



Article

Integrated Methodologies (SWOT, TOWS, LCA) for Improving Production Chains and Environmental Sustainability of Kiwifruit and Baby Kiwi in Italy

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Abstract: Italy’s kiwifruit growers are considered to be world-leading players of the past 20 years. However, with this success come its challenges. In the last five years, a bacterial canker of kiwifruit known as *Pseudomonas syringae* pv. *actinidiae* (Psa) has caused a dramatic reduction in the size of the areas cultivated, leading to several experienced Piedmontese *Actinidia deliciosa* growers beginning to cultivate the *A. arguta*. To better understand the potential for replacing the common kiwifruit in Italy’s Piedmont region with plantations of *A. arguta* and to attain a systematic approach and support for decision situations; we assessed the environmental impact of the two production chains (field and storage) from a technical-operational perspective. The assessment was conducted through interviews with producers, field and warehouse technicians and sales managers in order to reveal the strengths and weaknesses of the two systems. The work presented below considers the application of the Life Cycle Assessment (LCA) method for the field system (two different phases of the plantation) and the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis for the entire supply chain (field and warehouse management). Finally, a TOWS analysis (Threats, Opportunities, Weakness, Strengths) integrated the results of both LCA and SWOT analyses and permitted to highlight the development strategies for *A. arguta* in Piedmont. The total orchard cycle for *A. arguta* presents an impact of 0.14 kg CO₂ eq (GWP) and for *A. deliciosa* an impact of 0.11 kg CO₂ eq (GWP). Based on the synthesis of results from our TOWS analysis, we identified the following development strategies to help to shape the future *A. arguta* supply chain in Piedmont: Large-scale oriented; Berry fruits oriented; Export and organic oriented and Niche oriented.

Keywords: *A. deliciosa*; *A. arguta*; life cycle assessment (LCA); SWOT analysis; TOWS analysis; strategies

1. Introduction

Actinidia is a genus of berry-bearing shrubs and vines native to East Asia. In the first half of the twentieth century the cultivar ‘Hayward’ of *Actinidia deliciosa* (A. Chev.) Liang and Ferguson, was developed in New Zealand and still accounts for more than 90% of the total international market volume of kiwifruit. The global production of commercial kiwifruit now exceeds 2.4 million tonnes a year. China produces about half of the total international production, but only 1% of its volume is destined for export. Italy, New Zealand, Chile and Greece are jointly responsible for about 80% of all kiwis produced outside of China with most of their fruit destined for export [1]. A small part of the world production is made up of golden kiwifruit (*A. chinensis* Planch.). ‘Hort 16 A’ and ‘Jintao’ are the yellow-fleshed cultivar currently present on the market. They are protected cultivars, meaning that their cultivation is restricted to license holders. The marketing of the fruit is controlled by a consortia.

Other yellow-fleshed selections are likely to become important. They differ from green-fleshed *A. deliciosa* by having smooth skin, yellow-coloured flesh and lower storage stability. Other *Actinidia* species are of minor economic importance, including the hardy kiwi *A. arguta* (Siebold and Zucc.) Planch. ex Miq., also referred to as kiwi berry, baby kiwi or cocktail kiwi [2]. The hardy kiwifruit is clearly smaller than *A. deliciosa* and *A. chinensis* fruit and grows only to the size of dessert grapes. Its skin is thin and smooth and, depending on the variety, may be green, brown or purple. Hardy kiwifruit can be eaten whole with the peel included. Its short shelf life limits the commercial potential, but the plants have gained increasing popularity in the last five years. A major factor contributing to the popularity of hardy kiwifruit is its aroma [3].

Another factor that contributes to the successful expansion of the cultivation of *A. arguta* is that, following experiments, it has been included in the group of species (*Leiocarpae-A. macrosperma*, *A. valvata*, *A. polygama*, *A. melanandra*) which have shown resistance to (or tolerance of) *Pseudomonas syringae* pv. *actinidiae* (Psa) [4]. One of the most recent problems at the international level linked to the cultivation of kiwifruit has been the spread of the PSA bacteria, which causes kiwigreen bacterial canker. PSA first occurred in Japan in the 1980s [5] with subsequent isolated outbreaks in South Korea [6] and Italy [7]. From 2008–2011 there was a rapid spread of the PSA bacterial canker [8,9] due to dissemination between the plantations caused by bacterial exudates, formed by cankers during the autumn-winter seasons and often carried by wind [10–12].

This situation has led to a drop in production and invested surface of the classic varieties, particularly in the production of *A. chinensis* (Hort 16 A) in New Zealand, where it significantly declined from 92,200 tonnes in 2010 to 37,500 tonnes in 2013. Bacteriosis also concerns other important producer countries and has interrupted international production growth of kiwifruit. For example, from 2008 to the present day, Italy reduced the invested surface and led to a decline in production between 2010 and 2013 of about 15% [13]. The situation is slowly recovering today, with about 25,000 hectares of *Actinidia* cultivars cultivated in Italy. To mitigate PSA in Italy's Piedmont region, around 1,000 hectares of plantations have been cut down in the last five years. This action was declared in the recent Regional Plan of Action, a decree passed in 2013 by the Italian Ministry of Agriculture [14].

At the moment, international research is exploring solutions that producers can implement in the short term. On one hand, a series of products such as copper-based compounds, plant extracts and biological control agents (BCAs) are being tested in vitro, in greenhouse and in the field [15,16]. As highlighted, it is hoped that a combined strategy can be found which will consider the treatment and correct management of pruning (including the disinfection of tools and the protection of pruning incisions), fertilization and irrigation [17].

Research is also being pursued in other directions such as photo-selective nets being tested in Italy and plastic canopies on trial in New Zealand [18]. In New Zealand, particular attention is paid to obtaining and cultivating new varieties as Gold 3 and Gold 9 [18].

Although no information on the differences in susceptibility of new cultivars of kiwi or other species of kiwi has been released up to now, in all the research relating to the resistance/susceptibility of the different species of *Actinidia*, *A. arguta* is discovered to be the least affected by bacterium canker, both in Europe and in New Zealand [19]. This is why one of the alternative proposals to *Actinidia deliciosa* in Italy could be the cultivation of *A. arguta*.

Today, two new commercial kiwi cultivars, 'Hortgem Tahī[®]' and 'Hortgem Rua[®]', are being grown in Italy, France and Portugal. They have been sold in European retail stores under the Nergi[®] brand since 2013. The challenge is to have similar plantations from an operational point of view but with kiwis that are very different from the common species (*A. deliciosa* and *A. chinensis*), namely *A. arguta* kiwis that are smaller (max. 15–20 g), bright green and smooth so that they can be eaten whole, without peeling, a lot like berry fruits.

To better understand the potential for replacement of the common kiwifruit in Piedmont with plantations of *A. arguta* and to attain a systematic approach and a support for decision making,

we assessed the environmental impact of the two production chains (field and storage), also from a technical-operational perspective.

The assessment was conducted through interviews with producers, field and warehouse technicians and sales managers in order to reveal the strengths and weaknesses of the two systems. The work presented here considers the application of the Life Cycle Assessment (LCA) method for the field system (two different phases of the plantation: young plants and adult plants in full production) and the SWOT analysis for the entire supply chain (field and warehouse management). The combined interpretation of the results with the TOWS analysis, different arrangements of the words Strengths, Weakness, Opportunities and Threats compared to SWOT analysis, permitted to highlight the development strategies for *A. arguta* in Piedmont. The ability of SWOT is the matching of specific internal (strengths and weaknesses) and external (threats, opportunities) factors, which provides a strategic matrix (Wehrich 1982) [20]. It is essential to note that the internal factors are within the control of the *A. arguta* system, such as field operations, marketing, and other areas. On the other hand, the external factors are out of the system’s control, such as the macroeconomic and political factors, new technologies, and competition [21]. The interpretation of the TOWS matrix, permitted to develop alternatives strategies on the basis of relationships between threats, opportunities, weaknesses and strengths indicated from SWOT [22] including, between the internal factors the impacts obtained by LCA analysis. Figure 1 shows the flowchart used in conceptual framework.

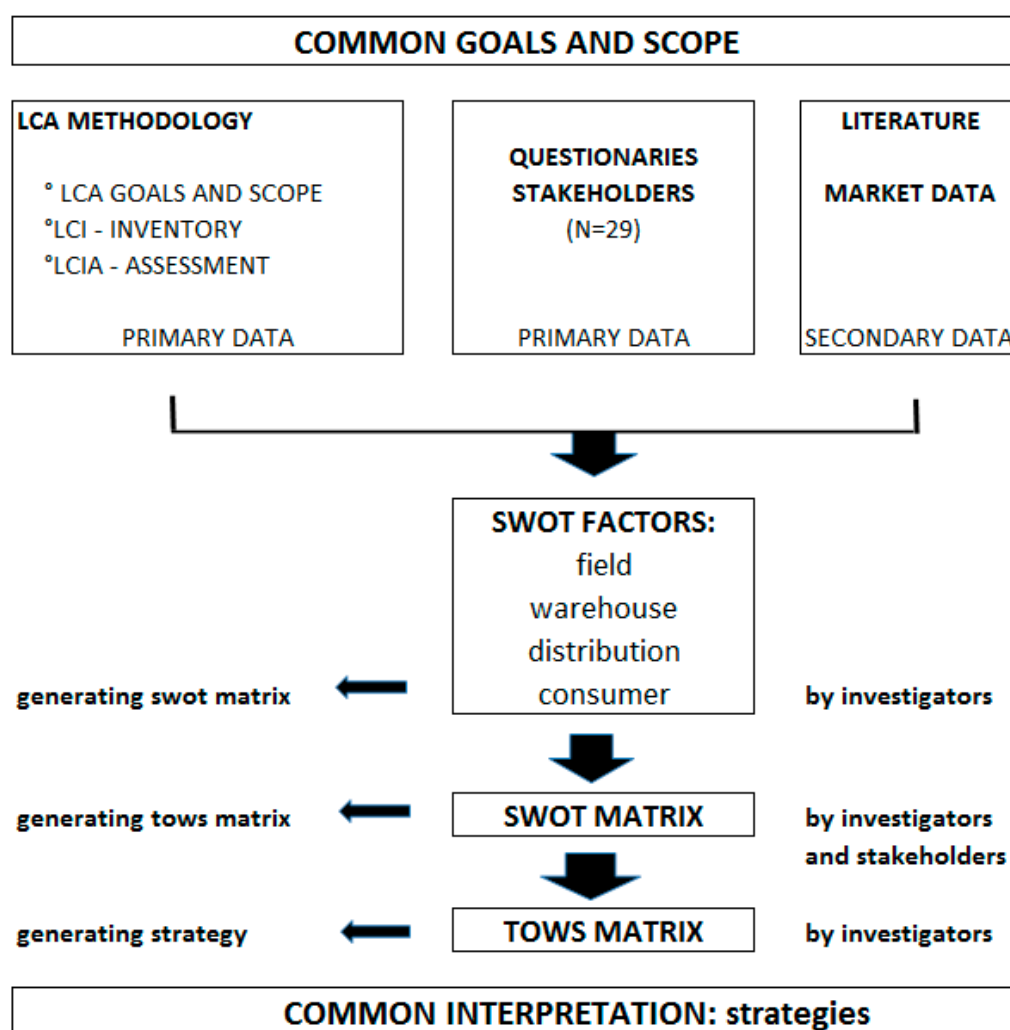


Figure 1. Flowchart conceptual model.

2. Materials and Methods

It is necessary for all stakeholders, from primary producer to buyer, to be involved in the processes related to strategic planning for the kiwifruit industry. This includes identifying current and potential issues. To achieve this, it is important to identify appropriate tools. Thus, after defining the common goal and scope among stakeholders, a performance assessment was conducted based on the parallel application of the Life Cycle Assessment (LCA), SWOT and TOWS analyses with a common purpose but applied independently. To achieve this aim, the study pursued two paths starting in 2015.

The first path developed a quantitative analysis evaluating the efficiency of the agricultural and warehouse system in terms of environmental sustainability with the LCA approach. The second step involved a qualitative analysis through semi-structured interviews. In total, 29 questionnaires (administered to producers and other stakeholders) were filled out during face-to-face interviews and on-site visits. The interviews included questions about field production, warehouse management and sales management.

2.1. Geographical Context

Regarding production and dissemination of kiwifruits throughout Italy, Piedmont is the second largest region after Lazio, with approximately 5300 hectares distributed throughout the provinces of Cuneo and Turin, and accounting for over 20% of Italian production [13]. With 10,800 fruit farms, Piedmont's fruit production occupies an area of 51,273 hectares, representing 5% of the region's total agricultural land and weighing 15% in terms of production at basic prices (480 million euro estimated in 2007) [23]. Piedmont is strongly specialized in exports, providing approximately 40% of all kiwifruit production in Italy (the rest coming from the Lazio region and Southern Italy).

In terms of territorial characteristics, the climate is continental both in the plains and in the hills; winters are cold (with temperatures falling to $-10\text{ }^{\circ}\text{C}$) and long, while summers are hot (up to $+35\text{ }^{\circ}\text{C}$) and short. Rainfall is concentrated mainly in the spring and autumn (annual average 1114 mm) [24].

2.2. LCA Goal and Scope

The life cycle assessment (LCA) method was applied to this work and followed the guidelines of the International Organization for Standardization (ISO)'s 14040:2006 (ISO 2006). The LCA method has also been successfully applied in farming and agri-food systems [25–28].

The aim of this LCA was to assess the environmental impact of the production of 1 kg of *A. arguta* (cv 'Hortgem Tahī[®]' and 'Hortgem Rua[®]') and the production of 1 kg of *A. Deliciosa* (cv Hayward), in the field phase (I input, Figure 2) and in the field + warehouse phase (II input, Figure 2).

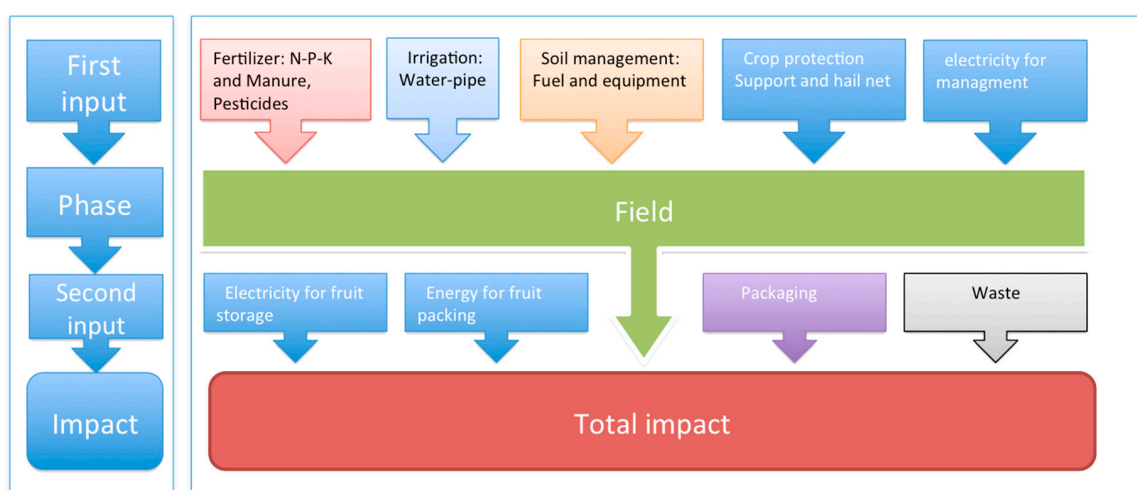


Figure 2. Impacts diagram for the production of *Actinidia arguta* and *Actinidia deliciosa*.

The impacts of the entire field cycle were calculated for both crop species, taking into consideration the young phase of the field and then added to the subsequent adult productive phase [29,30].

For both crop species, the young phase lasts 4 years and the productive phase lasts 20 years (for a total cycle of 24 years). Regarding *A. deliciosa*, a production level of 10 t ha⁻¹ in the young phase and of 20 t ha⁻¹ in the productive phase was considered. For *A. arguta* the production levels considered were 7.5 t ha⁻¹ in the young phase and 15 t ha⁻¹ in the productive phase (grower's data).

This approach is based on the principle that the fruit sold can come from both the young and adult phases. This means that kiwifruits can come from a determined production phase of the field proportionate to the yield accumulated during that phase [30].

The impact on the entire life cycle (calculated using the Orchard cycle impact, Equation (1)) was obtained by weighing the various phases in relation to production (Yield contribution, Equation (2)) and was calculated as follows:

$$\text{Orchard cycle impact}_{j,k} = \sum_{i=1}^2 \text{impact}_{j,k,i} \times \text{yield contribution}_{k,i} \quad (1)$$

With the weighting factor "yield contribution":

$$\text{yield contribution}_{k,i} = \frac{\text{lifespan}_{k,i} \times \text{yield}_{k,i}}{\sum_{i=1}^2 \text{lifespan}_{k,i} \times \text{yield}_{k,i}} \quad (2)$$

whereby:

- $\text{impact}_{j,k,i}$ = annual median impact per kg for orchard production phase i , impact category j and production system k ;
- $\text{yield}_{k,i}$ = median yield obtained in orchard production phase i and production system k ;
- $\text{lifespan}_{k,i}$ = lifespan of orchard production phase i and production system k .

2.3. Life Cycle Inventory (LCI)

System Boundaries and Data Collection

The data used to carry out the field LCA were acquired through questionnaires filled out by 20 producers from 2015 to 2016. They all belonged to a producers' organisation located in Piedmont and produced both kiwifruit species. In addition to the interviews with producers, the field-books of each farm were analysed to quantify the resources used in cultivation. This permitted the study to obtain data from an average area of about 70 ha for both crops. In the case of *A. arguta*, this surface represents the totality of hectares currently in production. Regarding the aspects linked to the nursery phase, the figures were acquired from two plant nurseries which supply the plants to the farms. The information relating to the post-harvest phase was supplied by technical staff (3 people) of the fruit warehouse where the product is processed (Table 1).

Table 1. Principal inputs involved in the analysis of the field production and distribution chain for *A. arguta* and *A. deliciosa*.

Phase	Operation or Input	<i>A. deliciosa</i>		<i>A. arguta</i>	
		Material or Machine		Material or Machine	
Nursery	Rooting	Substratum	300 L ha ⁻¹	Substratum	300 L ha ⁻¹
	Mulching	Black PE	400 kg ha ⁻¹	Black PE	400 kg ha ⁻¹
	Covering	White PE	6.7 kg ha ⁻¹	White PE	6.7 kg ha ⁻¹
	Covering	Metal supports	7.5 kg ha ⁻¹	Metal supports	7.5 kg ha ⁻¹
	Fertigation system	PVC piping	46 kg ha ⁻¹	PVC piping	46 kg ha ⁻¹
	Fertigation system	PVC tubing	46 kg ha ⁻¹	PVC tubing	46 kg ha ⁻¹
	Fertigation	Compost mix	300 kg ha ⁻¹	Compost mix	300 kg ha ⁻¹
	Fertigation	Water	40 m ³ ha ⁻¹	Water	40 m ³ ha ⁻¹
	Cold storage	Electrical energy	35 kWh m ³	Electrical energy	35 kWh m ³

Table 1. Cont.

Phase	Operation or Input	<i>A. deliciosa</i>		<i>A. arguta</i>	
		Material or Machine		Material or Machine	
Filet	Soil preparation	Plough or cultivator	1 h ha ⁻¹	Plough or cultivator	1 h ha ⁻¹
	Soil preparation	Harrow	1 h ha ⁻¹	Harrow	1 h ha ⁻¹
	Irrigation system	PVC piping	379.1 kg ha ⁻¹	PVC piping	379.1 kg ha ⁻¹
	Irrigation system	PVC tubing	52.8 kg ha ⁻¹	PVC tubing	52.8 kg ha ⁻¹
	Irrigation	Water	1440 m ³ ha ⁻¹	Water	1500 m ³ ha ⁻¹
	Base fertilization	Manure	40 t ha ⁻¹	Manure	50 t ha ⁻¹
	Fertilization	N	60 kg ha ⁻¹	N	60 kg ha ⁻¹
	Fertilization	P	30 kg ha ⁻¹	P	30 kg ha ⁻¹
	Fertilization	K	110 kg ha ⁻¹	K	120 kg ha ⁻¹
	Covering	hail net	600 kg ha ⁻¹	hail net	600 kg ha ⁻¹
	Covering	Wood supports	700 kg ha ⁻¹	Wood supports	700 kg ha ⁻¹
	Plant supports	Metal supports	300 kg ha ⁻¹	Metal support	300 kg ha ⁻¹
	Plant protection treatments	p.a.	2.5 kg ha ⁻¹	p.a.	1.5 kg ha ⁻¹
Total processes	Diesel consumption	400 kg ha ⁻¹	Diesel consumption	220 kg ha ⁻¹	
Post-harvesting	Refrigeration/storage	Electrical energy	0.33 kwh kg ⁻¹	Electrical energy	0.17 kwh kg ⁻¹
	fruit calibration	Electrical energy	0.006 kwh kg ⁻¹	Electrical energy	0.005 kwh kg ⁻¹
	Packaging	PE	0.02 kg kg ⁻¹	PE	0.019 kg kg ⁻¹
	Packaging	Cardboard	0.080 kg kg ⁻¹	PE bag	0.004 kg kg ⁻²

All the processes necessary for crop management and the post-harvest phase were considered, including the associated auxiliary processes, such as transportation of materials and the waste generated in each phase. The consumption phase and transportation from the point of sale (market) to the end consumer were not considered. However, the disposal of packaging materials was included in the analysis.

The main differences between *A. arguta* and *A. deliciosa* are summarized in Figure 3. Both are climbing lianas.

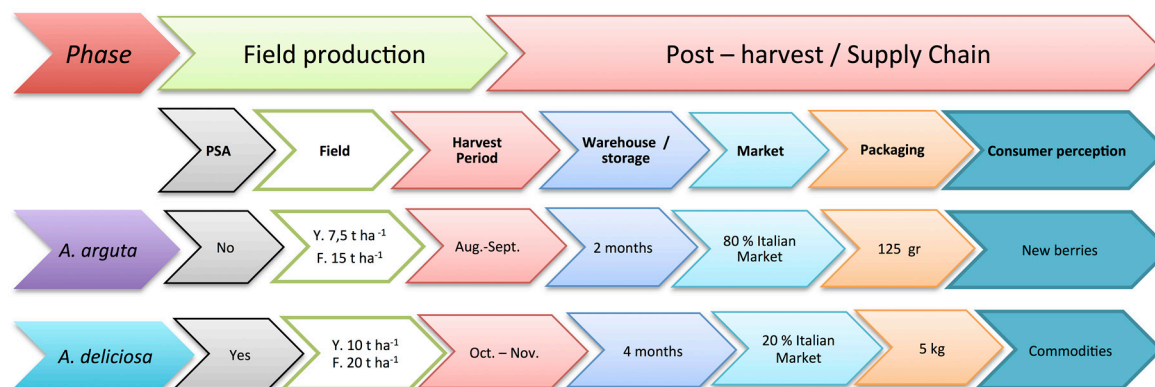


Figure 3. Principal differences in field production and warehouse from farm to fork management between *A. arguta* and *A. deliciosa*.

Some of the major differences between both species are the weight, skin type and harvesting seasons. In the case of *A. deliciosa*, the fruit has a hairy skin and an average weight of 100 g and has hairy, inedible skin. Conversely, the weight of *A. arguta* varies between 15 and 20 g and has smooth, edible skin. *A. deliciosa* is harvested in Piedmont in late October-early November. *A. arguta* is harvested in the first ten days of September. Both are harvested by hand, but for *A. arguta* the operators have to wear gloves to prevent damage to the fruit's skin. The fruit of *A. deliciosa* are placed in plastic bins with a volume of half a cubic meter (300 kg) before going to the processing warehouses (post-harvest) where they are kept for an average of 4 months. Then the fruit is calibrated, divided by size, and any imperfect fruit is discarded. The fruit of *A. arguta* is particularly delicate, so they are harvested into plateaux containing an average of 10 kg of product. After harvesting, the product is sent to the

warehouses, where they are calibrated and placed into PET punnets with lids (125 g) and kept for a maximum of 2 months, without being further handled.

2.4. Life Cycle Impact Assessment (LCIA)

The environmental footprint of the products and relative International Life Cycle Data (ILCD) develops through 16 categories of impact, as declared by Goossens et al. (2017) [30]. In our case, we based our selection of impact categories on literature [26,31,32] and focused our analysis on global warming potential (GWP) according to the Intergovernmental Panel on Climate Change (IPCC GWP 100a kg CO₂ eq), and non-renewable energy (MJ primary). The choice of these impact categories was related to the need of providing an impact evaluation of the examined production in relation to climate change that can be readily communicated and understood by stakeholders. The non-renewable energy source category was selected to provide a view of the impacts in relation to emissions and also to consumption; the latter is considered as one of the most critical issues in the primary sector.

To analyse the data collected during the Life Cycle Inventory, we used SimaPro 7.3 software and subsequent upgrades [33]. The software allowed the monitoring and analysis of the life cycles, systematically and transparently, following the ISO standards of the 14040 (2006) [34]. A cut-off was applied at the 2% mark and all of the data registering below this percentage were grouped together in the “other” category. The databases used for the inventory are present in Ecoinvent 2.2 and LCA alimentary DK [35].

2.5. SWOT and TOWS Analyses

Through recommendations made by international literature [36–40] we decided to use the SWOT analysis as an important base to think strategically about developing the *A. arguta* production chain in Piedmont. Analogously to Demont and Rutsaert (2017) [41] when elaborating the SWOT matrix, the favourable and unfavourable aspects were established regarding the development of *A. arguta* in the area, while distinguishing the internal (strengths, weaknesses) and external (opportunities threats) variables. To overcome the objections raised in relation to the use of the SWOT analysis [42] in its simplistic and subjective nature, primary data were collected by authors through field observations and in-depth interviews with key stakeholders. The data include meetings and questionnaires filled in by 10 producers of *A. arguta*, 10 producers of *A. deliciosa*, 3 technicians, 3 sales department managers and 3 mass retail buyers. Moreover, following the suggestions of Lozano and Valles (2007) [38], secondary data were collected from related publications and documents issued by the competent institutions (National Institute of Statistics, Fruit Growers Associations, Agriculture Ministry, Regional government of Piemonte). The official statistics on trends in production, market and consumption of kiwifruits, berry fruits and other general fruits in Italy and the world was also included in the analysis [1,16,43]. Lastly, sections in the SWOT matrix have been distinguished by field, warehouse, distribution and consumer, which represent the main steps of the Fresh Fruit Supply Chain [44].

After the creation of the SWOT matrix, the TOWS matrix was developed to provide alternative strategies on the basis of relationships between threats, opportunities, weaknesses and strengths indicated by SWOT [20]. The TOWS analysis can also be applied to the development of tactics necessary to implement strategies and to find more specific actions that support these tactics. The analysis examines threats and opportunities first, followed by weaknesses and strengths. According to Weihrich (1982) [20], TOWS involves four possible types of strategy:

1. WT strategies employ the principle of minimising both threats and drawbacks (Min–Min), reducing threats and overcoming shortcomings;
2. WO strategies use the principle of minimising drawbacks and maximising opportunities (Min–Max), decreasing weaknesses and using opportunities;
3. ST strategies use the principle of maximising strengths and minimising threats (Max–Min), strengthening advantages and averting risks;

- SO strategies use the principle of maximising both strengths and opportunities (Max–Max), enhancing merits and taking advantage of opportunities.

3. Results and Discussion

3.1. LCIA Field Production System

Table 2 lists the annual average impacts per kilogram of *A. arguta* and *A. deliciosa* within each orchard phase and the impact of the total field production cycle as represented by Goossens et al. (2017) [30]. The full production phase has the highest yield contribution while the young trees have the lowest yield contribution. Based on these yield contributions and on the annual average impact values, it is evident that the two orchard phases have contributed to the orchard cycle impacts in different ways. This affirms that the contribution of the young production phase to the orchard cycle impact is higher than the full production phase. This occurs for both species (*A. arguta* and *A. deliciosa*) although it is more evident in the case of *A. arguta*. The young production phase of *A. arguta* is 0.21 kg CO₂ eq (GWP) and the full phase is 0.13 kg CO₂ eq (GWP). With regards to the total orchard cycle, *A. arguta* presents an impact of 0.14 kg CO₂ eq (GWP) and *A. deliciosa* presents an impact of 0.11 kg CO₂ eq (GWP), both lower than that highlighted by Nikkhah et al. (2016) [45] in a case study from the Guilan province of Iran where npk fertilizer levels are higher. The greater impact of *A. arguta* also in terms of IPCC is due to the higher input for the disease protection of the crop [18]. For NRE, the situation is exactly the opposite because there is a higher impact for the cultivation of green-fleshed kiwifruits (2.86 MeJ). This data item can be traced back to the higher number of agronomical practices and plant treatments that have been carried out in the orchards to mitigate PSA bacterium [18]. It is worth noting that the young phase value is always higher than the full phase, similarly in the case of apples [30].

Table 2. Annual average impacts per kg di *A. arguta* and *A. deliciosa* within each orchard phase (young and adult) for the three impact categories under examination (global warming, non-renewable energy and Intergovernmental Panel on Climate Change (IPCC) global warming potential (GWP) 100a). The values between brackets for the young productive phases indicate how these phases perform compared to the full productive phase: positive values refer to the lower productive phase having a higher environmental impact than the full production phase, while negative values refer to a lower environmental impact for the young productive phase. The last column lists the impacts associated with a full orchard cycle.

Impact Category	Unit	<i>A. arguta</i>			<i>A. deliciosa</i>		
		Young Phase	Full Phase	Total Orchard Cycle	Young Phase	Full Phase	Total Orchard Cycle
Global Warming	kg CO ₂ eq	0.21 (+58%)	0.13	0.14	0.172 (+59%)	0.11	0.11
Non-renewable energy	MJ primary	3.58 (+65)	2.17	2.3	4.74 (+78%)	2.67	2.86
Ippc GWP 100a	kg CO ₂ eq	0.23 (+54%)	0.15	0.16	0.19 (+56%)	0.12	0.13

Figure 4 examines how the various crop inputs influenced the different impacts (A: non-renewable energy, B: global warming potential, C: IPCC GWP 100a). The main input is nitrogen fertilisation (15–20%) for both *A. arguta* and *A. deliciosa*, as already highlighted by Muller et al. (2015) [46] in a study performed in New Zealand. Another input from our study that has a consistent impact is water, accounting for about 20–25% for both species and for all impact categories. A study developed in Greece by Michos et al. [47] analyses production coefficient in field in term of energy (MJ ha⁻¹), indicate irrigation as having the one with the greatest impact (47.3%) in organic kiwifruit orchards.

From our system in Italy, the most consistent impact comes from the anti-hail system, consisting of numerous wooden supports and an anti-hail net. This situation reflects the outcome of numerous life cycle assessment (LCA) studies in fruit and vegetable species where the greenhouse structure is considered [26,48]. This protection is essential for Actinidia in order to guarantee high-quality production and to protect the plant against stress in case of hailstorms according to Muller et al. (2015) [46] chain (field and warehouse systems).

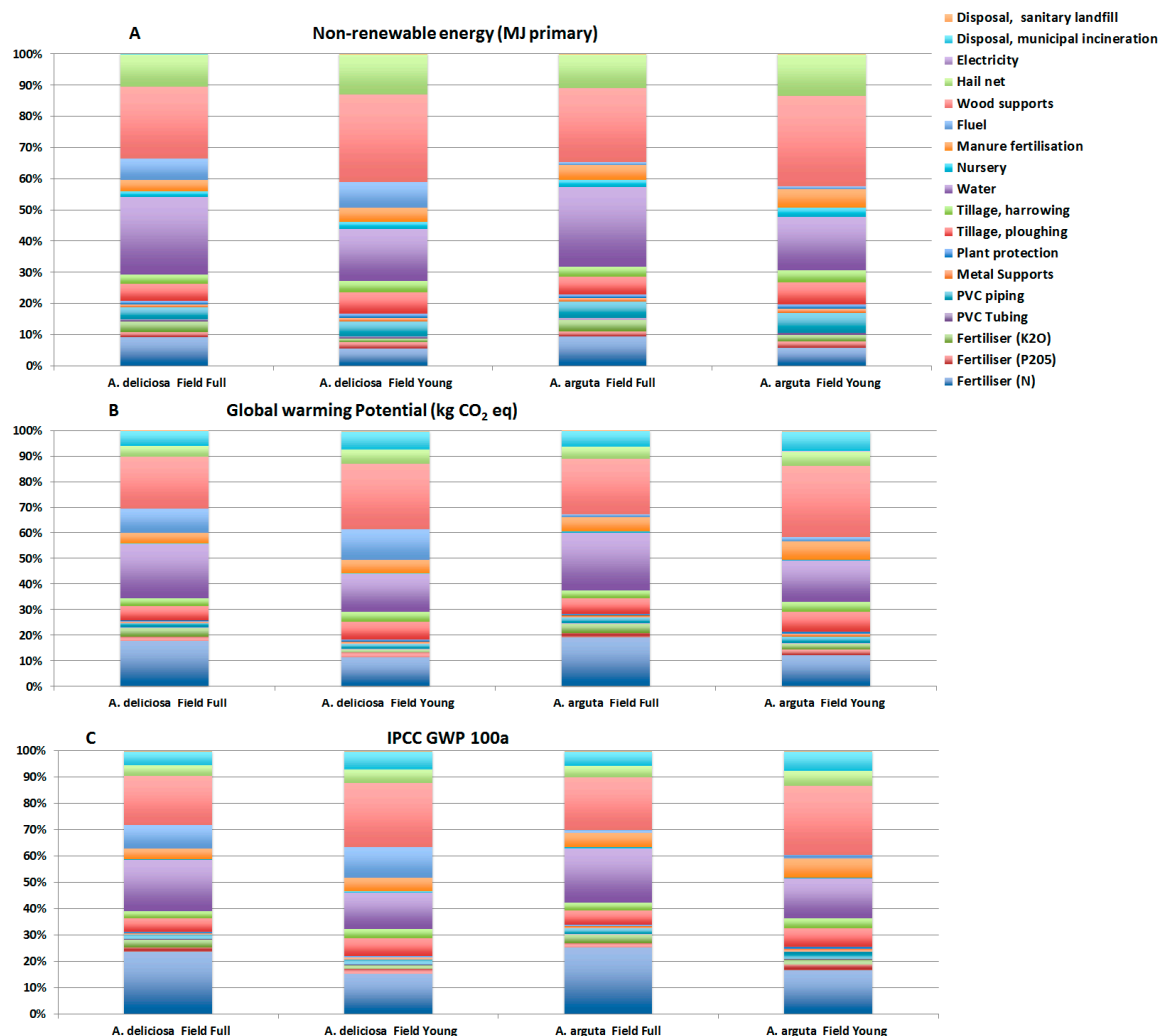


Figure 4. Orchard cycle impacts for producing 1 kg of *A. arguta* and *A. deliciosa*: relative contributions of 2 orchard production phases for each production system ((A): non-renewable energy; (B): global warming potential; (C): IPCC GWP 100a).

The results of the impact of the entire production phase (field + warehouse) are recorded in Table 3. Based on all three categories of impact (non-renewable energy, global warming potential (GWP), and IPCC GWP 100a), the *A. deliciosa* production chain shows higher values than *A. arguta*, and in line with New Zealand supply chain [49]. Analysing Figure 5 relating to the single inputs, it is interesting to note that in all the production chains and in every orchard cycle (young and full) the field phase covers 20% to 50% of impact of the entire chain. 50% refers to the input field in the case of the *A. arguta* young phase which, as already pointed out, presents very low yields. 20% refers to the *A. deliciosa* full phase.

Table 3. Annual average impacts per kg di *A. arguta* and *A. deliciosa* within each orchard phase (young and adult) plus the warehouse for the three impact categories under examination (global warming, non-renewable energy and IPCC GWP 100a). The values between brackets for the young productive phases indicate how these phases perform compared to the full productive phase: positive values refer to the lower productive phase having a higher environmental impact than the full production phase, while negative values refer to a lower environmental impact for the young productive phase. The last column lists the impacts associated with a full orchard cycle.

Impact Category	Unit	<i>A. arguta</i>			<i>A. deliciosa</i>		
		Young Phase	Full Phase	Total Orchard + Warehouse Cycle	Young Phase	Full Phase	Total Orchard + Warehouse Cycle
Global Warming	kg CO ₂ eq	0.39 (+23%)	0.32	0.33	0.53 (+13%)	0.47	0.48
Non-renewable energy	MJ primary	7.05 (+24%)	5.70	5.82	11.20 (+22%)	9.21	9.39
IPCC GWP 100 ^o	kg CO ₂ eq	0.42 (+22%)	0.34	0.35	0.56 (+13%)	0.50	0.50

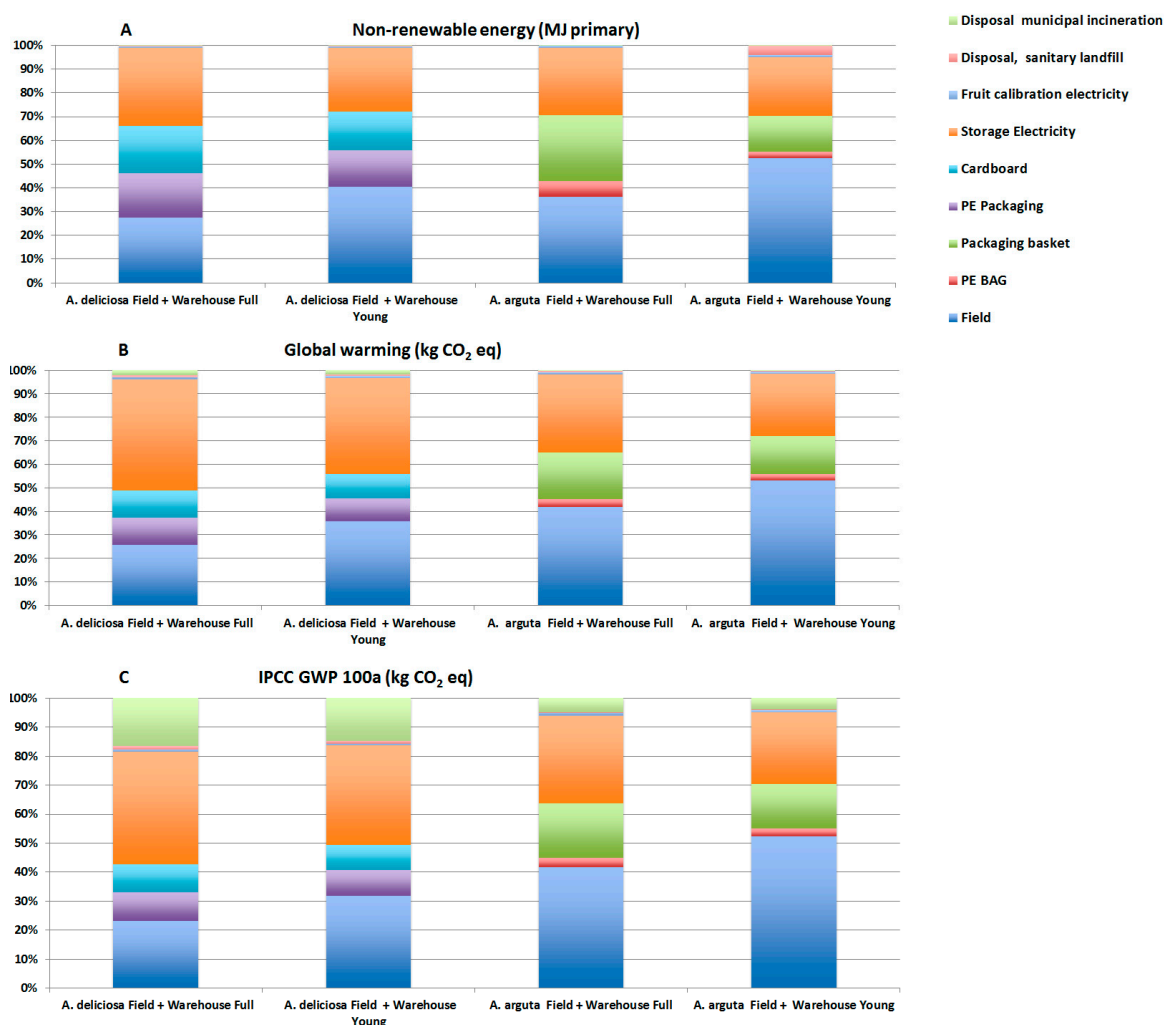


Figure 5. Field and warehouse impacts for 1 kg of salable product of *A. arguta* and *A. deliciosa*. ((A): Non-renewable energy; (B): global warming potential; (C): IPCC GWC 100a).

According to studies developed for Zespri® International Ltd. in Tauranga, New Zealand, energy use for pack-house and cooled store activities represents the highest input of about 45% for *A. deliciosa* [50].

Figure 5 also analyses how both crop inputs influence the various impacts (non-renewable energy, global warming potential, and IPCC GWC 100a). In the case of *A. arguta*, storage energy is a significant input (35%) but still lower than the field input (40%). Our study did not consider transportation to final markets because the assessment of the impacts is functional to the accomplishment of territorial strategies for the expansion of the *A. arguta* chain. The impact of packaging is not particularly high (20%) but could be further mitigated by replacing the materials used at present with bio-based materials [50,51]. In this case, packaging could be fundamental for an eco-branding strategy [52].

3.2. SWOT and TOWS Analyses

The basic parameters of the following SWOT analysis, which are common for this kind of research, are divided into the two general categories: internal and external [53].

The term strengths (internal factors) comprises of the subsidies and benefits that emerge in the cultivation of cv Thai® (*A. arguta*) vs. cv Hayward (*A. deliciosa*) [54]. Similarly, the weaknesses (internal factors) include the factors and elements that represent an obstacle for the development of a production chain of *A. arguta* in Piedmont.

The opportunities (external factors) represent the benefits and what happens generally in the Piedmontese kiwi production chain (*A. chinensis*, *A. deliciosa*, *A. arguta*). Lastly, the threats (external factors) contain the problems that arise and the potential obstacles to avoid for Piedmontese kiwifruits. This analysis generates a series of interesting issues which simplify the debate on future strategies.

In our case (Figure 6), the findings are analysed with separate consideration of the four Fresh Fruit Supply Chain steps (from farm to fork). The strengths, weaknesses, opportunities and threats are included in the point of the production chain where they have been reported by the stakeholders, and often influence the other steps.

3.2.1. Internal Parameters

Strengths

It is significant to highlight that there have been no reports of PSA bacterium and kiwi decline in *A. arguta*, unlike in *A. deliciosa* [4,10,55]. The answers from the stakeholders also show constant yields per hectare with *A. arguta* compared to consistent fluctuations in the production of *A. deliciosa* over the past 10 years. The sales turnover per hectare is much higher (+450%) for producers. Additionally, in the case of *A. arguta*, the cv. 'Hortgem Tahī®' analysed in the present study is a patented variety. Its production and sale are part of a European programme managed by the Nergi® Consortium, which protects farmers from the risks of supply market excesses [56,57].

Regarding warehouse storage, *A. arguta* allows for economies of scale if processing and conditioning take place using the technical equipment already used for other fruits in other seasons, such as berry fruits [58]. Moreover, the environmental impact is calculated using the life cycle assessment (LCA) method; the values in the overall production chain of *A. arguta* are lower than for *A. deliciosa* (-30% GWP) with reference to the energy consumption during storage. Stakeholders have also reported higher earnings due to easier placement within the European fruit market. A major strength of the *A. arguta* species for both warehouse and distribution is the possibility to provide quantities to market throughout the year. Additionally, the *A. arguta* supply chain has the possibility to exploit the expertise already developed by berry fruit producers. Certainly one of *A. arguta*'s main characteristic strengths is its ready-to-eat quality (small, smooth, ripe), which is considerably different from *A. deliciosa* [2,54]. Stakeholders have also emphasised that *A. arguta* belongs rightfully to the category of specialties, like berry fruits [36], giving it prioritised placement in the point of sale.









Fresh Fruit Supply Chain step	INTERNAL FACTORS	
	STRENGTHS	WEAKNESSES
 Field production	SF1 absence of warnings of PSA for <i>A. arguta</i> at world level SF2 constant yields SF3 sale turnover per hectare production value more elevate (+450%) SF4 existence of patented varieties (and relative association)	WF1 hectare production lower (-20%) WF2 higher harvesting costs (+500%) WF3 higher field LCA (+25%)
 Warehouse	SW1 lower field+warehouse LCA (-30%) SW2 economies of scale connected with berry fruits SW3 higher earnings	WW1 low maximum storage period (10 weeks) WW2 fruit harder to handle
 Distribution	SD1 easier volume planning SD2 expertise connected to berry fruits	WD1 lower presence in the market (10 weeks) WD2 difficult placement on mass retailer shelves
 Consumer	SC1 consumption ease (snack with smooth skin) SC2 perceived as a berry fruit (specialty)	WC1 consumption limitations if associated to berry fruits WC2 new and almost unknown product WC3 higher price for end consumer
Fresh Fruit Supply Chain step	EXTERNAL FACTORS	
	OPPORTUNITIES	THREATS
 Field production	OF1 organic production easy to implement OF2 varietal Innovation (breeding experimented by consortium)	TF1 PSA and kiwi decline TF2 increase of treatments could reduce the product sustainability TF3 spread of varieties with different color flesh (yellow and red)
 Warehouse	OW1 implementation of the storage technology (in order to improve shelf-life and increase quality standards)	TW1 post harvest pathologies
 Distribution	OD1 export oriented supply-chain with marketing expertise developed in the last 40 years	TD1 likely competition with other kiwi supply-chains with lower production costs (e.g. Greece)
 Consumer	OC1 growing consumption trend for "healthy products" OC2 increasing consumer attention for products' origin	TC1 consumer loyalty with "strong" brands TC2 brands with higher retention for all the year (365/365)

Figure 6. Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis of *A. arguta*.

Weaknesses

In the first stage (field), *A. arguta* retains lower unitary production volumes than *A. deliciosa* (−20%). Harvesting costs (labour + accessory costs) are much higher (+500%). The calculation of the *A. arguta* environmental impact with the LCA method are about 25% higher for GWP compared to *A. deliciosa*. In the second stage (warehouse), the limits highlighted by the stakeholders interviewed are twofold: short storage time and high predisposition to mechanical damage, which can make it harder to handle. For distribution operators, the limitations of *A. arguta* are mainly represented by a short sale period (2.5 months) and the difficulty in identifying the correct placement on the shelf [59]. At the third stage (consumption), challenges are represented by the lack of knowledge about the product. For example, customers tend to confuse *A. arguta* with other similar looking products such as olives. Furthermore, as with most specialty products, *A. arguta* could be considered unsuitable for everyday purchase due to its high price [60,61].

3.2.2. External Parameters

Opportunities

The characteristics of the kiwifruit production chain in Piedmont provide an easy opportunity for implementation of sustainable fruit farming models, namely organic production [62,63].

There are additional opportunities in the years to come based on outcomes of national and international breeding programmes that could lead to the cultivation of cultivar with different levels of sensitivity to PSA and kiwi decline [4]. As the level of technological innovation continues to improve, new post-harvesting technologies will be able to achieve improved storage times and overall quality of the fruits [64]. During the distribution stage, the expertise developed over the years by Piedmontese

distributors represents a positive aspect for further increase of exports in new markets like Russia, Brazil and India [23].

In the final step of the Fresh Fruit Supply Chain, the constant development and advocacy for “healthy products” represents a growth opportunity for the whole Piedmontese kiwifruit sector, as well as a greater attention payed by consumers to the origin of bought products.

Threats

Despite reporting a reduction in PSA bacterium outbreaks, the problem relating to this pathology and the kiwi decline is far from being solved by the replacement of *Actinidia* with other fruit species. Compared to the non-PSA growing seasons of the *Actinidia* variety in Italy, there has been a need in field management, to increase the use of pesticides to cope with increasingly critical situations with the consequent reduction of the system’s environmental and economic sustainability [46].

The arrival of new selections and cultivars on the market with different coloured flesh (yellow and red), as well as different soil and climatic requirements (new production areas), could lead to an increase in competition. Although technological innovation in recent years has limited post-harvest alterations during long-term storage, *Botrytis* and *Phyalophora* spp. still represent a threat and a real possibility to increase waste.

During the distribution stage, stakeholders in Piedmont have expressed concern that Piedmontese production can suffer due to competition of kiwifruits with lower production cost (e.g., Greek products). Lastly, the biggest challenge comes from consumers who often become loyal to international brands such as Chiquita® and Zespri® since Piedmontese products displayed in points of sale are often unrecognisable [65]. The presence of these international brands at point-of-sale shelves every day of the year limits opportunities for market growth of Piedmontese brands.

Results from the SWOT analysis can be used to develop the *A. arguta* system in Piedmontese strategies using the TOWS matrix (Table 4). Deciding on a strategy is important, especially when it comes to the marketing of products [66]. The TOWS matrix allows producers to use their strengths to take advantage of opportunities and avoid any potential threats [67]. They can use the opportunities to overcome weaknesses and develop a defence strategy to help minimize weaknesses and avoid threats. As described earlier in more detail, the strategies can be divided into 4 groups i.e., SO, ST, WO and WT (Table 4).

Table 4. Application of Threats, Opportunities, Weakness, Strengths (TOWS) matrix to the *A. arguta* system. The first letter of the acronyms reported in TOWS matrix, as codified in Figure 6, refers to one of the 4 typologies of factors analysed in SWOT (Strengths, Weaknesses, Opportunities, Threats) the second letter indicates one of the four steps of the Fresh Fruit supply chain (Field, Warehouse, Distribution, Consumer).

SO Strategy (Max–Max)	WO Strategy (Min–Max)
1. large scale oriented SF1, SW1, SD1, SC1 OF1, OW, OC1, OC2	3. export and organic oriented WD2, WC1, WW1 OF1, OC1, OC2, OF1, OD1
ST Strategy (Max–Min)	WT Strategy (Min–Min)
2. berry-fruit market oriented SF1, SF4, SW3, SC2, SW1 TF1, TW1, TD1, TC1	4. niche oriented WF1, WW1, WD1, WD2, WC1, WC3 TF3, TW1, TD1, TC1

Regarding the SO strategy identified by investigators in Table 4, large-scale development of *A. arguta* is made possible by the absence of PSA and by the practicality of consumption of the fruit (ready to eat). It is also possible to exploit the positive trend of consumption linked to health and environmental aspects. This strategy also makes it possible to exploit economies of scale.

The ST strategy aims to characterise the fruit of *A. arguta* associating with berry fruit references (i.e., baby kiwi). The similarity with this category of product is also linked to the practicality of consumption through the small size of the fruits, as well as their aromatic qualities and taste.

The WO strategy envisages the development of an export oriented chain focusing on countries with consumers who are environmentally conscious and who are willing to pay higher prices for organically produced products.

Lastly, the WT strategy is linked to a differentiation guided by the placement on a niche market of the Nergi[®] brand, with consequent considerable investments in marketing.

4. Conclusions

This study contributes to a more systematic understanding of the factors, that are important drivers and constraints in the advancement of *A. arguta* and its possible acceptance as a new fruit system in the Piedmont region. Our analysis serves as a vehicle to solicit the opinions of those involved with the kiwifruit industry in Piedmont as a means to identify, clarify and offer potential solutions to current enviro-socio-economic issues. Furthermore, our analysis aims to foster a more comprehensive dialogue about the options available in terms of future species and varieties among local stakeholders. The life cycle assessment (LCA) helped us to conclude that the potential replacement of *A. deliciosa* with *A. arguta* would not change the current environmental impact of the cultivation of kiwifruits in the area. From an economic point of view, this crop, despite being labour intensive, is considered by the stakeholders involved as a good possibility due to its high and stable earnings. It should be noted that there are converging opinions among those interviewed in the different groups of interest (growers, technicians, distributors, mass retail buyers). This, in turn, demonstrates the ability for kiwifruit industry stakeholders in Piedmont to work harmoniously and foreshadows a successful management programme for *A. arguta*.

Based on synthesis of results from our TOWS analysis, we recommend the following development strategies to help to shape the future *A. arguta* supply chain in Piedmont:

1. Large-scale oriented;
2. Berry fruits oriented;
3. Export and organic oriented;
4. Niche oriented.

Given the current crisis of the kiwifruit industry in Italy, we believe that we have provided useful next steps in the strategic planning by identifying current and potential future issues, with perspectives and options offered by the supply chain stakeholders. The methods used in the study described here are subject to limitations. Nonetheless, we believe that the chosen methods are suitable for identifying the relevant propensities with respect to the substitution of *A. deliciosa* with *A. arguta* in the Piedmont region. We emphasise that the results of this study may not be applied to other regions as most of the relevant circumstances (e.g., climatic conditions, socio-economic environment, and entrepreneurial skill) significantly differ from the area in which our analysis is focused. It will be necessary in the short term to carry out a detailed economic assessment, which can lead to the definition of a cost-benefit analysis of the replacement. Lastly, this assessment can help investigate matters with a more technical-agronomical perspective, or confirmation of the possible resistance of *A. arguta* to PSA bacterium.

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