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Assessing the Resilience and Sustainability of a Hazelnut Farming System in Central Italy with a Participatory Approach

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Abstract: European agriculture is facing increasing economic, environmental, institutional, and social challenges, from changes in demographic trends to the effects of climate change. In this context of high instability, the agricultural sector in Europe needs to improve its resilience and sustainability. Local assessments and strategies at the farming system level are needed, and this paper focuses on a hazelnut farming system in central Italy. For the assessment, a participatory approach was used, based on a stakeholder workshop. The results depicted a system with a strong economic and productive role, but which seems to overlook natural resources. This would suggest a relatively low environmental sustainability of the system, although the actual environmental impact of hazelnut farming is controversial. In terms of resilience, we assessed it by looking at the perceived level of three capacities: robustness, adaptability, and transformability. The results portrayed a highly robust system, but with relatively lower adaptability and transformability. Taking the farming system as the focal level was important to consider the role of different actors. While mechanisation has played a central role in enhancing past and present system resilience, future improvements can be achieved through collective strategies and system diversification, and by strengthening the local hazelnut value chain.

Keywords: resilience; sustainability; farming system; participatory assessment; perennial system; Viterbo; specialisation

1. Introduction

In recent years, European farmers have faced an increasing number of economic, environmental, institutional, and social challenges [1]. Examples include food price volatility and changes in the Common Agricultural Policy (CAP) [2]. Farmers are now experiencing an increasing pressure to reduce the environmental impact of their activities [3], while being negatively affected by the consequences of climate change [4]. Additionally, European agriculture is undergoing a structural change, in which the number of farms is declining, especially small family-farms, while their size and specialisation level is growing. The farmers' population is experiencing a demographic change, since the average age of farmers is increasing, with negative effects in terms of knowledge preservation and potential for innovation [5,6]. In this context of high uncertainty, the European agricultural sector needs to maintain its functionality despite perturbations, while ensuring that the present production levels do not compromise future functioning [7]. Being resilient can prevent farming systems from suffering

from irreversible negative changes. Since a large share of the EU agricultural sector is affected by instability, assessing and improving resilience is a very relevant goal for the European context. The SURE-Farm project ("Towards SUstainable and REsilient EU FARMing systems") therefore aims to assess the resilience and sustainability of farming systems across Europe [8].

The concept of resilience is controversial, and it defies simple definitions. Introduced in 1973 by Holling in relation to natural systems, as their capacity to go back to their original state after a disturbance [9], this concept has then been applied to socio-ecological systems (SESs) such as farming systems, in which the human component manages and influences system resilience [10,11]. We define resilience and sustainability in relation to the capacity of a system to perform its functions, related to both private and public goods. A resilient system should be able to maintain the delivery of private and public goods in the face of shocks and persistent pressures. Likewise, in a sustainable system a balanced delivery of private and public goods should be maintained over time, so as to ensure economic, social, and environmental sustainability. Hence, resilience and sustainability are complementary and they influence each other [1,7,12]. We consider resilience in terms of three capacities: robustness, the capacity to resist shocks and stresses; adaptability, the capacity to modify some aspects of the system (e.g., inputs and production, risk management) in response to disturbances, but without changing its structure; and transformability, the capacity to change the system's structures and feedback mechanisms in response to shocks and long-term pressures [10,11,13].

In this study, an assessment was carried out at the farming system level, operating at a regional scale, as this constitutes a higher hierarchical level than individual farms, where a certain degree of self-organisation is possible [1,14]. We define farming systems as such that their social boundaries include actors with an influence on the farms, and who are influenced by these farms in return [1]. Farming systems, as SESs in general, include interacting processes and components at multiple levels, and they are also strongly interconnected with other systems [7]. This complexity makes resilience assessment particularly important: changes in resilience can affect all of the components and connections, and ultimately cause undesirable transformations leading, for example, to decreased sustainability [11,15]. Moreover, multiple types of stakeholders are involved in the dynamics of a farming system. This makes resilience multifaceted and difficult to assess, as the stakeholders often differ in their interpretations and perceptions of the system's resilience. This diversity in perspectives needs to be taken into account in resilience assessment [7,16–18], and therefore, participatory approaches involving stakeholders are required to assess resilience.

The aim of this study was to assess the current and past resilience and sustainability of the hazelnut farming system in the province of Viterbo, central Italy. This system has an important role in the hazelnut sector, Italy being the second biggest hazelnut producer in the world, and Viterbo the first province in the country in terms of hazelnut harvest [19–21]. The assessment was conducted using a participatory approach, which allowed to capture the perceptions of different stakeholders in the system, and hence to identify their needs in terms of policy strategies to improve system resilience and sustainability. The following topics were addressed: definition of the farming system; identification of the main challenges; ranking and assessing of the performance of system functions; analysis of the resilience capacities; and identification and ranking of resilience-enhancing attributes.

2. Materials and Methods

2.1. Case Study Description

The production of hazelnut (*Corylus avellana*) in Italy is concentrated in a few specialised areas in the regions of Piedmont, Lazio, Campania, and Sicily, as a result of suitable environmental and socio-economic conditions [22–24]. Our case study is located in the Lazio region and it includes most of the Viterbo province, excluding the coastal zones. This province is the first in Italy for hazelnut production, with a harvest of 48,400 tons in 2017 [19,20]. Most hazelnut plantations are located in the area of the Monti Cimini (south-eastern part of the province), especially around the Vico Lake, but

the production has now expanded to the rest of the province [25]. The main cultivar in the area is the "Tonda Gentile Romana", which is registered under the PDO (Protected Denomination of Origin) scheme [26]. All steps of production take place locally, apart from the final transformations, which are carried out in confectionary industries outside of the region. The machinery industry is well developed, and the system of cooperatives and Producer Organisations (POs) is highly organised [25]. In a global perspective, Turkey is the largest hazelnut producer, holding 67% of the world's production. Hence, Turkey strongly influences the global and Italian market, Italy being the second of the world's largest producers (13% of the global hazelnut production) [21]. However, Italy plays a crucial role in the supply of high-quality hazelnut products, which are increasingly requested by the confectionary industry [27,28]. Given the growing demand for hazelnuts at a global scale, over the last few decades there has been an expansion of the hazelnut cultivated area worldwide [20,21]. This has occurred in the Viterbo province as well, leading to criticism stating that the growing demand has led to intensive and specialised production patterns [29]. This has been associated with potentially negative environmental and social effects, that pushed some municipalities to constrain the use of chemicals and, in one case, the planting of new hazelnut nearby the Bolsena Lake [30].

Hazelnut is a natural component of the temperate broadleaf and mixed forests of northern Lazio, and its domestication allowed for the agricultural exploitation of the local hilly landscape. Traditional hazelnut agroecosystems were based on a polyculture with chestnut (*Castanea sativa*) and olive trees (*Olea europaea*), a system allowing for soil conservation and for the preservation of biodiversity, landscape diversity, and ecological networks [31]. However, the increased market demand and competition, as well as the massive introduction of mechanical harvesting, has led to a specialisation and modernisation of the production: hazelnut cultivations currently cover 43% of the Utilized Agricultural Area (UAA) in the province, mostly in monocultures with high tree density [25,31]. Within the 60 municipalities of the provinces, in 13 of them hazelnut represents more than 50% of the overall utilized agricultural area [32]. As hazelnut is a drought-sensitive crop, several farms in the area practise irrigation [26,33]; the maximum amount of irrigation per year ranges from 350–550 m^3/ha [34]. According to the Farm Accountancy Data Network (FADN), a sample of 226 hazelnut farms in the province (of which 88 practised irrigation) used an average of 223 m^3/ha per year during the period 2008–2017; 30% of the UAA of these farms was equipped for irrigation (own elaboration of Italian FADN data; [35]). As for nutrient applications, national data on hazelnut cultivation show that, on average, farmers apply 73.5 kg/ha of N, 63 kg/ha of P, 84 kg/ha of K, and 70 kg of Ca (as calcium nitrate). Crop protection products are also applied, namely fungicides (10 kg/ha), sulphur (20 L/ha), herbicides (10 L/ha), and insecticides (3 L/ha) [28]. The use of fertilisers and pesticides in the province is a subject of discussion, as hazelnut farming is claimed to be responsible for the pollution of the Vico Lake [36]. However, the application of nutrients and crop protection products in the province of Viterbo may be lower than the national average, thanks to the increased environmental awareness and to the support from the Rural Development Programme (RDP) and Producers' Organisations (POs).

2.2. Theoretical Background

The concept of resilience used in this paper is based on the metaphor of adaptive cycles, a model for describing a potential system change over time in response to disturbances [11]. In this cycle (Figure 1), a phase of resource exploitation or growth is followed by a conservation phase, in which systems develop and become more stable and less flexible. Moving on along the cycle, a phase of release and collapse or decline occurs, potentially followed by a reorganisation phase in which opportunities for innovation can be taken [11,37]. According to this model, resilience can be considered as the capacity of a system to successfully go through all stages of the cycle [38], i.e., it needs to have the capacity to be robust, to adapt and transform. This, however, does not imply that a system has to go through all phases; a release can be partial and followed by incremental changes. Adaptive cycles are also present in different processes and at different scales; interactions between these are essential in shaping the dynamics and resilience of SESs [11]. We considered this cycle in four processes: agricultural

production (e.g., productivity, technology development, profitability), farm demographics (farm types, demographic trends in the system), governance (policy, connections with external actors), and risk management (diversity and general buffering capacity of the system) [1,39].
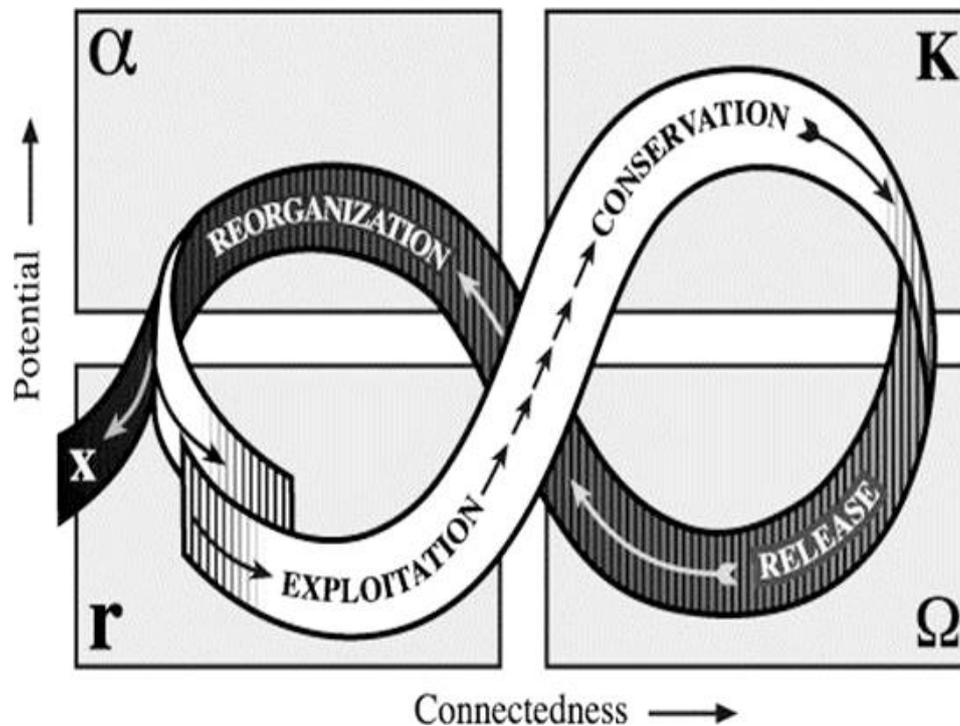

Figure 1. Adaptive cycle. Source: Resilience Alliance [40], originally from Holling and Gunderson [37].

2.3. Methodology for the Participatory Assessment of Resilience and Sustainability

The assessment was conducted through a workshop aimed at understanding how different stakeholders perceived the past and present resilience and sustainability of the system. The workshop included individual and group activities, following the SURE-Farm Framework for Participatory Impact Assessment (FoPIA-SURE-Farm; [39,41]), and it was accompanied by a preparation and an evaluation phase. The workshop involved 21 participants, classified as Farmers (eight participants), Government (three participants), Industry (three participants), and Others (members of NGOs and associations, agronomists; seven participants in total) [42]. The participants were selected to ensure that the perceptions of different types of stakeholders in the system would be captured, with farmers being the most represented group (about 40%). The basis of the workshop was the resilience framework developed by Meuwissen et al. [1], in which five steps are followed for resilience assessment.

1.　　Resilience of what: farming system

First of all, the farming system was defined. This was done in the preparation phase, by identifying different types of actors: all actors having mutual influences with farms were included in the system, whereas actors having influence on the farms but not being influenced by them were considered as part of the system context. The developed system vision (see Figure 2) was presented to the stakeholders to clarify the focus of the workshop, and to allow participants to exclude or include actors.

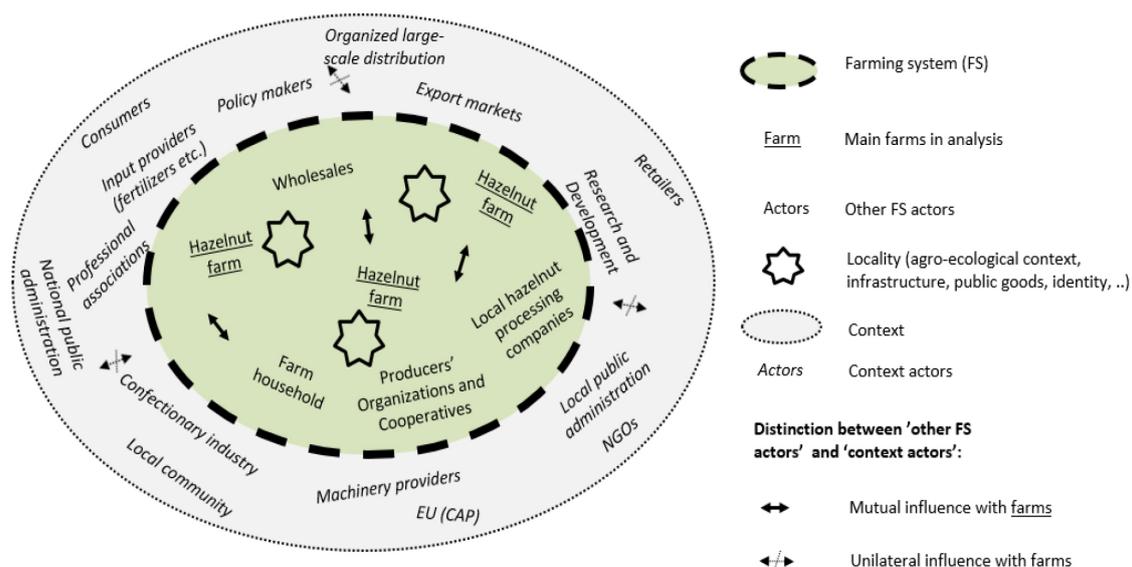2.　　Resilience for what purpose: system functions

Figure 2. Actors inside and outside the farming system. CAP: Common Agricultural Policy. Adapted from Meuwissen et al. [1].

Seven system functions were identified in this study, based on the list from Meuwissen et al. [1], divided in functions related to the provision of private and public goods. The assessment of system functions particularly relates to sustainability, in accordance with the definition provided in the Introduction (i.e., capacity to maintain a balanced delivery of private and public goods over time) [1]. For each function, in the preparation phase, we identified two or three indicators which could represent the function at the farming system level (Table 1). The selection was made by trying to include indicators with information available in international, national, and regional databases (e.g., FADN, Italian National Statistics Institute, Viterbo Chamber of Commerce), as well as indicators that are usually hard to measure, such as social indicators. Literature was also consulted to come up with well-defined and suitable indicators [43,44]. Criteria for indicators were comprehensibility, applicability to the case study, and ease of communication with the participants. During the workshop, the participants were asked to: rate the importance of the functions, by distributing 100 points among the functions based on their current importance in the system; rate the representativeness of the indicators, by distributing 100 points among the indicators of each function; score the current performance of the indicators, by giving a score from 1 (very poorly performing) to 5 (very well performing) [39].

3. Resilience to what: challenges

Based on importance, a few indicators were selected for a more detailed analysis. Included indicators had different performance levels, and belonged to functions related to private and to public goods. For these indicators, the participants identified, in small groups, the challenges that shaped their historical dynamics in the past few decades (see Appendix B). The participants also identified the main strategies adopted to face the challenges. Where necessary, a prepared list of challenges was used to stimulate discussions (Appendix A).

Table 1. Indicators per function, with most relevant stakeholder groups. Below each function (in italics), the short name commonly used in this paper. CAP: Common Agricultural Policy; RDP: Rural Development Programme.

Functions	Indicators	Stakeholder
Private Goods		
Deliver healthy and affordable food products (Food production)	Hazelnut production	All stakeholders
	Hazelnut quality	Farmers/Industry
Deliver other bio-based resources for the processing sector (Bio-based resources)	Shell production for heating	Farmers/Industry
	Production of pruning waste for energy generation	Farmers/Industry
Ensure economic viability (viable farms help to strengthen the economy and contribute to a balanced development) (Economic viability)	Gross Margin per hectare	Farmers
	Public support to agriculture (CAP and RDP)	Farmers/Government
	Margin from in situ processing activities	Industry
Improve quality of life in farming areas by providing employment and offering decent working conditions (Quality of life)	Number of people in the area employed in the farming system	All stakeholders
	Percentage of women among the people employed in the system	All stakeholders
	Health of agricultural workers	All stakeholders
Public Goods		
Maintain natural resources in good condition (water, soil, air) (Natural resources)	Groundwater availability	All stakeholders
	Water quality in the area	All stakeholders
Protect biodiversity of habitats, genes, and species (Biodiversity and habitat)	Diversification in land use	Government/Others
	Number of organic farms	Farmers/Government/Others
Ensure that rural areas are attractive places for residence and tourism (countryside, social structures) (Attractiveness of the area)	Touristic flow	All stakeholders
	Retention of young people in the area	Farmers/Government/Others

4. What resilience capacities

This step aimed to assess system resilience in its three capacities (robustness, adaptability, and transformability); hence, the workshop participants were introduced to these concepts. Based on Step 3, the participants scored the level of implementation of the identified strategies, from 1 (very poorly implemented) to 5 (very well implemented). Afterwards, they scored the potential contribution of each strategy at its highest implementation to each resilience capacity. The scoring scale was from −3 to +3, indicating negative or positive (−/+), and weak (1), medium (2), or strong (3) contributions (0 indicated no contribution) [39].

5. What enhances resilience

A list of 13 attributes (see Appendix A, Table A2) which enhance resilience was developed in Reidsma et al. [39], based on the list presented by Cabell and Oelofse [45]. The participants were asked to evaluate to what extent each of the attributes was present in the system, from 1 (not at all present) to 5 (highly present). As previously done for the strategies (Step 4), the participants also scored the potential contribution of each attribute at its highest level to robustness, adaptability, and transformability, from −3 to +3.

The workshop results were analysed in the evaluation phase, mainly in terms of calculating means and standard deviations (SD); differences across stakeholder groups were observed, and the overall results were analysed in relation to the available literature. For the rating of indicators per function, the scores were transformed so that the importance of indicators could be compared also across different functions. Hence, the values were transformed considering the scoring for the importance of the functions and the number of indicators per function (Equation (1)).

Relative indicator importance = (function importance × indicator representativeness)/100 × n° indicators representing the function   (1)

Some of the data were processed during the workshop, and graphic representations were developed and shown to the participants to stimulate discussion. During the workshop, the concept of adaptive cycles was not mentioned, as we considered this information too time-consuming and a potential risk for confusion next to other explanations on resilience concepts. Instead, in the evaluation phase, the research team has interpreted workshop outcomes in the light of adaptive cycles.

3. Results

3.1. Farming System

In the preparation phase, the research team prepared a visualisation of actors within and outside the farming system (Figure 2). Apart from farms and farm households, the farming system includes wholesalers, producers' organisations (POs) and cooperatives, and local hazelnut processing companies. All these actors influence farms and are influenced by them. The farming system is characterised by the presence of processing industries (for the first processing steps, i.e., shelling) and wholesales interacting with the confectionary industries outside the system. Therefore, these actors mainly have mutual economic influences with farms. Cooperatives (often organised in POs) have both economic and social influences on/from farms: they are the main form of social organisation in the system and they connect producers to confectionary industries and the downstream market. During a feedback session on the visualisation, participants indicated that public support (e.g., Rural Development Program) and machinery development have a strong influence on the farming system.

3.2. Functions

3.2.1. Function Performance

According to the participants' scoring, the most important function delivered by the system was "Economic viability" (33 points), followed by "Food production" (25 points) and, with a much lower importance, "Quality of life" (Figure 3). The lowest scores were given to the functions related to public goods, particularly to "Natural resources", "Attractiveness of the area", and "Biodiversity and habitat" (8, 7, and 6 points respectively). There was generally more agreement on the functions with the lowest scores, while the highly rated functions showed higher SD. Overall, the different stakeholder groups were relatively homogeneous in their scoring of function importance. Members of Industry tended to prefer "Food production" and then "Economic viability", whereas all other stakeholders put "Economic viability" first. Moreover, the Industry considered the importance of "Natural resources" higher compared to the average, whereas the Government group gave a much higher score to "Attractiveness of the area" compared to the others.
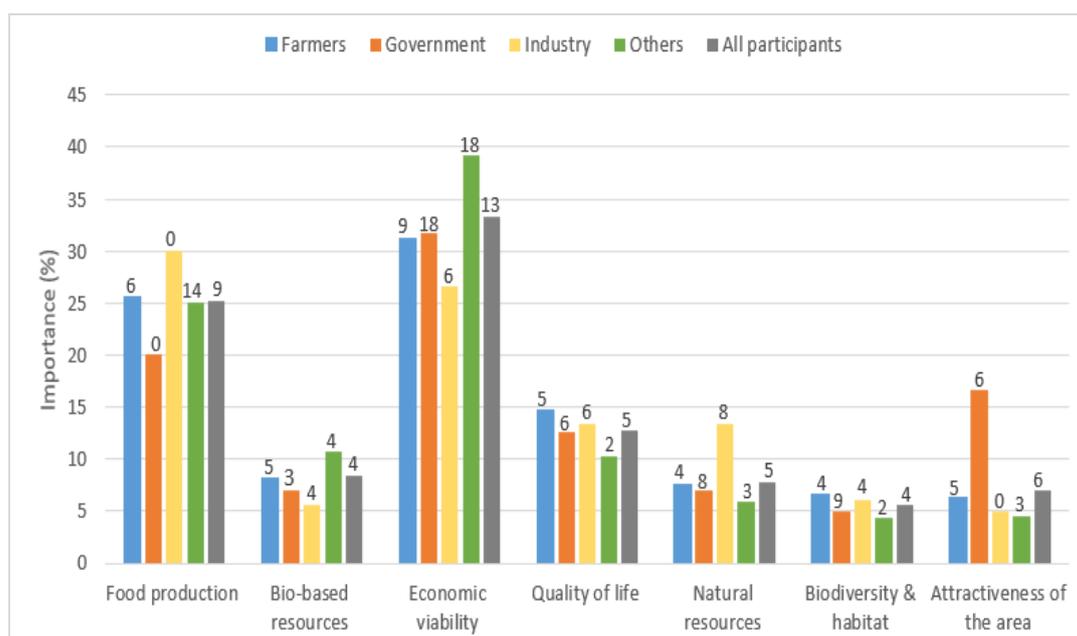
Figure 3. Average scoring per function, per stakeholder group. Values of standard deviation are indicated on top of each bar. 100 points were distributed among seven functions.

3.2.2. Indicator Importance

The participants agreed on the list of indicators defined in the preparation phase (see Table 1). With regard to the relative importance of indicators (see Equation (1)), "Gross Margin per hectare" showed the highest score (53 points), followed by "Hazelnut production" and "Margin from in situ processing activities" (equally rated with 26), and by "Hazelnut quality" (24 points) (Figure 4). This reflects the scoring of the functions, where "Economic viability" and "Food production" were the most important ones. "Gross Margin per hectare" and "Margin from in situ processing activities" had the highest SD, due to differences between and within stakeholder groups. The lowest average scores were given to the functions related to public goods, with the exception of "Number of people in the area employed in the farming system" (17 points) and "Health of agricultural workers" (15). "Production of pruning waste for energy generation" also had a low score of 5, despite representing a function related to private goods. Overall, the indicators with the lowest scores also showed low SD, demonstrating a general agreement among the participants. For each function, the stakeholders differed in their choice of the most representative indicator. The Government group tended to differ from all other stakeholders, and in some cases, Government and Industry shared the same choice.
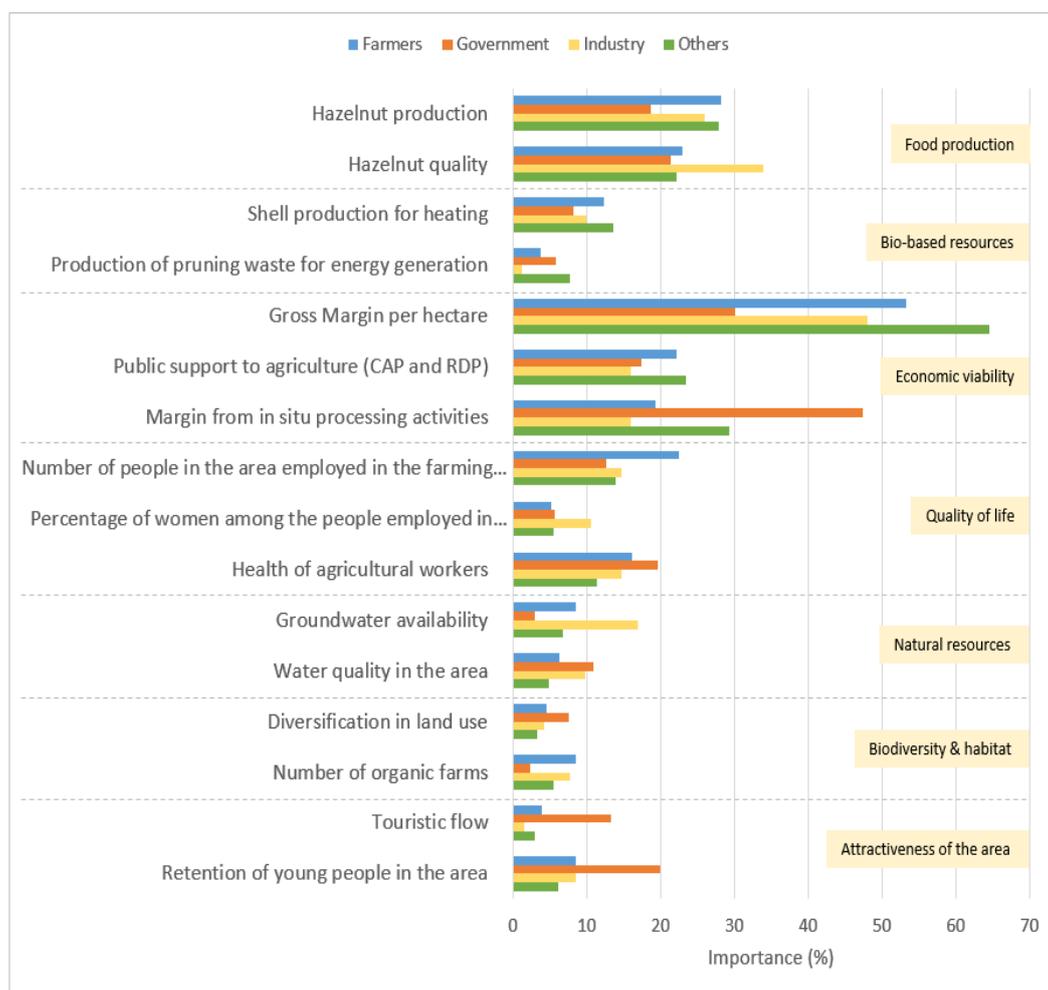
Figure 4. Relative importance of indicators to represent the functions (average scoring per stakeholder group), shown per function. 100 points were divided among the indicators of a certain function, and these values were transformed accounting for the importance of the functions and the number of indicators per function (see Equation (1)).

3.2.3. Indicator Performance

Overall, the indicator performance followed the same pattern as the importance of functions, with better performance for the indicators of functions related to private goods and worse for those related to public goods (Figure 5). The best performing indicators were perceived to be "Hazelnut production" (4.2), followed by "Hazelnut quality" and "Gross Margin per hectare", all representing functions that deliver private goods. The least performing indicators were perceived to be "Diversification in land use" (1.8) and "Touristic flow" (1.9), both representing functions that deliver public goods. Groundwater availability and water quality in the area were assessed to perform poor to moderate. Participants indicated that lower scores for these indicators were due to the expansion of hazelnut cultivation to dryer areas, affecting water availability, and the need for crop protection products, affecting water quality. Two exceptions to the general scoring pattern were "Production of pruning waste for energy generation" (private goods but scored only 2.3), and "Retention of young people in the area" (public goods, medium score of 3). However, many indicators showed high values of SD, particularly "Margin from in situ processing activities" due to variability among stakeholder groups, "Production of pruning waste for energy generation" and "Percentage of women among the people employed in the system". There was generally more agreement on the indicators with higher performance.
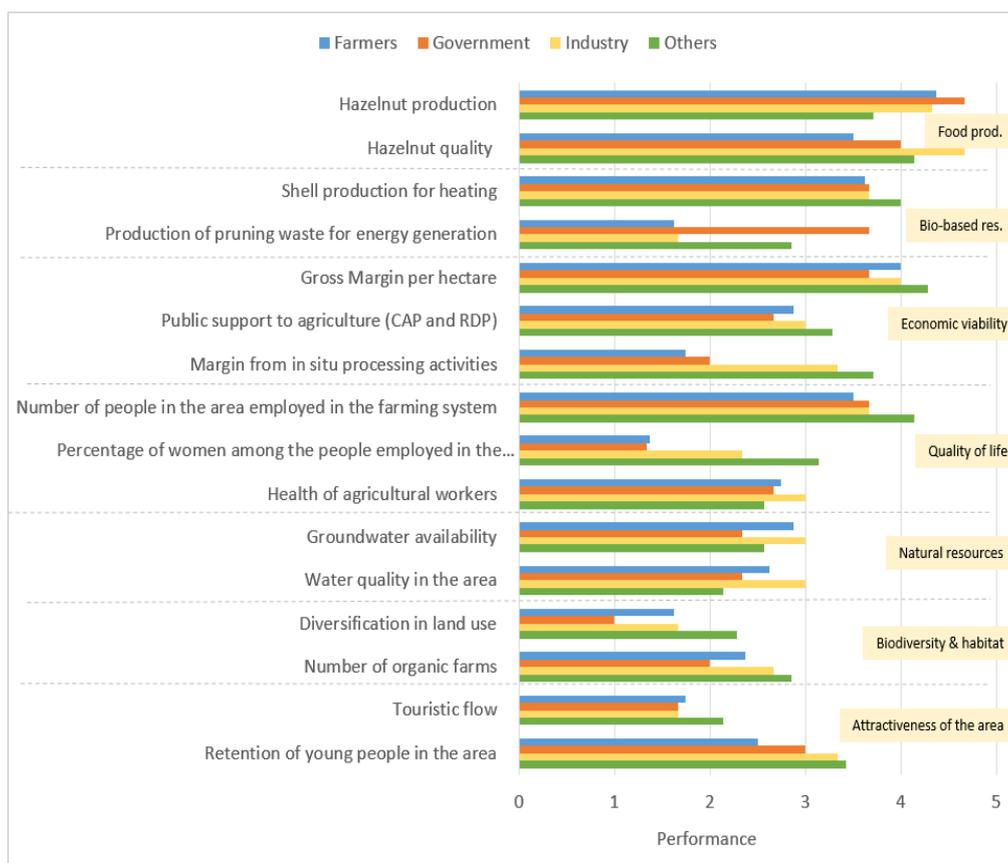
Figure 5. Performance of indicators (average scoring per stakeholder group), shown per function. Score from 1 (very poorly performing) to 5 (perfectly performing).

Looking at differences between stakeholders, the results were again homogeneous for the indicators with high performance. For "Margin from in situ processing activities", both Industry and Others gave significantly higher scores than the other two groups. The results also clearly differed for "Percentage of women among the people employed in the system"; and Others was the only group rating the performance as higher than moderate. For "Production of pruning waste for energy generation", the rating from the Government group was relatively high, in contrast with the low rating coming from Farmers and Industry, while Others gave a medium rating. "Diversification in land use", which had a low overall score, was unanimously rated as "very poorly performing" by all Government stakeholders.

3.3. From Indicators to Challenges, Strategies and Resilience Capacities

Based on the perceived importance and performance, five indicators were selected for further analysis, including some with high performance and some with moderate or low performance, and both private and public goods. The indicators "Hazelnut production" and "Hazelnut quality" were combined into one indicator that also included hazelnut price evolution ("Gross Saleable Production", the gross revenue). The four final indicators were: "Gross Saleable Production", "Gross Margin per hectare", "Number of organic farms" and "Retention of young people in the area". The participants described their dynamics over the last 20 to 40 years, specifying challenges and opportunities which shaped these dynamics and the strategies adopted to face them (Table 2; details on the indicator dynamics can be found in Appendix B). Although the initial time span suggested for this was 20 years, the participants asked to extend this to 30 or 40 years for some indicators, hazelnut being a perennial crop in which long-term dynamics are more representative.

Table 2. Challenges and strategies per indicator.

Group	Indicator	Challenge	Strategy
1	Gross Saleable Production	Lack of labour availability and high labour costs	Mechanisation
		Market instability	Cooperatives
2	Gross Margin/ha	High production costs	Mechanisation
		Production fragmentation	Producers' Organisations
3	Organic area	International competition	Rural Development Programme funds
4	Retention of young people	Abandonment of farming	Mechanisation
		Profitability reduction	Value chain activities

Mechanisation emerged as the main strategy in the past, and particularly the development of self-propelled machinery was reported to have reduced labour costs and allowed for an expansion of the hazelnut cultivated area in the province, making hazelnut farming more attractive for the youth. Strategies based on cooperation, such as cooperatives and POs, were also mentioned in relation to different challenges and indicators, mainly thanks to the fact that they have increased the farmers' bargaining power with the industry. The development of activities connected to the hazelnut value chain was reported to be essential for retaining youth in the area, as it created multiple job opportunities thus preventing outmigration. Finally, the use of the RDP funds appeared to be an ambiguous strategy: according to the participants, many farmers used RDP funds supporting organic farming (around 800 €/ha; [46]) to cover the planting costs in the first five years, when plants are not productive, but they switched to conventional farming after this period to increase the potential for high yield and reduce the risk of insect damage.

Overall, the strategies were perceived as well implemented by the participants (Table 3). Mechanisation was applied to challenges related to different indicators, and it was always considered as very well implemented (average score of 4.8). POs were also a very well implemented strategy, whereas cooperatives showed a lower level (3.8). Therefore, mechanisation appeared to be stronger than social organisation, thus indicating that shared strategies were perceived as less strongly implemented than on-farm strategies. A moderate to good implementation level was also assigned to the value chain activities, and a lower one to the use of RDP funds (3.4). Participants indicated that further inclusion of processing activities in the farming system was desirable.

Table 3. Values of mean and standard deviation (SD) for the implementation of strategies. Score from 1 (not, or very badly implemented) to 5 (very well implemented).

Selected Indicator	Strategy	Implementation Score	
		Mean	SD
Gross Saleable Production	Mechanisation	4.75	0.50
	Cooperatives	3.75	0.71
Gross Margin/ha	Mechanisation	4.75	0.50
	Producers' Organisations	4.75	0.71
Organic area	RDP funds	3.38	0.50
Retention of young people	Mechanisation	4.75	0.00
	Value chain activities	3.75	0.00

Afterwards, the participants evaluated the impact of the strategies on the resilience capacities (Figure 6). Considering "Gross Saleable Production", mechanisation was considered to have a strong

positive impact on robustness and a medium/weak positive impact on adaptability and transformability. Cooperatives also had an enhancing effect on all three capacities, between medium and strong. In relation to "Gross Margin per hectare", mechanisation had a very weak effect on the capacities: slightly positive for robustness and adaptability, negative for transformability. For this indicator, POs had a weak positive effect on robustness, which increased for adaptability and for transformability. The only strategy relating to "Organic area" (use of RDP funds) had a weak negative impact on robustness and adaptability, and a weak enhancing effect on transformability. For "Retention of young people in the area", the impact of mechanisation slightly decreased from robustness to transformability, but it was between medium and strong for all three capacities. For the second strategy (value chain activities), all capacities were strongly improved, with a maximum for adaptability and equally for the other two.
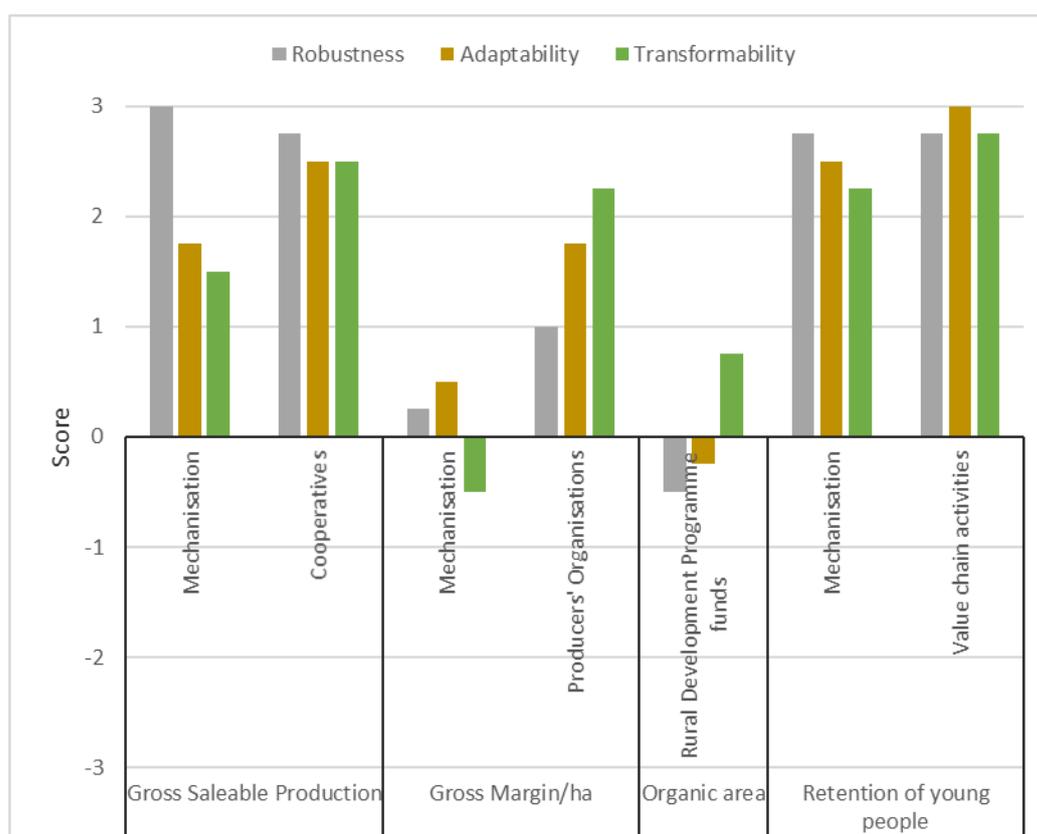

Figure 6. Relationships of the strategies with the resilience capacities of the indicators (average). Score from −3 to +3: 0 = no relationship; +1 or −1 = weak positive or negative relationship; +2 or −2 = intermediate positive or negative relationship; +3 or −3 = strong positive or negative relationship.

Considering the actual contribution of the strategies to the resilience capacities (their implementation level combined with their potential contribution to the capacities), the robustness of the system was strongly positively influenced by mechanisation, according to two groups. Adaptability was also enhanced by this strategy, but with lower strength, whereas its impact on transformability was ambiguous: the group working on "Gross Margin per hectare" indicated a negative relation between mechanisation and transformability. An improvement in the adaptability and transformability of the system could come from a higher implementation of cooperatives and value chain activities, which would also further improve the robustness of the system. This suggests that the long-term resilience of the system can be pursued trough a collective strategy. An increased use of RDP funds, the strategy with the lowest implementation level, would not have much influence on the capacities, as all potential contributions of this strategy (negative and positive) were close to zero.

3.4. Resilience Attributes

On average, the resilience attributes were perceived to be moderately present in the system, with a general average score of 2.9 and all attributes being scored between 2 and 4 (Figure 7). Social self-organisation and profitability were again the biggest strengths of the system. Other attributes with relative high presence were: "Optimally redundant (farms)", "Spatial and temporal heterogeneity (farm types)" and "Supports rural life". On the contrary, the attributes with the lowest scores were: "Exposed to disturbance", "Coupled with local and natural capital (production)" and "Diverse policies".
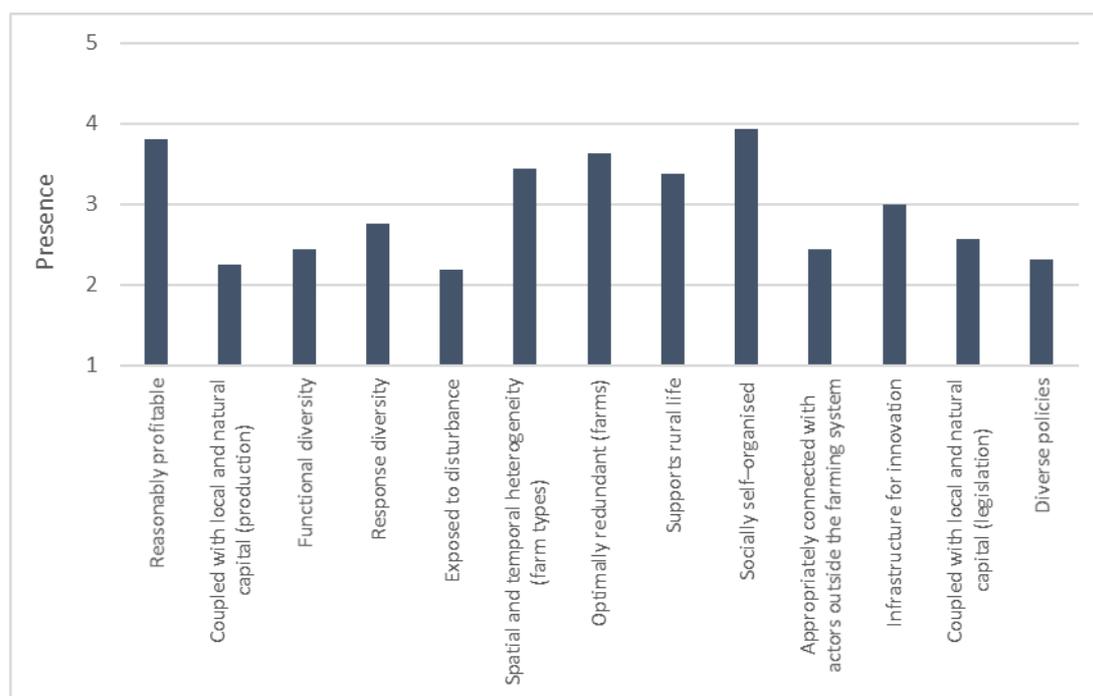

Figure 7. Average scores of the presence of attributes in the system. Scores from 1 (not present at all) to 5 (highly present).

The resilience attributes relate to four processes: agricultural production, risk management, farm demographics, governance (see Appendix A, Table A2). Based on the results of the scoring, the attributes with the highest presence were those related to farm demographics ("Optimally redundant", "Supports rural life", "Spatial and temporal heterogeneity"), followed by agricultural production (mainly "Reasonably profitable" and "Infrastructure for innovation"), risk management, and governance. However, the two attributes with the highest scores referred to agricultural production ("Reasonably profitable") and governance ("Socially self-organised").

All attributes were considered to have a positive impact on the resilience capacities (Figure 8). In general, attributes were assessed to contribute most positively to robustness, then adaptability and then transformability. There were a few exceptions to this, such as "Appropriately connected with actors outside the farming system" (which showed the opposite trend), "Socially self-organised" and "Infrastructure for innovation" (both having the most positive value for adaptability), and "Functional diversity" (lowest score for adaptability). The latter results come as a natural consequence of the high production specialisation of the system.
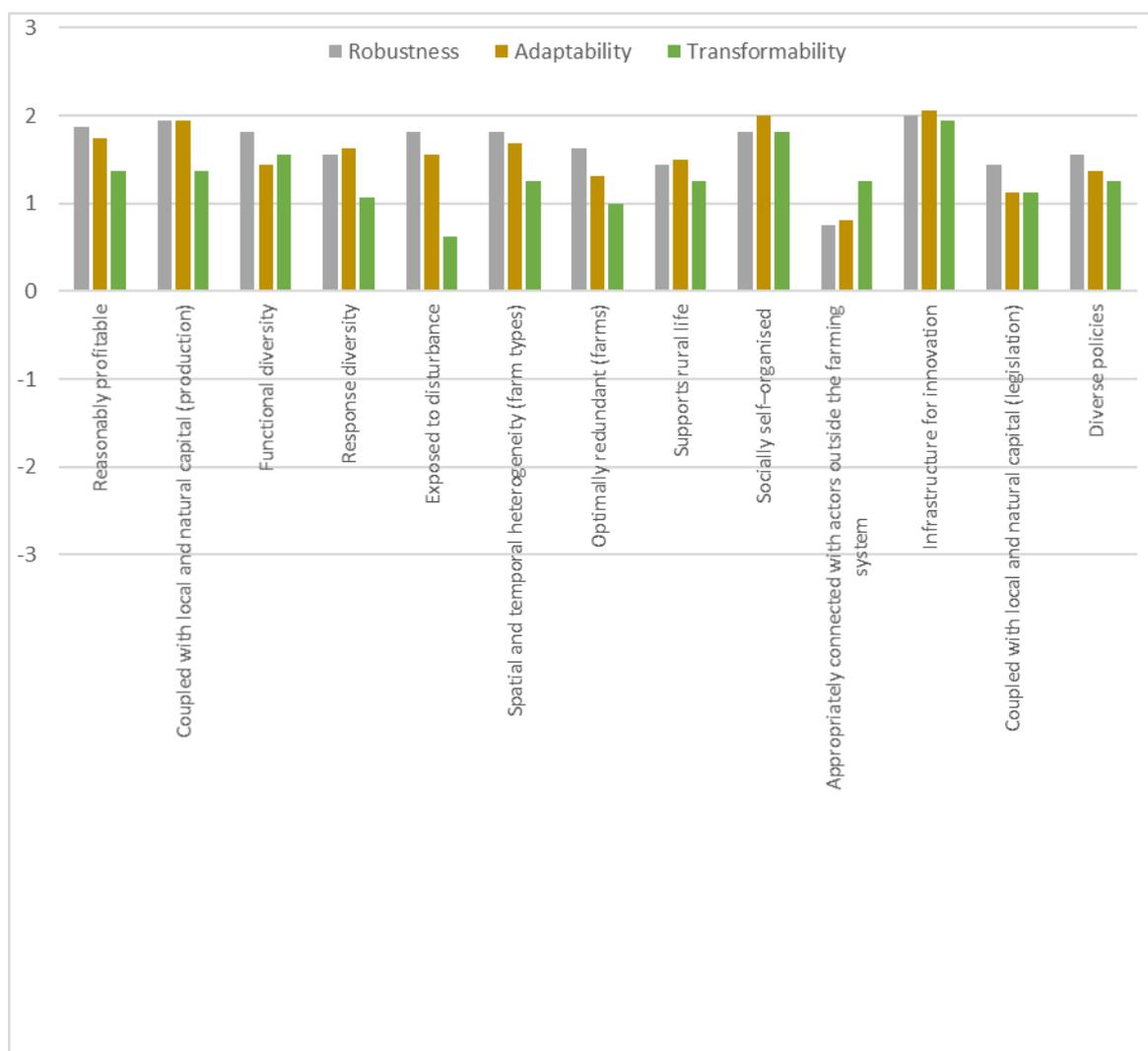
Figure 8. Relationships of the attributes with the resilience capacities of the farming system (average). Score from −3 to +3: 0 = no relationship; +1 or −1 = weak positive or negative relationship; +2 or −2 = intermediate positive or negative relationship; +3 or −3 = strong positive or negative relationship.

For some attributes, high levels of presence corresponded to a medium positive relation with the resilience capacities, and particularly with robustness. This applied to the attributes "Reasonably profitable" and "Socially self-organised", whereas "Spatial and temporal heterogeneity (farm types)", "Optimally redundant (farms)", and "Supports rural life" were present at relatively high levels (above 3) but had a less strong impact on the capacities, always decreasing from robustness to transformability. In some cases, attributes with low or medium scores also had a low or medium potential impact on the capacities, thus even if implemented at a higher level, they could not change significantly the resilience of the system, according to the stakeholders. Exceptions to this were the attributes "Coupled with local and natural capital (production)", "Functional diversity", "Response diversity", and "Exposed to disturbance". These attributes had low presence, but a higher level would have a relative strong positive impact on robustness and adaptability, and a medium or weak impact on transformability.

4. Discussion

4.1. Methodological Challenges

Overall, the stakeholder workshop was successful: the participants were active and interested in giving a contribution, and their feedback was generally positive. The main challenge during the workshop was to keep the participants' attention high, especially considering the abstract nature of some of the considered topics. Some of the workshop exercises were complex, particularly the scoring of the relationships between resilience attributes and resilience capacities. As pointed out by one participant, this scoring was particularly difficult because it required a certain level of conceptualisation and pre-knowledge on resilience. Another limitation was that the number of participants was low and that the stakeholders were not invited randomly, due to the need to have a balanced representation of NGOs and producers belonging to different POs. Most participants already knew each other; thus, they might have provided a uniform vision of the system. At the same time, this facilitated an active participation of the stakeholders to the discussions from the beginning of the workshop. Finally, due to the limited availability of data on the farming system, it is difficult to draw conclusions on the full reliability of the participants' perceptions. Only part of the results of the group exercise could be validated through existing information, as data were available only for some indicators. Nevertheless, this participatory assessment of resilience and sustainability of the farming system provides good insights, and can be followed up by additional quantitative assessments [47].

4.2. System Functions

According to the workshop participants, the identity of the system is defined through the functions related to private goods. The two functions perceived as the most important were "Economic viability" and "Food production", reflected by the choice of the most representative indicators ("Gross Margin per hectare", "Margin from in situ processing activities", "Hazelnut production", and "Hazelnut quality"). The high ranking of "Margin from in situ processing activities" shows the importance of processing for the farming system, which emerged in many discussions during the workshop. On the contrary, functions related to the delivery of public goods seemed to be overlooked in the system, and they were not perceived as important by the stakeholders for improving the system's performance.

The major economic role of the farming system is affirmed in the literature: hazelnut production dominates the local economy, and it is tightly linked with the industry and with the provision of local services [20,48]. As for the low scores for the provision of public goods, the negative environmental impact of hazelnut farming is highly debated. Particularly controversial is the pollution of the Vico Lake, around which most of the production is concentrated [25]. Although the cause of its high pollution and eutrophication has not been proven, some authors associate these problems with hazelnut farming, as the bare soils preferred for mechanical harvesting facilitate erosion [36,49]. In contrast, the positive effect of perennial crops on soil quality is also recognised in literature, particularly concerning water and nutrient preservation and protection from soil erosion (e.g., [50]).

4.3. Robustness, Adaptability, and Transformability of the Farming System

Overall, the workshop results depicted a robust system, with lower adaptability and transformability (see Figures 6 and 8). However, the three resilience capacities operate in different time scales: robustness mainly concerns short-term answers to disturbances, whereas adaptation to change happens on an intermediate time scale, and transformations of the system are usually possible over longer time scales [51]. This may have influenced the participants' evaluation, as robustness might be easier to perceive, compared to the potential medium- and long-term responses of the system. Based on the workshop results, robustness is mainly enhanced by the high profitability, as well as by the high self-organisation (increasing all three capacities, and particularly adaptability). The transformability of the system is relatively low. This is partially due to the fact that hazelnut is a perennial crop, as this makes transformations of the system difficult; moreover, most of the attributes that could enhance

transformability according to participants ("Functional diversity", "Appropriately connected with actors outside the farming system") have a low presence.

The functional and response diversity of the system are particularly low; this is a negative point, as in the literature, diversity is often considered to be essential for resilience. It can help to face unexpected negative conditions affecting one part of the system (e.g., a specific crop), provide buffer to shocks, or offer options for transformation; and crop and landscape diversity can guarantee services such as pest control [52,53]. However, the same authors admit that lower diversity allows for a better exploitation of resources during stable times, and that the economic benefits of diversity still need to be proved empirically, as they also depend on local conditions and on the degree of diversification. Moreover, low diversification in economic activities often implies a higher institutional efficiency in providing solutions for farmers. Thus, homogeneity in a system can strengthen its robustness (and partially its adaptability), despite affecting its transformability in the long term [14]. The low level of diversity in the system can be interpreted as a confirmation of its strong economic orientation and specialisation, and as a factor that further strengthens the system's robustness.

4.4. Resilience and Sustainability of the Farming System

The farming system performs well for two functions (profitability and production), while having a medium or poor performance for most of the others, and robustness seems to be the strongest resilience capacity in the system. This suggests that the system is mainly managed for high efficiency and control, rather than for resilience and diversity [54]. The scoring of the system attributes also seems to confirm this. However, the system's high redundancy and well-developed self-organisation determine a decentralisation and a compartmental division, which are associated with resilience [54]. Therefore, the farming system is overall resilient, but mostly in terms of robustness; the system's management is mainly focused on efficiency, while including elements of resilience (heterogeneity, redundancy). Furthermore, the system has high specified resilience, against specific kinds of disturbances [55]. For instance, machinery and social organisation allow facing labour-related and economic challenges. However, the high level of specialisation increases the vulnerability to other types of perturbations, such as environmental ones: due to the low diversity, the areas of the province with the highest density of hazelnut cultivations experience a high incidence of the hazelnut weevil *Curculio nucum* [24,56]. The dependence on a single production sector with heavy downstream market concentration (confectionary industry) makes the system vulnerable to disturbances that require transformation [52,53,57], and perturbations are likely to happen more often as the system specialises and its dynamics are modified [54].

Hazelnut production seems to put pressure on natural resources, as shown by the low performance of indicators related to "Natural resources" and "Biodiversity and habitat", and by the low level of the attribute "Coupled with local and natural capital (production)". Moreover, in the production chain, the raw products and the final products are very distanced, as the confectionary industries are outside of the system [25]. According to Sundkvist et al. [58], feedbacks between production, ecosystems, and consumers should be tightened in order to move towards more sustainable food systems. The authors argue that factors limiting the tightening of feedbacks include intensification and specialisation in production, geographic distancing, and concentration of actors for specific economic activities. These factors are present in the Viterbo hazelnut farming system, possibly preventing relevant feedback signals being processed in time. For instance, some of the environmental consequences of hazelnut farming can affect the production in the long term, as in the case of irrigation. Given the increased dry conditions in the area, the use of irrigation systems could deplete water resources and affect hazelnut production in the long term [26,33,59]. Based on these arguments, the sustainability of the system can be considered to be relatively low. However, the environmental impact of hazelnut farming is controversial. Briamonte [22] defines hazelnut as the ideal crop for preserving landscape quality in Viterbo. In the past, the system has adjusted to a growing environmental concern: according to Bignami [33], in the early 2000s a high percentage of farmers complied with environmental measures

requiring reduced fertiliser applications. Additionally, the use of grass covers has become widespread as a way to control weeds while preventing soil erosion [33,60]. Moreover, the Lazio Region has restricted the use of pesticides in the area of Vico Lake, favouring the implementation of integrated pest management practices to reduce lake pollution from agriculture [61]. Therefore, the system could be able to adjust again in the future and increase its environmental sustainability.

4.5. Position of the Farming System in the Adaptive Cycle

Based on the original paper on resilience attributes by Cabell and Oelofse [45], the farming system could be located between the exploitation and the conservation phases in the adaptive cycle [11,37,45]. According to the workshop participants, several attributes which link to these phases are highly present in the system (e.g., "Reasonably profitable", "Spatial and temporal heterogeneity", "Optimally redundant"). The identified past strategies also confirm this, as they are mainly based on exploiting resources and specialising in successful activities, whereas no strategy concerns an adjustment or reorganisation of the system [52]. While the high level of heterogeneity suggests that the system is closer to the exploitation phase, other elements indicate a position at the end of the conservation phase, closer to release (e.g., the high level of redundancy) [45,52]. Moreover, the system has specialised and expanded in the past few years [24,33], which suggests that it has undergone exploitation and conservation [52]; since the expansion has already included less suitable areas in the province, the system has exploited the available resources and it might be close to its maximum potential growth, which would imply a proximity to release [33,52].

Several elements could enable the system to extend the conservation phase or to successfully go through a reorganisation. Despite the high level of specialisation, different stakeholders seem inclined to a system innovation: the workshop participants claimed the importance of starting new economic activities (particularly local processing), and the infrastructure for innovation was scored as one of the most present attributes in the system. Innovation could reduce system rigidity and help to defer release [38]. Rigidity could also be reduced through an increase in system diversity, which can protect the system from collapsing [38,45]. In addition, the high economic reserves of the system could help to undergo a reorganisation: even though they could facilitate a release (as they increase the rigidity of the system), they could provide resources for the reorganisation phase [38,45]. In the future, an increase in the global hazelnut production can be expected, given the growing trend observed in the last few years [21]. This factor will play a role in shaping the future resilience of the system, also depending on the economic dynamics of other major producers (especially Turkey).

4.6. Improving the Resilience of the Farming System

Several factors emerged from the workshop as contributing to the past and present system's resilience, thus they can be expected to play a role in further improving it. Mechanisation is one of the most important of them. It made hazelnut farming less physically demanding, particularly with regard to harvesting (the most intense phase of the process), thus reducing the harvesting costs [26]. As it emerged from the workshop, this has had a positive effect in terms of production, quality, profitability, and attractiveness for young people. Another element improving past and present resilience is the strong social organisation in the system, which was mentioned in the workshop as increasing farmers' bargaining power with the industry. The focus on quality could play a role in enhancing system resilience, but the benefits of quality production for the system are unclear. The definition of the "Tonda Gentile Romana" under the PDO scheme, as well as the inclusion in the local brand "Tuscia Viterbese" for traditional products of the province, are often mentioned in literature as a strength of the system [20,26,62]. However, while the inclusion in a protected denomination scheme has had a strong positive impact in other hazelnut systems in Italy (particularly in Piedmont), the same benefits might not occur in all systems. In Viterbo, the lack of local processing industries and of local traditional products based on hazelnuts reduces the impact of the PDO trademark, as hazelnuts are processed by big confectionary industries outside of the system [22]. Apart from the strategies that

were implemented in the past, the participants in the workshop, as well as in related interviews and surveys [5,63], stressed the importance of developing local processing activities in the future, so that the added value of the product could be retained in the system. This is supported in the literature: Franco et al. [23] suggest that in the areas of the Viterbo province where the local economy mainly depends on hazelnut production, policy measures should be taken to promote vertical integration, bringing the value chain at the local level. This would, in turn, increase the local concentration of marketing activities, both for the national and international market [22,23].

The implementation of the above-mentioned strategies in the future would probably reinforce the robustness and the strong economic role of the system, but it would not improve the other resilience capacities nor strengthen the coupling with natural resources. In contrast, enhancing system diversity could improve system resilience in the long term [52,53]. Moreover, according to the workshop results, an increase in adaptability and transformability can be achieved by focusing on shared strategies.

5. Conclusions

The objective of this study was to perform a participatory assessment of the sustainability and resilience of the Viterbo hazelnut farming system. The methodology proved to be overall successful in providing the points of view of different stakeholders, thus constructing an overview of the locally-perceived system sustainability and resilience. The system is very specialised, and it has a strong economic and productive role, but it seems to overlook and properly maintain its natural resources. This would suggest a relatively low environmental sustainability of the system, particularly in relation to issues such as groundwater depletion due to irrigation and use of chemical inputs. However, more quantitative data would be necessary to complement the participants' perceptions and to draw sound conclusions on the environmental impact of hazelnut farming. Looking at resilience, the system seems to be mainly robust, whereas its adaptability and transformability appear to be lower. The system is mainly efficient in its productive and economic role; the reduced diversity would suggest a lower resilience, partially compensated by a high level of redundancy and heterogeneity. The system seems to be located in the conservation phase of the adaptive cycle, and several elements suggest that it is close to a release. Nonetheless, some of the characteristics of the system (i.e., high innovation, high economic reserves) could enable it to extend the conservation phase, or to successfully reorganise after a release.

The obtained results can be used to support recommendations for policy measures fostering system resilience and sustainability, for several reasons. First of all, the methodology allowed to identify aspects and dimensions of resilience and sustainability in which policy interventions are more needed, and thanks to the participatory nature of the approach, a shared vision could be reached on these interventions. More specifically, a need for improved environmental sustainability was acknowledged, in contrast with a good performance in the economic and social dimensions, and improvements in the system's adaptability and transformability were also deemed necessary. Additionally, the assessment showed which resilience attributes can potentially improve adaptability and transformability, especially thanks to the decomposition of the attribute score in the components "presence" and "impact". This information can be used to plan policy interventions targeting specific attributes. Given the limited resources for policy interventions, we suggest to further study and foster those attributes with current low presence but high potential impact for improving adaptability and transformability. In the case of hazelnut production in Viterbo, this would imply more attention for having production coupled with local and natural capital, improving functional diversity, and increasing the system's exposure to mild shocks and stresses.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Challenges for the Viterbo hazelnut farming system. Classified as shocks and long-term pressures, and as economic, environmental, institutional, and social challenges.

Challenges	Economic	Environmental	Institutional	Social
Shocks (permanent and non-permanent)	Hazelnut price volatility	Spring frost	Payment delays from RDPs (Rural Development Programmes)	
	Volume of Turkish production	Drought	Processors' strategic decisions (for vertical integration)	
	Turkish economic conditions (e.g., policies, exchange rate)	Hail	Binding local environmental regulations	
		Pests and diseases		
		Heat-related issues (e.g., sterility, fruit development)		
Long-term pressures	Expansion of hazelnut cultivated area, in Italy and worldwide	Climate change		Increasing societal awareness on environmental issues (e.g., pollution from agrochemicals)
	Market power of the confectionary industry	Depletion of groundwater resources		

Table A2. List of 13 resilience attributes, with a short explanation and the related processes and principles. From Reidsma et al. [39].

Attribute	Explanation	Process	Principle
Reasonably profitable	Farmers and farm workers earn a viable wage while not depending heavily on subsidies.	Agricultural production	System reserves
Coupled with local and natural capital (production)	Soil fertility, water resources and existing nature are maintained well.	Agricultural production	System reserves
Functional diversity	There is a high variety of inputs, outputs, income sources and markets.	Risk management	Diversity

Table A2. *Cont.*

Attribute	Explanation	Process	Principle
Response diversity	There is a high diversity of risk management strategies, e.g., different pest controls, weather insurance, flexible payment arrangements.	Risk management	Diversity
Exposed to disturbance	The amount of year to year economic, environmental, social or institutional disturbance is small (well dosed) in order to timely adapt to a changing environment.	Risk management	Openness
Spatial and temporal heterogeneity (farm types)	There is a high diversity of farm types with regard to economic size, intensity, orientation and degree of specialisation.	Farm demographics, Risk management	Modularity, Diversity
Optimally redundant (farms)	Farmers can stop without endangering continuation of the farming system and new farmers can enter the farming system easily.	Farm demographics, Risk management	Modularity
Supports rural life	Rural life is supported by the presence of people from all generations, and also supported by enough facilities in the nearby area (e.g., supermarkets, hospital, shops).	Farm demographics	System reserves
Socially self-organised	Farmers are able to organize themselves into networks and institutions such as co-ops, community associations, advisory networks and clusters with the processing industry.	Governance	Tightness of feedbacks
Appropriately connected with actors outside the farming system	Farmers and other actors in the farming system are able to reach out to policy makers, suppliers and markets that operate at the national and EU level.	Governance	Tightness of feedbacks
Infrastructure for innovation	Existing infrastructure facilitates knowledge and adoption of cutting-edge technologies (e.g., digital).	Governance, Agricultural production	Openness, System reserves
Coupled with local and natural capital (legislation)	Norms, legislation and regulatory frameworks are well adapted to the local conditions.	Governance, Agricultural production	System reserves
Diverse policies	Policies stimulate all three capacities of resilience, i.e., robustness, adaptability, transformability.	Governance	Diversity

Appendix B

This Appendix reports the digitalised versions of the participants' drawings of the past indicator dynamics, with short explanations.

Appendix B.1. Gross Saleable Production

The first group of participants sketched the dynamics of the indicator "Gross Saleable Production" (combining production quantity, quality, and prices) between 1981 and 2018 (Figure A1). After an initial fast increase in the indicator, determined by machinery development, the first interventions for quality standardisation stabilised the indicator between the early 1980s and the year 1990. Then the opening of the Turkish market caused a significant drop. A further development of mechanisation in 1993 (self-propelled machinery) determined an increase, quick at first and then steadier from the middle 1990s. This constant increase continued until 2014, maintained by several factors: a crisis of the industrial district, leading to an increase in investments in hazelnut farming; the launching of RDP tenders; the incoming of big confectionary industries, associated with the introduction of strict qualitative parameters. The peak in 2014 was determined by a frost in Turkey, which determined a price peak in Italy and an increasing interest for the hazelnut sector. With the recovery of the Turkish market and an increase in production costs, the Gross Saleable Production went back to the previous trend.
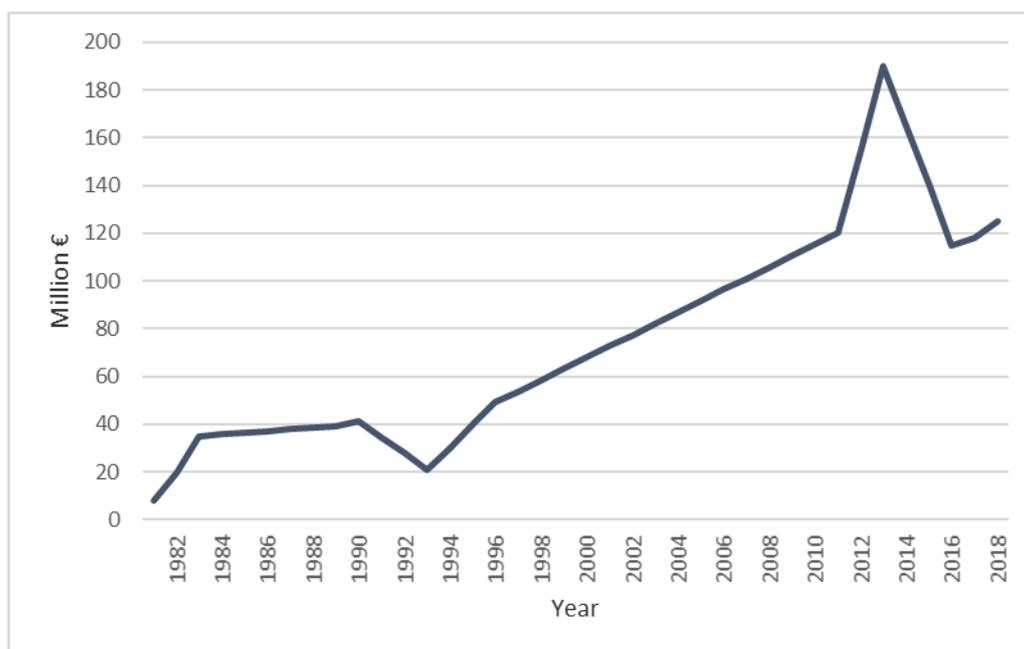

Figure A1. Dynamics of the Gross Saleable Production (combining hazelnut production, hazelnut quality, price evolution) from the year 1981. Values were indicated by the participants for the years 2000 (68 million €) and 2018 (125 million €).

Appendix B.2. Gross Margin per Hectare

The second group sketched the dynamics of "Gross Margin per hectare" between 1990 and 2018 (Figure A2). The indicator had the lowest point in 1993, as the incoming of the Turkish production on the market caused the initial decreasing trend. Starting from 1993, a fast machinery development determined an increase in the Gross Margin, which became faster with the Common Agricultural Policy (CAP) incentives in 2004. Around 2014 the Gross Margin had a peak, due to a frost in Turkey, and afterwards, the price was stabilised by the incoming of a big multinational industry. The only values indicated on the drawing were 100 and 200, but since no unit was reported, they were probably

intended as indicative values. For this reason, in the digitalised graph, the units are not specified on the vertical axis.
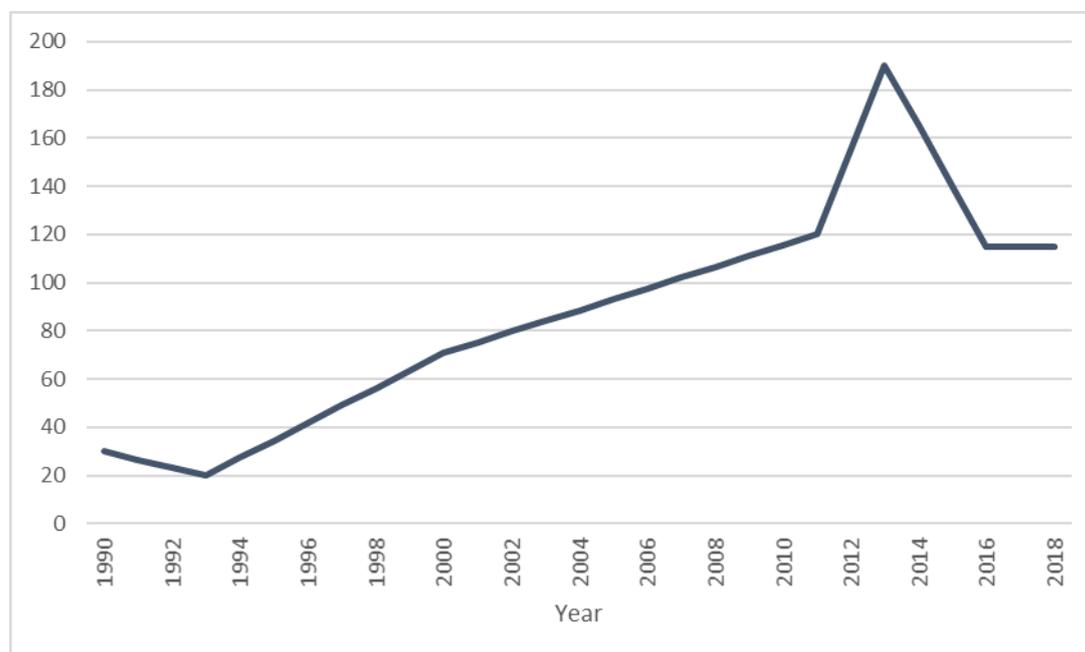

Figure A2. Dynamics of the Gross Margin per hectare from the year 1990. Values based on the participants' drawing (units on the vertical axis were intentionally omitted, due to unclarity in the original drawing).

Appendix B.3. Number of Organic Farms

The third group described the dynamics of "Organic cultivated area". They took 1000 ha as an initial reference number, and then showed the dynamics of the indicator in relation to it without specifying other values. They also showed the dynamics of the related function "Biodiversity and habitats". Between 2000 and 2007, the organic area had a slightly growing trend, mainly connected to the launching of tenders for organic production (Figure A3). Between 2007 and 2012, the indicator was generally lower but oscillating, caused by the fact that the RDP started operating and therefore, the organic area depended on funding availability: according to the participants, organic areas in Italy tend to expand at the end of the tenders, when financial resources become available for organic production and farmers can apply for funding. Around 2012, the rise of the indicator was determined by a frost in Turkey, which led to an increase in the investments in hazelnuts in Viterbo and to the establishment of new plantations. At the same time, a big multinational company entered in the production chain, due to the positive price peak. In order to expand the areas, many farmers used the funding from the RDP for organic production, thus determining an increase in the organic area. Since the organic expansion was associated with a general expansion of monoculture, biodiversity showed a general decreasing trend, which became stronger from 2012.
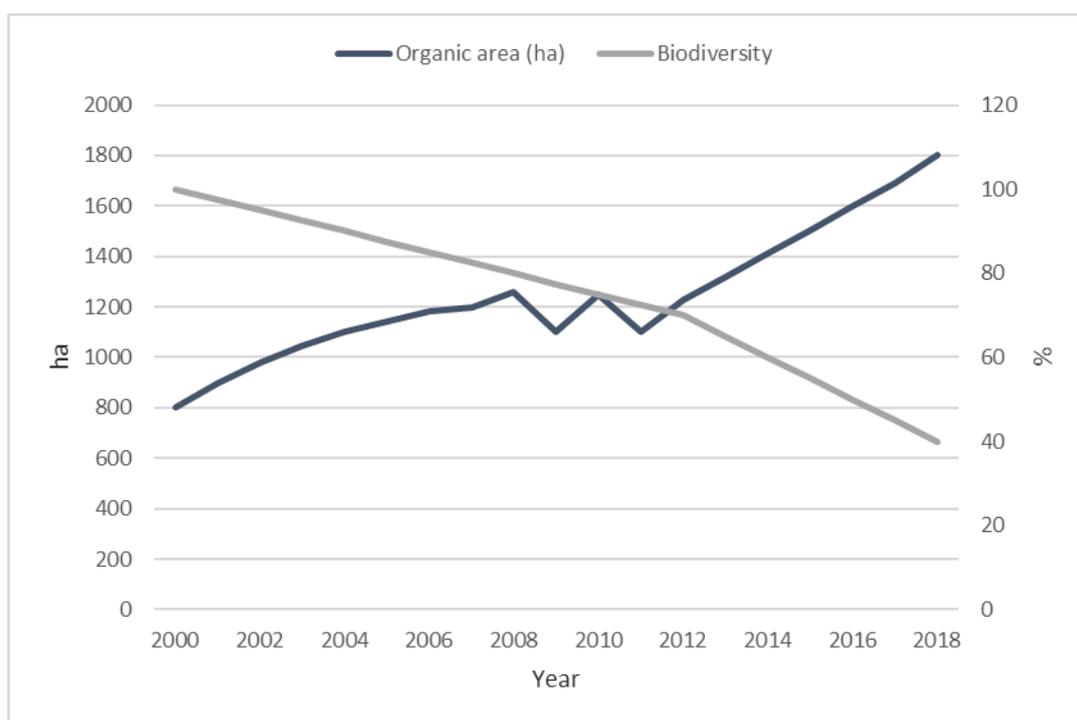
Figure A3. Dynamics of the organic cultivated area and biodiversity since the year 2000. The only value indicated by the participants was 1000 ha as a reference for the period until 2012. For biodiversity no value was indicated, therefore the graph is based on a relative scale, with the level in the year 2000 considered as 100%.

Appendix B.4. Retention of Young People in the Area

According to the fourth group of participants, the retention of young people was stable over time (Figure A4), as most young people remained in the area. From 2000 onwards, the hazelnut value chain generated many jobs, allowing to include more skilled labour in the system. Together with mechanisation, which helped to make hazelnut farming more attractive to the youth, this strategy prevented the outmigration of young people. The group argued that, until the present, there has been a good generational renewal in the area, with young farmers taking the lead of their family farms. The group also drew a hypothetical dynamic of the indicator, under the scenario of the complete disappearance of hazelnut farming: in this case, the retention of young people would have decreased over time, because the system has become so specialised that other activities which used to be important have disappeared. The current economy of the area has a very low diversification; therefore, it would be difficult to find new strategies.
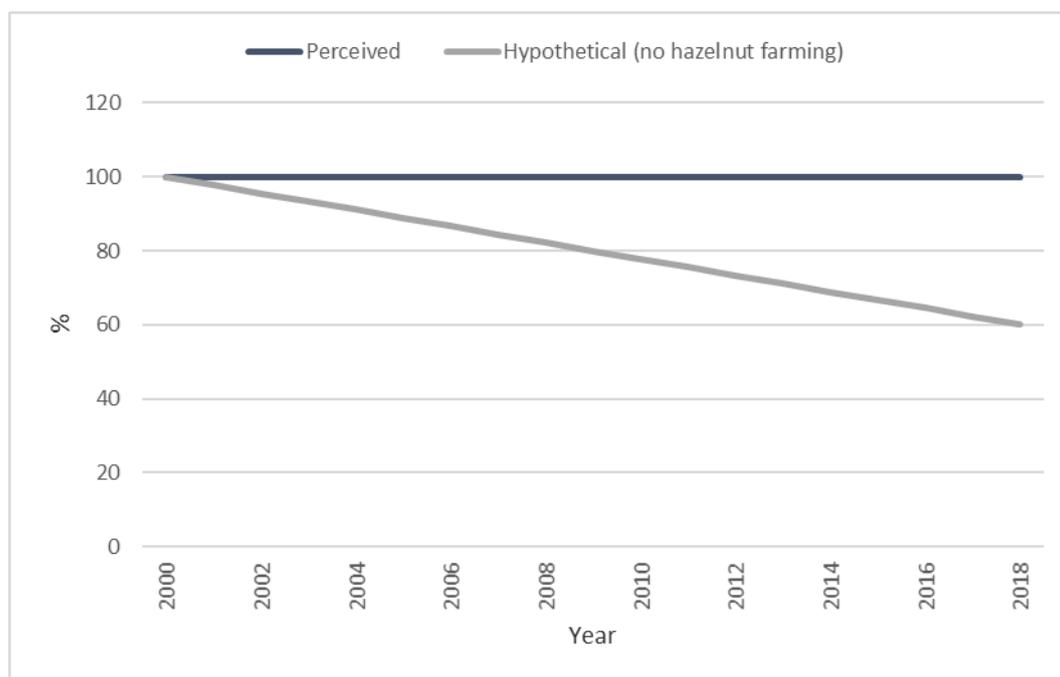
Figure A4. Dynamics of the retention of young people in the area from the year 2000, perceived and hypothetical (under the scenario of no hazelnut farming). Relative scale, the level in the year 2000 is considered as 100%.

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