivers and the respective subcategories. Among the latter, we stressed the most significant for the case study. The results are synthesized in Table 3.

Table 3. A socio-ecological categorization of the Valtiberina Red Onion localized agri-food system drivers.

Socioeconomic Drivers
Public policy and institutional framework
International and EU-integrated policies and legal framework
<ul style="list-style-type: none"> • Both the international and EU institutional frameworks sustain and regulate the ongoing integration between environmental and rural development goals and policy measures (e.g., EU Biodiversity Strategy for 2030; Europe 2020 strategy for sustainable, smart and inclusive growth; EU CAP evolution, Rural Development Policy, etc.) [11,51,112]. Agrobiodiversity resource protection and valorization are recognized as a self-standing objective closely related to rural territorial growth and sustainable development issues • More or less specific national and local laws and policies are provided, supporting and regulating public–private participatory initiatives towards conservation of local genetic resources and related traditions, sustainable use, and equitable sharing of benefits, with particular attention to underutilized or neglected landraces
Agrobiodiversity-specific Italian National and Tuscany Regional policies and institutions
<ul style="list-style-type: none"> • A multi-faceted path involving both national policy makers and regional administrations culminated in the adoption of the specific national law 194/2015 under implementation [91], establishing a uniform multi-layered national system for agrobiodiversity protection and valorization supplementing and harmonizing the existing regional policy goals and measures • The new national system and the Tuscany Regional legislation (Regional law 64/2004 and Regional regulation 12/2007) [90,92] recognize and treat agrobiodiversity resources as territorial commons: (i). Local genetic resources and related traditional culture are publicly recognized as belonging to the territory where they originated and/or adapted, and as being an integral part of local specific assets; (ii). Both public engagement and the maintenance of public control and responsibility over the reproduction and use of agrobiodiversity assets is justified, with particular reference to recovery and conservation of threatened landraces

Table 3. Cont.

Socioeconomic Drivers
Agrobiodiversity-specific Italian National and Tuscany Regional policies and institutions
<ul style="list-style-type: none"> ● The combined national and regional systems set out the foundations of a polycentric governance structure, enhancing public and private action and collective participation networks for better acknowledgment and coherent management of threatened local genetic resources, considering: <ul style="list-style-type: none"> ○ The determinant role of the specific regional laws and policy framework in supporting local farmers and other stakeholders with respect to characterization of threatened landraces and the restoration of their knowledge and local cultivation; ○ The high expectations around implementation of the L. 194/2015 [91] valorization tools supporting the enhancement of agrobiodiversity product marketing and sustainable upscaling and territorial development of landrace-based localized agri-food systems
Market dynamics
Western markets: evolving consumption patterns and trends
Neo-luxury and sustainability macro-trends are driving agri-food markets toward new sustainable patterns:
<ul style="list-style-type: none"> ● Informed, attentive, ethical, responsible consumption choices and habits ● Buying agri-food products is increasingly perceived as an emotional, learning and social experience (e.g., consumers show their interest in buying local, participating in trade fairs and traditional markets, knowing the origin and distinctive qualities of products, etc.) ● Increase in market value of agri-food products due to their origin and sustainable character, qualified as product locality, typicality, seasonality, wholeness and healthiness, nutritional content, social fairness and low environmental impact ● Increase in market value of signaling tools qualifying and communicating agri-food product territorial linkages and their social and environmental qualities (e.g., collective marks, certifications, food quality systems, etc.)
Italian and Tuscan market trends for agrobiodiversity
Growing market attractiveness and value of landrace-based and agrobiodiverse products:
<ul style="list-style-type: none"> ● Local consumers' growing knowledge and interest (e.g., active participation in local trade fairs, events, promotion initiatives, etc.) about agrobiodiversity resources (as local genetic resources) and agrobiodiversity products (valorizing local genetic resources and related traditions) as well as their inherent sociocultural and environmental values ● Higher demand and willingness to pay in both local and traditional channels and modern distribution for products supporting the use of underutilized or neglected plant landraces and the adoption of traditional farming and transformation methods ● Increase in market value of specific signaling tools for qualification of landrace-based agrobiodiversity products, specifically those valorizing local genetic resources and traditions recognized and protected by the L.R. 64/2004 Tuscany Regional system (e.g., specific logos, packaging, collective marks, etc.) [90]
Biophysical drivers
Geomorphology, soil and water
<ul style="list-style-type: none"> ● Valtiberina rural territory and agro-ecosystem specific characteristics (e.g., specific soil and water composition, hydrography and morphological features, etc.) are favorable to: <ul style="list-style-type: none"> ○ The recovery and on-farm conservation of the Valtiberina Red Onion as a threatened genetic resource seed; ○ The profitable and low-impact cultivation of the original and locally evolved plant landrace, supporting the use of extensive and traditional agricultural practices (e.g., high yield and resilience of the local crop variety with reduced use of chemicals or pesticides, etc.)
Climate and weather
<ul style="list-style-type: none"> ● Climate change threats call for innovation of agri-food products and processes; innovation strategies can be based on the rediscovery and valorization of underutilized or neglected crops with beneficial effects in terms of quality, sustainability, and resilience at both a global and local level ● Valtiberina's local specific climate and weather conditions (e.g., temperature, precipitation, light exposure, etc.) are favorable to: <ul style="list-style-type: none"> ○ The recovery and on-farm conservation of the Valtiberina Red Onion seed as a genetic resource; ○ The profitable and low-impact cultivation of the original and locally evolved plant landrace, with the use of extensive and traditional agricultural practices (e.g., high yield and resilience of the local crop variety with reduced use of energy, nutrients, and water, etc.)

Source: our elaboration on primary and secondary data and [30,42,44,113,114].

Interviewees highlighted in particular how socioeconomic factors worked as the most effective triggers in stimulating public and private decisions and practices for landrace recovery, characterization and valorization. Specifically, they recognized the determining role of the integrated policy framework and the multi-level legal and institutional context. At the same time, the interviews showed how new consumption patterns and trends affecting the evolution of western agri-food markets [30,113,114], together with the specificities of the Italian and Tuscan markets, worked as fundamental triggers for the activation and commitment of local farmers and agri-food chain actors for the identification and conservation of the genetic resource, as well as for the realization of collaborative production and marketing strategies.

4.3. The Human Action Processes: The Landrace-Based Quality Valorization Virtuous Circle and Underlying Hybrid Management Mechanisms

The Valtiberina Red Onion localized agri-food system development was determined by a combination of public and private decisions and practices. The application of the new SES framework to the analysis of the implemented public and private initiatives led us to characterize them as the processes of human action that underline the evolving stages of the Valtiberina Onion quality valorization virtuous circle. The following paragraphs describe the hybrid management mechanisms supporting each of the identified restoration and valorization stages. In accordance with the SES model, the beneficial effects produced all around the circle by the actions undertaken are analyzed and described as a separate conceptual category in Section 4.4.

4.3.1. The Valtiberina Red Onion Identification and the Activation of the Landrace-Based Localized Security and Conservation Network

The Valtiberina Red Onion crop variety was recovered and characterized by the initiative of a small group of farmers in the Tuscan area of Sansepolcro (Arezzo), and thanks to the sustainment and collaboration of local research institutes and competent Tuscany Regional Offices. The L.R. 64/2004 supplied them with financial support and technical assistance and disciplined the commitment of the Tuscany Region Germplasm Bank in the realization of a dedicated participatory characterization project [90]. As anticipated in Section 4.1, the project culminated in 2010 with the landrace's inscription in the Tuscany Regional Repertories of Local Breeds and Varieties [90]. In 2018, the landrace was also inscribed in the National Registry of biodiversity for agriculture and food in accordance with the new National law 194/2015 statements [91].

Interviewed Regional Officers evidenced how local farmers activated to characterize the landrace to both counteract the risk of extinction and actualize local genetic resource production and market potential. Once registered, based on the L.R. 64/2004 provisions Valtiberina Red Onion seed was selected and entrusted to the Conservation and Security Network for breeding and reproduction (Figure 2) [90]. As members of the publicly funded and controlled network within the geographical boundaries of the landrace registered typical production area (Section 4.1), both the Central and the Valtiberina Regional Germplasm Bank sections, together with eleven local farmers (so-called custodian farmers), took action for conservation of the Valtiberina Red Onion.

Custodian farmers involved mostly older local farmers and hobbyists, except for a group of five custodians comprising market-oriented young entrepreneurs and medium-sized farms. Acting under the control and with the assistance of the competent Regional Offices (Figure 2), these farmers were committed to the conservation of landrace pure seed in situ, and to the yearly renewal of the seed conserved ex situ by the Germplasm Bank's dedicated sections. For their activity, the custodians receive an annual lump-sum custody fee of about EUR 340 (D.G.R 327 18/04/2016 [115]).

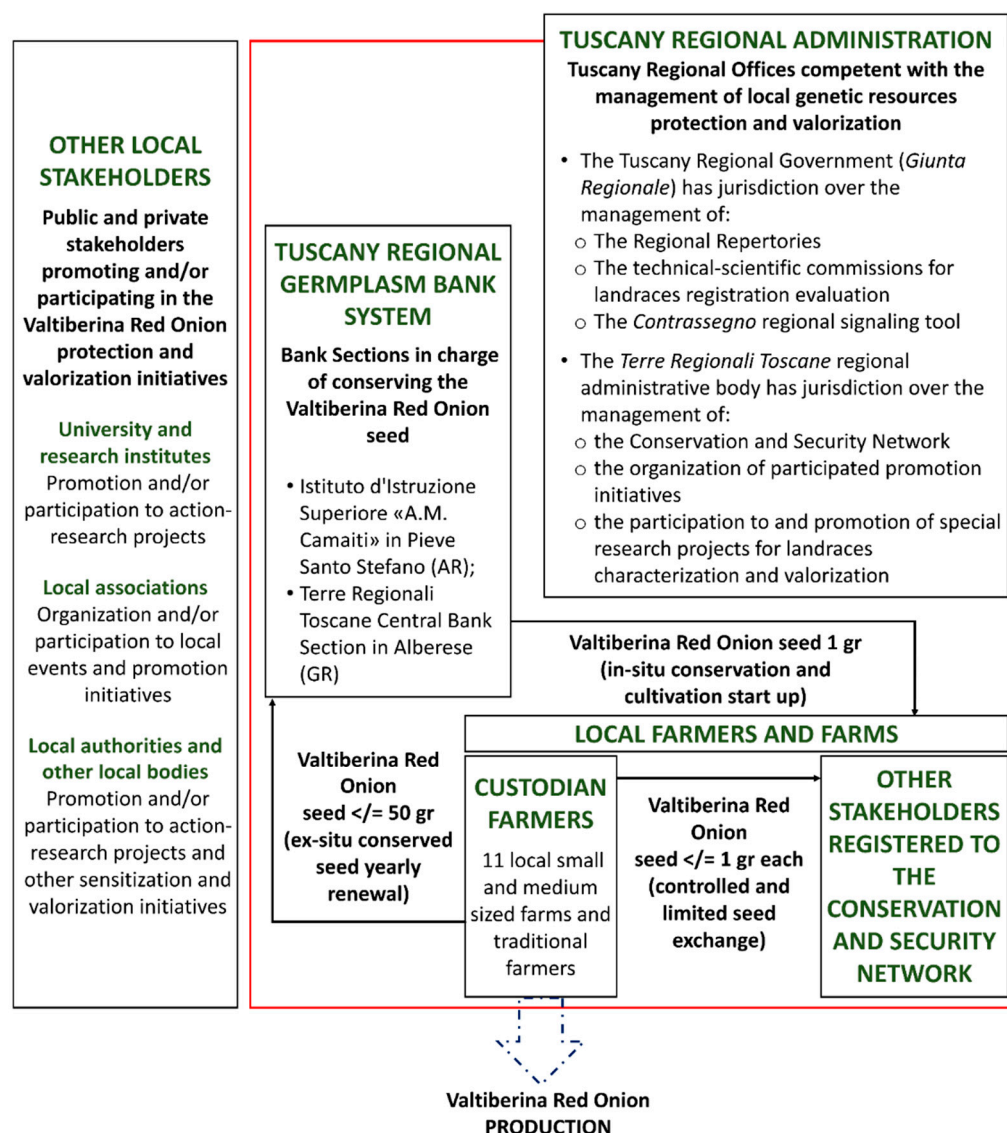


Figure 2. The Valtiberina Red Onion Conservation and Security Network. Source: our elaboration on primary and secondary data.

Interviews evidenced the determinant role of custodians with respect to other stakeholders (Figure 2), not only in the securing and conservation of threatened genetic resource, but also in the restoration and diffusion of knowledge and cultivation towards the creation of a landrace-based localized agri-food system, confirming the content and aims of the Regional law 64/2004 [90]. In particular, custodians could locally exchange the seed they reproduce on their farms, in limited quantity and free of charge, among the Conservation and Security Network members (e.g., Germplasm Bank sections, custodian farmers, other registered public and private stakeholders) together with their specific knowledge, competencies and skills. Furthermore, the small group of market-oriented farmers were engaged in promoting the agricultural use and market potential of the onion seed on their farms. Specifically, the latter acted as the main group responsible for of the participatory research, organization and promotional activities, leading to the enhancement of the landrace's reputation and identity, as well as the structuring of a Valtiberina Red Onion-based production and marketing system (as presented in Figure 3).

4.3.2. The Valtiberina Red Onion and Derived Products: Qualification and Remuneration

Primary and secondary data analysis highlighted that custodian farmers represent the main engine of the Valtiberina Red Onion localized production and marketing system through collaboration with other actors in the local agri-food chain, universities and research institutes, local associations, local authorities and other territorial bodies (Figure 3).

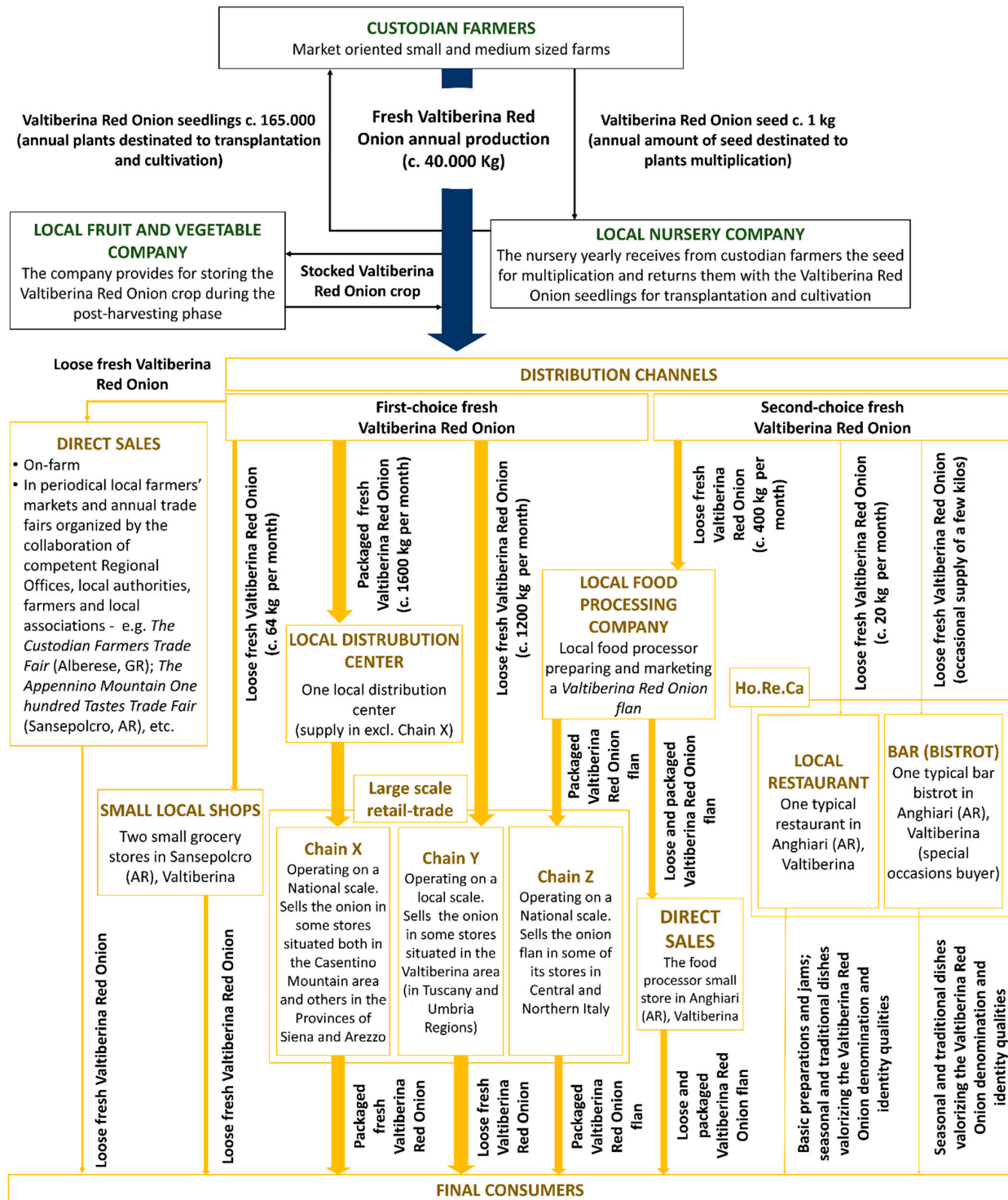


Figure 3. The Valtiberina Red Onion localized production and marketing system. Source: our elaboration on primary and secondary data.

The system is currently based on both informal governance settlements and formal supply chain agreements. On the one hand, the group of custodian farmers have established an internal systematic collaboration consisting of verbal and private agreements that allows for the realization and continuous adaptation of joint production and marketing strategies. Furthermore, different kinds of formal agreements are periodically initiated and renovated with other local actors, both upstream (e.g., local nursery company) and downstream (e.g., local fruit and vegetable companies, local processor, restaurants, small- and large-scale retailers, etc.) in the agri-food chain.

Local farmers have designed joint production and marketing strategies and also institutionalized supply chain collaborations that support the qualification and remuneration of the Valtiberina Red Onion and its related traditions. Within the limits imposed on the agricultural use and marketing of registered threatened landraces [90,91], they were able to jointly organize and manage the breeding, harvesting and storage activities and the promotion and distribution of different Valtiberina Red Onion products through both traditional and modern channels. The co-design and collaborative implementation of the onion valorization strategies consist of non-systematic activities of research and planning, the temporary sharing of some of production and logistical inputs, risks and costs, and the informal mechanisms of reciprocal support and control.

As shown in Figure 3, a Valtiberina Red Onion localized agricultural system was developed at the production level. The group of market-oriented custodians cultivates the landrace seed they yearly reproduce on farms under competent Regional Office control and with Germplasm Bank technical support [90]. With the aim of increasing the controlled onion seed production and yield, they externalized the stage of multiplication to a local nursery company. The latter receives the onion seeds reproduced on farms by custodians and returns them with seedlings for transplantation. Custodian farmers jointly experiment with innovative agronomic and harvesting techniques together with ad hoc handicraft machineries in an attempt to balance increased production with the maintenance of low-impact and traditional methods. Eventually, to favor the post-harvesting resistance of a growing volume of bulbs, storage activity was externalized to a local fruit and vegetable company with more adequate space and facilities.

Valtiberina Red Onion valorization is currently based on the marketing of landrace-based agrobiodiversity products through both direct and indirect channels. Thanks to the commitment of the market-oriented custodians together with local processors and on-trade operators, the Valtiberina Red Onion is currently qualified by means of fresh or processed goods and finds remuneration through both traditional trade and modern distribution (Figure 3).

In this respect, all of the interviewees spoke of the fundamental role played by custodian farmers in designing a specific Valtiberina Red Onion logo, packaging and information material. They use the latter as signaling tools to identify the onion's production and quality and market its distinctive denomination and qualities (e.g., historical, organoleptic, culinary) such as its belonging to the Tuscany Region's system for agrobiodiversity resources, protection and valorization [90].

The design and management of the logo and the other communication tools are based on verbal agreements among the custodians, such as informal reciprocal mechanisms of control and user regulation. Nonetheless, these tools have successfully contributed to the enhancement of the awareness of local supply chain actors, the community and consumers of the remuneration of the landrace and landrace-based products' identity values. Thanks to the latter, custodians have also managed to make up for the lack of specific and effective public signaling tools to qualify agrobiodiversity products or custodian farmer activities (i.e., lack of a national specific collective mark; interviewed farmers perceived inefficacy and high cost when using the L.R. 64/2004 provided label, called *Contrassegno* [90]).

Furthermore, interviews evidenced the important collaboration between the group of producer custodians and a local food processor in the creation of Valtiberina Red Onion flan, marketed both directly in stores and indirectly by regularly supplying a national large

retailer (Figure 3). The interviewed processor affirmed that he successfully promotes the Valtiberina Red Onion registered denomination as an identity quality attribute for product differentiation, thus obtaining an increase in product placement and sales volume, selling price, and final consumer value.

Even the presence of a few local restaurants was highlighted. These started to regularly or periodically buy the onion landrace from the custodian farms. In this respect, the interviewed restaurant owner affirmed that he chose the Valtiberina Red Onion as a costlier but tastier and more delicate seasonal alternative to conventional varieties for the usual preparation of sauces and sides, and to be occasionally valorized in seasonal or traditional dishes with a high premium price.

The combined efforts of public and private actors together with the significant increase in the Valtiberina Red Onion's reputation among operators and consumers has sustained the ongoing process of landrace-based product market structuring and expansion. On the one hand, interviews evidenced how the relevant growth of consumer demand and willingness to pay drove an increase in local farms asking Regional Offices to enter the Conservation and Security Network and access the threatened landrace seed, taking charge of its on-farm conservation and supporting its agricultural and market use. On the other hand, the market-oriented farms accessing the system were incentivized to organize and collaborate in order to increase their production volumes, expand and penetrate the sale channels served, and identify a shared onion premium price policy.

Accordingly, we considered it of particular interest that the custodian farmers currently marketing the Valtiberina Red Onion play a role as price setters. Indeed, they internally collaborate through verbal agreements in order to maintain a shared premium price policy. The latter is based on their evaluation of onion production costs and fair profit margins and is regulated by annual supply agreements with traders and processors. For instance, in 2018, Valtiberina Red Onion producer prices were set in a range from EUR 0.80 for 1 kg loose (on the Ho.re.ca and local food processor channels) to EUR 1.50 for 1 kg packaged (on the G.D.O Chain X channel). At the same time, onion consumer prices varied in a range from EUR 2.00–2.50 for 1 kg loose (in direct sale channels) to a maximum of EUR 2.54 for 1 kg packaged (G.D.O Chain X channel).

Interviewed custodians affirmed they obtained a landrace producer price up to three times above that of conventional varieties; respectively, of EUR 1.50/kg instead of EUR 0.45/kg. Notably, they evidenced that the higher onion market prices, when added to the custody fee and free technical assistance they receive from the Regional Administration, fairly cover the costs and risks of the landrace seed on farm conservation and remunerate their specific production and marketing efforts. Moreover, as previously said, the restaurant and food processor also pointed out that they obtain premium consumer prices for their Valtiberina Red Onion preparations. As an example, a local food processor yearly sets the Valtiberina Red Onion flan consumer price (EUR 3.90 for a two-flan pack) in both direct and indirect channels (G.D.O. Chain Z). The price is regulated by annual supply agreements, taking on onions given producer prices and recharging the processor for a fair profit margin.

4.3.3. The Valtiberina Red Onion Enhancement and Localized Agri-Food System Reproduction and Scaling-up

The combined action of competent Regional Offices, custodian farmers, and other stakeholders was successful in restoring and enhancing landrace knowledge and reputation and promoting its use through the structure of a Valtiberina Red Onion localized agri-food system. In particular, interviews and desk analysis evidenced how the public–private participatory initiatives for the identification and management of the landrace identity qualities and territorial linkage contributed to sustaining the recovery and reproduction of the threatened genetic resource and the enhancement and fair distribution of the inherent economic, social and environmental values. These action processes underlie the Valtiberina Red Onion capital enhancement and reproduction, and determine the growth and sustainability potential of the localized agri-food system.

In fact, the ongoing expansion of the landrace consumer demand and large-scale retail trade volumes are driving toward a demand excess compared to the present agri-food system supply. To meet market demand, in only three years (from 2016 to 2018) Valtiberina Red Onion production volume has increased tenfold (from 4000 to 40,000 kg), thus approaching saturation of the production capacity of the landrace-based agricultural system. In addition, the entrance of new custodian farmers asking to access the landrace seed and taking charge of its custody has reached the maximum legally allowed number of eleven [90], consequently limiting further expansion of the system's production base. This situation creates strong pressure on:

- Custodian farmers' business structure and organization (small- and medium-size family-run businesses);
- Their inadequate specific knowledge of funding opportunities and project planning (e.g., lack of awareness and access around specific public supporting tools such as Rural Development Programme (RDP) measures, integrated supply chain and territorial projects, etc.);
- L.R. 64/2004-imposed public control and responsibility over threatened landrace security and collective property rights [90];
- Low support from the regional public system for landrace-based collective product qualification and marketing.

This investigation highlights that custodian farmers' opportunity to enhance and benefit from the Valtiberina Red Onion's multi-functional product potential and marketability depends on their capacity to face these pressures and realize effective solutions for sustainable scaling up. Specifically, custodians and other interviewed stakeholders seemed to perceive as important development goals the landrace-based localized agri-food system's territorial identity protection, the expanding of onion production while avoiding agricultural intensification in respect of genetic resource security and conservation, the avoidance of opportunistic behaviors to misuse the genetic resource seed and denomination (e.g., cultivation and sale of crops based on seed circulating and reproduced outside of the Conservation and Security Network), and multi-actor governance of the system in order to preserve public control and collective property rights.

Interviewees evidenced critical aspects at both the private and public levels. On the private side, the involved farmers' businesses deficiencies (e.g., their need for enhanced breeding and planting techniques, the lack of suitable soft mechanization, the necessity to improve storage and distribution facilities, etc.) were highlighted. On the public side, they underlined the regional conservation and security system's failures and constraints in marketable threatened landraces qualification and territorial valorization (e.g., the limits on controlled seed use and circulation to the Conservation and Security Network members, the custodian farmers' obligation to cultivate only the seed they reproduce on their farms, the limited number of allowed custodians, the lack of specific public tools supporting the landrace-based agri-food system qualification and controlled expansion, etc.).

Both the interviewed custodians and competent Regional Offices highlighted how the opportunity to overcome the identified limits and sustain the Valtiberina Red Onion localized agri-food system's sustainable growth could depend on the realization of effective up-scaled multi-actor marketing strategies. The latter should be able to combine private collaborative efforts with the adoption of adequate public supporting tools in order to on the one hand, guarantee landrace security and conservation and the maintenance of public control and responsibility over its collective use, and on the other, enhance its market potential and territorial value and provide for equitable sharing of related benefits with local farmers and other local and non-local stakeholders. To that end, all of the interviewees evinced a willingness to enhance their reciprocal dialogue, learning and collaboration towards the up-scaling of the landrace production base and the possible creation of a traced and integrated Valtiberina Red Onion supply chain. Particular consideration was given to the possibility of adopting collective marks or quality regimes and the potential of the new public tools provided by National law 194/2015 [91].

The interviewed custodians and competent Regional Offices considered the latter as possible effective solutions for landrace-based product value enhancements and the support of agrobiodiversity-oriented food systems through formal organization and territorial development. Specifically, they valued the new National law attempting to harmonize legal constraints related to threatened local genetic resources, seed reproduction, and cultivation with the opportunities offered by Italian regulation on conservation and marketing of seed varieties (D.Lgs.149/2009 [116] and D.Lgs.267/2010 [117]). Considering the Valtiberina Red Onion case, they affirmed that the registration of the landrace in the dedicated section of the National Registries for seed commercialization could give to the involved custodian farmers the opportunity to locally and directly sell the pure seed they reproduce on their farms, adding to their right to exchange it within the conservation and security network. As a consequence, this inscription could allow a controlled and territorially-identified expansion of the landrace production base and sustain the localized agri-food system's qualification and traceability.

Lastly, all the interviewees positively evaluated the opportunity to participate in the valorization of the Valtiberina Red Onion in a wider territorial perspective. In this regard, they gave particular consideration to the new national tools of L. 194/2015 [91]. Among these, they specifically pointed to those supporting the creation of specific Communities of Food and Biodiversity for Agriculture and Food or Routes of Biodiversity for Agriculture and Food, the access of local farmers and stakeholders to specific financial and technical support (e.g., institution of the Ministerial Fund for the Protection of Biodiversity for Agriculture and Food), and access to RDP funds and priority measures (e.g., landrace inscription to the National Registry of Biodiversity for Agriculture and Food, custodian farmers participation in the new National Network of Biodiversity for Agriculture and Food), etc.

4.4. The Public and Private Goods and Services Production and Related Multiple Benefits

Considering the presented SES framework, we analyzed the human action effects produced all around the quality valorization virtuous circle as a separate conceptual category. We aimed to show how development of the Valtiberina Red Onion localized agri-food system led local farmers and other involved stakeholders to combine primary production of private goods and services with the delivery of social and environmental goods and services and the generation of multiple beneficial effects directly affecting the local farming system and food chain, supporting territorial growth and human well-being.

In accordance with the conceptual categories of the SES model, Table 4 reports a synthesis of the main private and public goods and services produced by the analyzed agrobiodiversity-oriented food system.

Both interviews and desk analysis showed that the private and public goods and services synthesized in Table 4 had multiple benefits in the economic, environmental and social dimensions. We analyzed them by considering how the production of public and private goods and services sustained the organization of a high-value added Valtiberina Red Onion localized agri-food system, and determined its level of sustainability and multifunctionality (i.e., the contribution it gave to economic growth and territorial development, the protection of the environment and the ecosystem, and the enhancement of rural culture and human well-being at a wider, especially local, level).

At first, we considered the economic dimension. Interviews with custodian farmers showed how their potential profit from onion valorization was favored by the public system of support and regulation guaranteeing custodian farmers free access to pure onion seed, providing for mechanisms of control over its reproduction and circulation, preserving the resource's territorial identity and linkage, allowing custodians the agricultural use of the landrace seed they produce, and marketing landrace-based products. In this respect, the fundamental role of multi-actor collaboration was also pointed out. Custodians' reciprocal informal governance settlements and their occasional collaboration with competent regional authorities, local associations, universities and research institutes as well as the

supply agreements stipulated with processors, retailers and restaurants have created favorable conditions for structuring a high-value Valtiberina Red Onion localized agri-food system. Moreover, all the interviewees saw the strengthening of these collaborations as the first step towards scaling up, economic optimization and territorial leveraging.

Table 4. The Valtiberina Red Onion localized agri-food system's production of private and public goods and services.

Private Goods and Services	Public Goods and Services
<ul style="list-style-type: none"> ● Agrobiodiversity food products valorizing Valtiberina Red Onion use and identity attributes: <ul style="list-style-type: none"> ○ Fresh Valtiberina Red Onion ○ Valtiberina Red Onion flan ○ Valtiberina Red Onion-based traditional dishes, seasonal recipes and basic preparations ○ On-farm didactic activities and hospitality services ● Byproducts (reusable waste; natural pigments; natural fertilizers) ● Preservation, renewal and enhancement of local farmers' natural, cultural and social assets ● Agri-food products promoting the use and distinctive qualities of other plant species used by local farmers during four-year crop rotation: <ul style="list-style-type: none"> ○ Fresh pumpkins, field beans and other species ○ Processed agri-food products based on pumpkins, field beans and other crops prepared and sold by local processors to feed humans or animals, served in local bars or restaurants, in basic preparations, and with typical or special recipes 	<ul style="list-style-type: none"> ● Recovery and uniform characterization of the Valtiberina Red Onion as a threatened local genetic resource ● Landrace denomination and identification as part of Tuscany's specific agrobiodiversity assets and common territorial capital (registration in dedicated public repertories) ● Valtiberina Red Onion pure seed publicly controlled for conservation and local circulation and cultivation, with a public guarantee to securing the landrace and collective property rights) ● Preservation and enhancement of the landrace's specific traditional rural landscape, agricultural practices, typical food and non-food uses, and consumption habits ● Contribution to the maintenance and enhancement of the quality of soil, air and water in the Valtiberina Red Onion's legally admitted zone of conservation and cultivation (the locally adapted and resistant variety and sustainability-based market trends favor the onion's extensive cultivation) ● Enhancement of knowledge about the landrace, related traditions and its specific market potential and territorial linkage among local farmers and supply chain actors ● Valtiberina Red Onion-based products promoted as experience goods and services (e.g., use of specific logo, packaging and information material; participation in local festivals, dedicated tasting dinners and custodian farmers' trade fairs; farm visits and didactic activities, etc.) which can contribute to entertain consumers, educate them on agrobiodiversity values and critical conservation aspects, increase their emotional involvement and responsible buying behavior ● Contribution to the enhancement and reproduction of the specific social capital of the Tuscan Valtiberina: higher social awareness of threatened local genetic and cultural resources, identity, and values; higher social responsibility and participation in their conservation and sustainable use ● Contribution of Valtiberina Red Onion food production to higher consumer health and safe nutrition thanks to distinctive food and nutritional functions

Source: our elaboration on primary and secondary data.

Custodians highlighted how the initiation and extension of Valtiberina Red Onion production and marketing through both traditional and modern channels contributed to differentiate their offerings, enhance and diversify their incomes, increase their bargaining power and reduce their market risk.

As a second step, the focus of the analysis moved to the environmental and sociocultural dimensions. To illustrate these, both the interviews and desk analysis showed how the participatory characterization, protection and valorization of the threatened landrace and related traditional culture contributed, if in a small part, to the preservation and enhancement of the Tuscan Valtiberina's specific agricultural biodiversity, both directly through the restoration and valorization of the knowledge and use of the Valtiberina Red Onion and securing of a local genetic resource, and indirectly, thanks to the qualification and

successful remuneration of landrace-based agrobiodiversity products, incentivizing local farmers' commitment to the characterization, conservation and cultivation of a growing number of underutilized and neglected landraces and the interest of local supply chains operators in their valorization.

In more general terms, the restoration and growing extension of Valtiberina Red Onion cultivation in its specific registered typical production area (Section 4.1) provides small but significant support in both environmental and sociocultural terms to the preservation of the local agro-ecosystem and the enhancement of related agro-ecosystem services. Interview analysis showed how in both the medium and long term the development, up-scaling and reproduction of the Valtiberina Red Onion localized agri-food system can sustain and favor the enhancement of natural resources, local farmers' livelihoods, and the well-being of the entire rural community.

Both the direct contribution and impulse to the increase in the area of the share of locally originated or adapted crop varieties and the use of traditional methods could reduce the environmental impact of local farming and favor the preservation and enhancement of specific natural assets and the increase in organic production. Similarly, interviews also showed the potential of promotion as a premium-price agrobiodiversity product in avoiding the intensification of production; the onion caught the interest of high-value market segments which value product origin and sustainability instead of quantity and standardization. At the same time, these effects could stimulate local actors towards the identification and qualification of a growing number of landrace-related human and cultural resources (e.g., history, rural traditions, landscape) pertaining to common territorial capital.

In the sociocultural dimension, as anticipated, a social learning effect was generated. It led local farmers, supply chain actors, consumers and community to increase, on the one hand, their knowledge of the Valtiberina Red Onion and other endangered landraces and their existence and socio-ecological identity, and on the other, their awareness of the opportunity to consider them not only as specific local resources to preserve, but also as common assets to collectively valorize for their own benefit and that of the territory in the wider perspective of sustainability.

Lastly, with regard to human health, Valtiberina Red Onion crop cultivation and food production could provide a contribution in terms of safe nutrition thanks to the landrace's demonstrated high nutritional and nutraceutical value (Section 4.1). The research institute and custodian farmers we interviewed expressed their willingness to continue their collaboration towards a wider and deeper identification of these qualities from a marketing and valorization perspective.

5. Discussion

The analysis carried out here aims at providing a contribution to the conceptualization of biodiversity-oriented food system structure and dynamics [2,30]. The SES theoretical approach has been positively evaluated for the analysis of agrobiodiversity-based transformation and territorial development processes [85]. As a matter of fact, the SES favors the interpretation of the complex nature of local genetic and cultural resources together with the human–natural interactions activating and sustaining their qualification, fair remuneration, reproduction and territorial valorization [55,69,84,118].

Following the holistic SES theoretical approach, we innovatively identify agrobiodiversity-oriented food systems as socio-ecological systems characterized by quality valorization virtuous circles of endangered landraces and related traditions. In this regard, we designed a new conceptual model considering the SES frameworks by Dwyer et al. (2015) [86] and Maréchal et al. (2016) [71] in combination with the origin-linked quality virtuous circle by Vandecastelaere et al. (2010) [65] and Belletti et al. (2017) [66].

The application of the new SES model to the case study analysis proved its potential to identify and describe the relevant assets, drivers, human action processes and generated beneficial effects concerning the development and reproduction of the Valtiberina Red

Onion localized agri-food system. In a wider perspective, the case study evidenced the novelty of the framework as a useful tool for the categorization, systematization and comprehension of the structural and dynamic elements characterizing public–private initiatives directed to the creation of agrobiodiversity-oriented food systems and the enhancement of their sustainability and multifunctional role.

With a view to the analysis of agrobiodiversity-oriented food systems' sustainability, the new SES model permits us to consider and evaluate the combined production of private and public goods and services stemming from the development and reproduction of landrace-based quality valorization virtuous circles [9,96]. Significantly, the description of the generated beneficial effects, their sharing, and their distribution provided us with insights on agrobiodiversity-oriented food systems and their capacity to benefit local farmers and supply chain actors, the territory, and the community, as well as to contribute to the wider goals of environmental protection and human well-being [36,40,60,71].

The extent of agrobiodiversity-oriented food systems' sustainability in joining private goods and services production with social and environmental benefits is determined by the level of involved stakeholder knowledge and awareness of agrobiodiversity resources and of the multiple related values, as well as the coherence of the implemented management mechanisms. Moreover, the structuring effects of institutions and governance settings must be considered [30,119].

In this regard, the literature shows the determinant role of public policy in supporting social learning and favoring stakeholder recognition and collective action towards underutilized or neglected landraces' protection and valorization as territorial capital assets [27,30,60,62,64,120].

The new model is designed to facilitate the understanding of enabling policies and combined public–private strategies towards the creation of sustainable agrobiodiversity-oriented food systems. Specifically, the case study analysis pointed out as a fundamental policy driver the public recognition of agrobiodiversity resources as a specific territorial commons (L.R. 64/2004 [90] and L. 194/2015 [91]), thus legitimating as a public goal their collective conservation and sustainable use (that is, non-exclusive, in the interest of the entire local community and characterized by non-appropriability) [21–24,37,41] and the enhancement of the diverse beneficial economic, sociocultural and environmental outcomes [66,87].

In order to be effective in sustaining agrobiodiversity-oriented food system development and multi-functionality, coordination between public policies and private action implies the integration and balanced satisfaction of all the public and private interests at stake. To that end, we considered as a determinant step the understanding of these interests and of the main arising synergies and trade-offs, as well as of possible hybrid management solutions.

In light of these aims, the new framework proved to be suitable for highlighting the main private and public interests involved. With regard to private interests, local farmers and agri-food chain actors are concerned with the opportunity to increase and diversify their incomes and enhance their market positioning with respect to landrace cultivation and use. At the same time, the increased reputation and territorial valorization of landrace-based agrobiodiversity products can generate spillover effects benefiting other local stakeholders operating in different but related economic sectors (e.g., tourism, crafts, local trade, etc.) [32,33].

As for public interests, they essentially involve the optimization of the evolving agrobiodiversity-oriented food system's sociocultural and environmental performance. Specifically, policy makers are mainly concerned with the maintenance of public control and responsibility over underutilized and neglected landrace protection and valorization activities in order to pursue their fundamental contribution to the preservation and enhancement of the environment and local agro-ecosystem, as well as the generation of social and cultural benefits affecting human development and well-being both at the local level and in a wider global perspective [40,66,87,121].

Hence, we have outlined both convergences and divergences emerging among the abovementioned interests. The model worked as a useful tool for their identification in light of the supporting or limiting effects they generate on the landrace-based localized agri-food system's public and private goods and services production and the equitable sharing and fair distribution of generated benefits.

On one side, we considered trade-offs arising when the prevalence of either private or public interests limits the agrobiodiversity-oriented food system's multifunctionality. We highlighted how legal constraints limiting seed access, breeding, and circulation can put a brake on system up-scaling, negatively affecting the opportunity to expand marketing channels and sustain demand growth. As a result, the necessity of maintaining public control and responsibility for securing the landrace and related collective property rights led to public interests prevailing at the expense of full actualization of the economic potential of agrobiodiversity assets. On the contrary, private interests prevail when local farmers favor the custody and cultivation of only the landraces showing a higher market attractiveness and suitability to modern distribution channels. In the latter case, the prevalence of local farmers' economic orientation may negatively affect public goals about the preservation and enhancement of the most endangered local genetic resources, independent of their actual market value.

Secondly, we found synergies arising when the pursuit of private interest becomes functional to the achievement of public goals, and vice versa [120]. In particular, the results confirm findings in the literature that highlight how the opportunity of local farmers and supply chain actors to obtain fair remuneration from the marketing of landrace-based agrobiodiversity products pushes their commitment towards securing threatened landraces and their qualification, together with related culture and traditions [15,33,61] as well as the realization of landrace-based extended territorial paths [16,34].

With regard to the integration and balancing of the identified synergies and trade-offs, a fundamental role is played by the implementation of effective management mechanisms and governance settings in attaining sustainability. This study confirmed the potential of the new SES framework in supporting their identification and evaluation with a view to enhancing the processes of policy development and decision making [27,64,70,80,94,122,123].

In particular, our analysis highlighted the relevance of public and private actors' reciprocal learning and action coordination to integrate and balance all the interests at stake in the actualization and renewal of adequate policies and legal measures, as well as the importance of multi-stakeholder strategies based on both formal or informal statements, rules and control mechanisms and capable of developing and optimizing the economic potential of agrobiodiversity-oriented food systems and their inherently beneficial environmental and sociocultural effects (e.g., sustainable scaling up of the Valtiberina Red Onion localized agri-food system) [17,30,62,66,71].

The results confirm the importance of hybrid public-private mechanisms [124,125] for the multi-functional organization, enhancement and sustainability of landrace-based localized agri-food systems. At the same time, the concurrence of agrobiodiversity-dedicated integrated policies, multi-level laws and regulations with stakeholder collaboration in participatory initiatives for endangered landrace protection, market and social valorization sustains and feeds the development of tailored multi-actor polycentric governance [119], favoring coherent management with fair representation, equal protection and balanced satisfaction of the interests at stake [67,119,126,127].

In more detail, on the public side specific policies should support local farmers' and other stakeholders' awareness and responsibility on securing threatened landraces and their multiple value potential. Thanks to the enhancement of public technical and financial assistance, free learning, and training activities local farmers could be remunerated for and improve their active participation in the characterization and on-farm conservation of local genetic resources and traditional practices, and promote landrace knowledge and cultivation independent from the opportunity to valorize them on the market [22,62,120]. Secondly, policy makers should sustain custodians, supply-chain operators and other

interested actors (e.g., associations, researchers, etc.) in creating sound collaborations intended to appropriately qualify and fairly remunerate marketable landraces [32–34,61] and providing for their structuring and formalization by specific public or collective tools.

Specifically, for those landraces that prove to be suitable for large-scale cultivation and modern distribution public policies should support local actors towards controlled and sustainable scaling up, expanding production and marketed volumes and prices while at the same time avoiding agricultural intensification and guaranteeing fair distribution of the higher value created. Public assistance and learning activities should be directed to enhance custodian farmers' business and marketing skills and sustain the collaborative creation, protection and valorization of collective marks and landrace-based traced integrated supply chains. Alternatively, there are other situations where landraces demonstrate better suitability for small-scale cultivation or traditional market channels. In these cases, public support should be directed to favor the creation of landrace-based niche markets for agrobiodiversity products. Here, the participation of small or part time farmers could be supported to realize small-scale high-value added supply chains by experimenting with neglected traditional or innovative alternative uses of landraces and involving local traditional processors and retailers.

Whatever the case, public policies should incentivize local actors in accessing research projects for better landrace characterization (e.g., genetic, organoleptic, nutritional and nutraceutical, etc.), as well as specific funds, financial measures and valorization tools (National law 194/2015 [91]) and participation in integrated supply chains or territorial participatory plans. Furthermore, provisions for the maintenance of public control and responsibility over securing local genetic resources and collective property rights should be effectively harmonized with public jurisdiction over traditional agri-food products, quality schemes, the conservation of varieties, seed breeding and commercialization. This should favor the securing and tracing of seed, avoid potential information asymmetries, and guarantee territorial linkage of landraces and landrace-based agrobiodiversity products and non-appropriability of rights. Lastly, the creation of national specific public marks for the qualification and market remuneration of agrobiodiversity products and custodian farmers' role in this should also be evaluated [61,62].

With a focus on the role of private actors, as shown in the case study, custodian farmers should serve as an engine for the activation and systematization of multi-actor strategies intended to conserve and characterize landraces and to tailor remuneration. They should improve their responsibility and participation in sensitization, learning and training activities in order to enhance their specific knowledge, agronomic and logistic skills and capability to share aims, costs, resources and facilities in the realization of participatory action–research projects and the organization of either small-scale landrace-based niche markets or large-scale integrated supply chains.

Moreover, the connections between landraces, local specific farming and processing methods within the territory represent important elements in defining the identity and quality of several products [128,129]. Our analysis proves the importance of local farmers and other stakeholders in the recognition of agrobiodiversity resources. This is especially relevant with reference to identity linkages with the territory they originate from and their commitment to protection and territorial valorization. While the first step could be the characterization and inscription of local genetic resources' denomination and territorial linkage in both agrobiodiversity-dedicated Regional Repertories [90] or National Registry [91], custodians and other stakeholders should also collaborate towards the creation of quality and territorial identification marks, e.g., Protected Designations of Origin (PDOs), Protected Geographical Indications (PGIs), Italian Traditional Agri-food Products (PAT), and the use of other forms e.g., *SlowFood*, for the qualification of landrace-based agrobiodiversity products.

One remark has to be made on the case of threatened landraces presenting no current market value. In these situations, local farmers should appreciate the role of dedicated non-market mechanisms as an alternative form of remuneration for non-marketable local genetic

resources, their characterization, conservation and valorization efforts, in satisfaction of their private interest [34,120]. On the public side, greater policy commitment to additional technical assistance, payments and training is justified by the beneficial environmental and sociocultural effects concerning the recovery and conservation of agrobiodiversity resources, even those with no actual market attractiveness [9,16,87,96].

In the end, both public and private actors should increase their involvement and act towards the realization of landrace-based territorial valorization paths. These could enhance endangered landraces' multiple value potential and the beneficial effects generated for agro-ecosystems, local agri-food chains, other related economic sectors and entire local communities. Collective territorial marks (e.g., territorial umbrella marks) could be created by custodians with other local actors such as processors, traders, tourist operators, craftsmen, local authorities, etc. At the same time, the case study offers a valuable example considering the new National law 194/2015 [91] on innovative provision for specific public tools (e.g., Routes or Communities of Food and Biodiversity for Food and Agriculture) and public funds with priority access to support the creation of agrobiodiversity-oriented territorial marketing strategies.

In synthesis, the new conceptual framework confirms its validity in supporting the analysis, interpretation and generalization of case study results by taking advantage of the adapted SES approach and quality valorization virtuous circle.

With a view to prove the model's general validity, we would like to make some remarks. As a matter of fact, the selected representative case study focused the analysis on the institutional context and policy frameworks of Italy and Tuscany and on local actors' initiatives for the protection and valorization of a threatened plant landrace. In that regard, we consider that the presented SES model could be extended and consolidated by widening the research field to include other countries and territories and the case of animal landraces.

6. Conclusions

Our work contributes to the understanding of how the restoring and valorization of the knowledge and use of endangered landraces and traditional practices among local farmers, supply chain actors, consumers and communities could sustain the development and reproduction of multifunctional agrobiodiversity-oriented food systems and act as a lever of territorial development and sustainability.

On a theoretical basis, we designed and tested a new conceptual model. By considering a holistic and transdisciplinary approach, we provided a contribution to the notion of biodiversity-oriented food systems and the analysis of their sustainability. We consider the model innovative in the conceptualization and analysis of agrobiodiversity-oriented food systems intended as socio-ecological systems. As the main outcome of this paper, we proved the new SES model's capability in identifying and describing the assets, drivers, human action processes and generated beneficial effects concerning the development and reproduction of landrace-based quality valorization virtuous circles.

Our research findings showed the high capability of the SES model to analyze agrobiodiversity-oriented food systems and their sustainability and territorial development. As a matter of fact, the conceptual framework considers as a determinant aspect the characterization of these systems' performance in combining the production of private and public goods and services and generating and fairly distributing a complex of economic, environmental and sociocultural benefits.

The new model favors the identification of the major private and public interests at stake in the development and reproduction of agrobiodiversity-oriented food systems and the understanding of the role of both public policies and private action in the implementation of hybrid management mechanisms and polycentric governance systems promoting their sustainability and multifunctional role.

Therefore, we demonstrated how the goals of sustainability and multifunctionality can be pursued thanks to the coordinated efforts of public and private actors. These objectives can be attained through the creation and enhancement of collaborative landrace-based

product qualification strategies, marketing approaches and territorial valorization paths. At the same time, the latter should be accompanied by the provision of adequate policy tools for supporting and maintaining public control and responsibility over local genetic resources, pure seed breeding, territorial linkage and collective property rights.

In this respect, it is important to highlight the enabling role of polycentric governance settings in sustaining specific public policies and multi-stakeholder participatory strategies for the development of agrobiodiversity virtuous quality valorization circles. In this way, the development and reproduction of agrobiodiversity-oriented food systems can favor the optimization of different landraces' market potential and, at the same time, the valorization and protection of their specific sociocultural and environmental functions.

In a wider perspective, agrobiodiversity-oriented food systems could play an increasing role in attaining higher resilience and sustainability in the involved farming systems and agri-food chains.

We think that this paper represents a further contribution to the scientific and institutional debate concerning the identification of innovative theoretical approaches and conceptual frameworks for the analysis and interpretation of agrobiodiversity-oriented processes of sustainable transformation and rural development.

The adaptation of the holistic SES approach to the characterization of agrobiodiversity-oriented food systems opens the new model's analytical potential towards future research in multiple directions. Special regard could be given to the analysis of multi-stakeholder innovation governance settings and participatory qualification and remuneration strategies, with a focus on the use of collective marks and quality regimes for landrace-based agrobiodiversity product protection and valorization in the broader territorial perspective.

We expect future research could corroborate the role of agrobiodiversity-oriented food systems in addressing evolving processes of transition towards sustainable agriculture and food chains. The new conceptual model's enhancement and validation can provide a contribution to the most recent theoretical efforts for the identification of a new agrobiodiversity-based paradigm for territorial development and global sustainability.

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