Carbon footprint of innovative plastic covers used as insects and pests control systems in organic apple orchards

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Abstract

Recently, physical covers (such as nets, plastic films or sheets) have found a great application in several high-income fruit cultivations as insects and pests control systems. Agronomic and economic factors are of primary importance, but environmental impacts should be considered too, especially GHG emissions and the climate change potential. Within the project ALT.RAMEinBIO, which aims to find alternatives to copper use in organic agriculture, the carbon footprint (CF) of different cover typologies (mono-block net, single-raw net and Keep In Touch®) have been analysed, throughout the life cycle assessment (LCA) methodology. The aim of this study is to gain a better understanding of the CF of these covers, to identify which steps along the chain impacts more, and to work towards the development and promotion of strategies for reducing the CF of pest control operations in the organic apple production. Our results show that covers requiring high amounts of plastic and metal components generate inevitably high CF, up to about 1,513.4kgCO_{2eq} per hectare per year. Against our expectations, the CF of certain covers is even higher than the one of the actual insects and pests control practice, which implies the spraying of pesticides, the use of mating disruption and the installation of traditional hail-nets.

Keywords: *Nets, Malus domestica*, GHG emissions, carbon footprint, life cycle assessment

Introduction

The European regulation (CE) on organic production N. 834/2007 and its application (889/2008) allow a limited number of plant protection products. These must be "natural or naturally-derived substances" and they often have a limited efficacy compared to the synthetic chemical plant protection products. Some organic producer associations in the northern countries (e.g. Bioland, Naturland, Demeter) restrict even more the allowed products´ list or the allowed dose (such as for the copper, the Spinosad, the synergist of pyrethrum (PBO), etc.).

However, the agri-food market globalization and the climate change favour the development and the spreading of several new diseases and pathogens (e.g. *Drosophila Suzukii, Marssonina Coronaria, Halyomorpha halys*). The organic production regulation proposes the use of mechanical and physical methods as possible remedies, besides the use of resistant variety, the rotation and the implementation of strategies for the protection of natural enemies.

In the last years physical coverings (such as nets, films or sheets) have found a great application in several high-income fruit cultivations.

The Laimburg Research Centre, is carrying out filed trials since 2010 to evaluate agronomical pro and cons of several physical covering techniques, showing good results. Nevertheless, an important aspect is the assessment of the environmental impacts of these alternatives techniques, in agreement with the Common European Agricultural Policy (CAP) 2014-2020. Indeed, CAP explicitly supports the shift toward a low-carbon and

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climate-resilient economy in the agriculture and the reduction of greenhouse gas emissions represents a priority (CAP 2014-2020).
In this context, different net typologies (mono-block net, single-raw net and Keep In Touch® net) are analysed in order to assess their carbon footprint (CF), throughout the life cycle assessment (LCA) methodology, which is one of the method most used in the food and agricultural production (Cerutti et al., 2011, Cerutti et al., 2015) to account for environmental impacts.
Moreover, we compare the GHG emissions of these technologies with the actual insects and pests control management, such as the use of traditional hail nets and the spraying of organic plant protection products together with the mating disruption.

Material and Methods

Life Cycle Assessment Methodology

In this study, we carry out a LCA to analyse the CF of different innovative covers used against pathogens. The LCA is of the attributional type and it is performed according to the ISO standards 14040 and 14044 (2006). The dedicated software SimaPro8 is used to model the system and to set up the balances. The analysis focuses on the assessment of the climate change potential due to GHG gasses emissions, which is express in kg of carbon dioxide equivalents (CO_2eq). The methodology to account the GWP is the one proposed by the IPCC (IPCC, 2007).

Goal and scope, functional unit, boundaries and Life Cycle Inventory

The main goal of the study is twofold: i) to assess the CF of three different nets for pest control in the organic apple fruit production in South Tyrol (mono-block net and single-raw net which are used against insects, and Keep In Touch® net), which resulted to be useful against insects (e.g.: codling moth) and fungal pathogens (e.g.: apple scab) (Kelderer & Casera, 2016), and ii) to compare the GHG emissions of these technologies with the actual insects and pests control management.
The functional unit is 1ha for one year of cultivation.
The approach of this study is from ‘‘cradle to grave’’. The boundaries of the system extend from the extraction and production of the raw materials used, to their manufacturing, to their transport to the farm, their installation, yearly use and management and finally their removal. However, processes of recycling or disposal of the material used have been excluded from the analysis, due to lack of data.
All the data regarding the materials used are taken from private companies that produce or sell the nets and the metal and plastic components required for their installation; field measurement have been carried out, too. Data regarding field operations (such as installation, management, removal of the nets and pesticides spraying) are given from expert of the Laimburg Research Centre. The background data are taken from the database Ecoinvent v3 (Wernet et al., 2016). Data regarding the pesticide sprays are taken from the farm´s records book of a local organic farmer, for the year 2016.

System descriptions

As showed in Fig.1, we modelled the three innovative nets: mono-block net, single-raw net and Keep In Touch®, as well as the traditional hail-net, which is commonly spread in South Tyrol.

All the components used for the support structures (cement poles, anchors, cables, etc.) have been considered to be the same for all the systems, as reported in Table 1. The life-time of the support structures has been decided to be 30 years. For the installation and removal of the support structures an excavator is used. We estimated a total time of 25h/ha with a consumption of 8l/h of diesel.

All the elements that compose the different net typologies has a life-time of 15 years, and they are reported in Table 2. The time and the energy consumption required for the nets' installation, removal at the end of the cycle and their yearly maintenance are reported in Table 3. To carry out these operations a platform (the one used for the fruit harvesting) is used, with a diesel consumption of 0.7l/h.

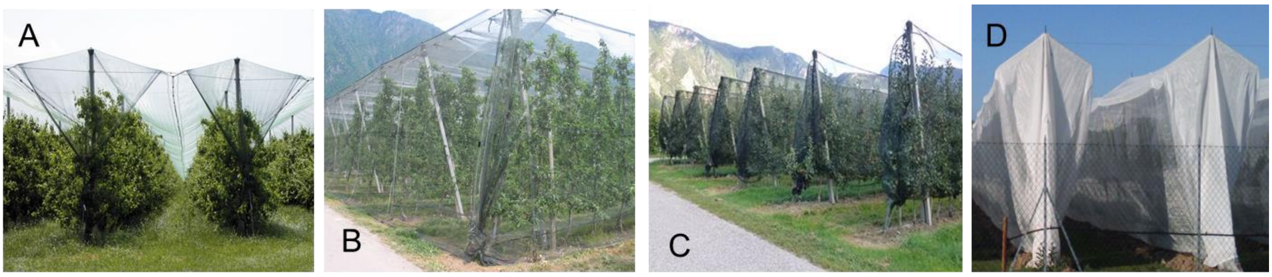

Figure 1: Nets modelled in the study. A= traditional hail-net, B= mono-block net, C= single-raw net, D= Keep InTouch®.

Table 1: Materials and components used for the support structure, common in all the assessed net systems. (D means diameter).

MATERIALS				
Components	**Material**	**n°/ ha**	**weight (kg/1p)**	**total weight (kg/ha)**
cement poles 9x9cm	reinforced concrete	94	88.32	8302.08
cement poles 7x7cm	reinforced concrete	429	55.46	23792.3
wire (D4mm)	aluminum-zinc	5280m	-	391.11
cables (D8mm)	steel	200m	-	60.79
ring wire at 3.5m	steel	94	1.52	142.86
clamps	steel	470	0.08	38.54
anchor D300mm	steel	94	4.44	417.59
anti-breach plates	steel	94	1	94

Table 2: Plastic and metals materials and components required for the assessed systems. (HDPE means high density polyethylene).

		Weight (kg/ha)			
Systems' components	Material	**Traditional hail-net**	**Mono-block net**	**Single-raw net**	**Keep In Touch®**
cables and wires	steel, zinc-iron	-	136.7	133.0	264.0
metallic components	steel, zinc-iron	32.6	32.7	909.2	2269.9
plastic components	HDPE	316.5	321.2	255.2	37.8
net	HDPE	552.0	628.8	1354.3	3841.2

Table 3: Materials, energy consumption and time required to install and remove the nets, as well as to manage it annually. (HDPE means high density polyethylene).

Nets' data	Traditional hail-net	Mono-block net	Single-raw net	Keep In Touch®
material	HDPE spun (3x8mm)	HDPE spun (3x8mm)	HDPE spun (3x8mm)	HDPE double string (D0.22) HDPE spun (3x8mm)
surface (m^2/ha)	11,500	13,100	28,215	29,040
weight (kg/ha)	552	628.8	1,354.32	3,841.2
energy consumption (kWh)/ha	411.87	469.16	1,010.43	3,020.26
Platform use (h/ha)				
installation and removal time	66	69.3	69.30	76.23
yearly management time	25	26.25	26.25	28.86

Furthermore, we assessed the GHG emissions of the organic pesticides spraying and of the mating disruption. We considered two apple varieties typically cultivated in South Tyrol: Gala and Braeburn. Gala received 20 treatments, whereas Braeburn received 22 treatments, since it is harvested 1.5 months later than Gala (Table 4). We took into consideration also the GHG emission due to the tractor coupled with an air-sprayer used to treat the apple trees. The diesel consumption has been calculated to be 4.5l/h, with a speed of 7km/h.

Table 4: Pesticides treatments in Gala and Braeburn in 2016.

Product	Quantity		Main target pathogens
	GALA	BRAEBURN	
Copper sulphate (kg/ha)	8.33	9.52	Scab
Sulfur (kg/ha)	11.16	13.97	Powdery mildew, scab
Calcium polysulfide (l/ha)	106.76	78.89	Scab
Paraffin oil (l/ha)	17.89	17.89	San José scale
Sodium bicarbonate (kg/ha)	-	12.74	Powdery mildew
Azadiractina (l/ha)	2.15	2.15	Aphids
Granulovirus (l/ha)	0.07	0.07	Tortrix
Bacillus Thuringensis (kg/ha)	1.33	-	Tortrix

We modelled the mating disruption considering the pheromones plastic dispensers. We accounted 900 dispensers in 1ha, as suggested by the producer-company guidelines. We considered 6h of platform-use to install and remove the dispenser.

Due to lack of data, we could not include in the calculation the emissions derived from the production of certain pesticides, such as *Bacillus Thuringensis*, Azadiractina, Granulovirus and the pheromones used in the mating disruption.

Results

Figure 2 shows the CF of each analysed net. The common supporting framework (cement poles, anchorages, wires and cables) represent an important part of CF of the assessed systems, accounting for about 423kgCO_{2eq}.

The Keep In Touch® system shows the higher CF, reaching 1,513.4kgCO_{2eq}. This is due because of the high quantity of plastic used to produce the net itself, and because of the higher amount of metal components required to create a steady and solid structure able to support the net-textile. Indeed, in this system the net, the metal components and the further cables and wires emit together 934.42kgCO_{2eq}, that correspond about the 62% of the total CF of the system.

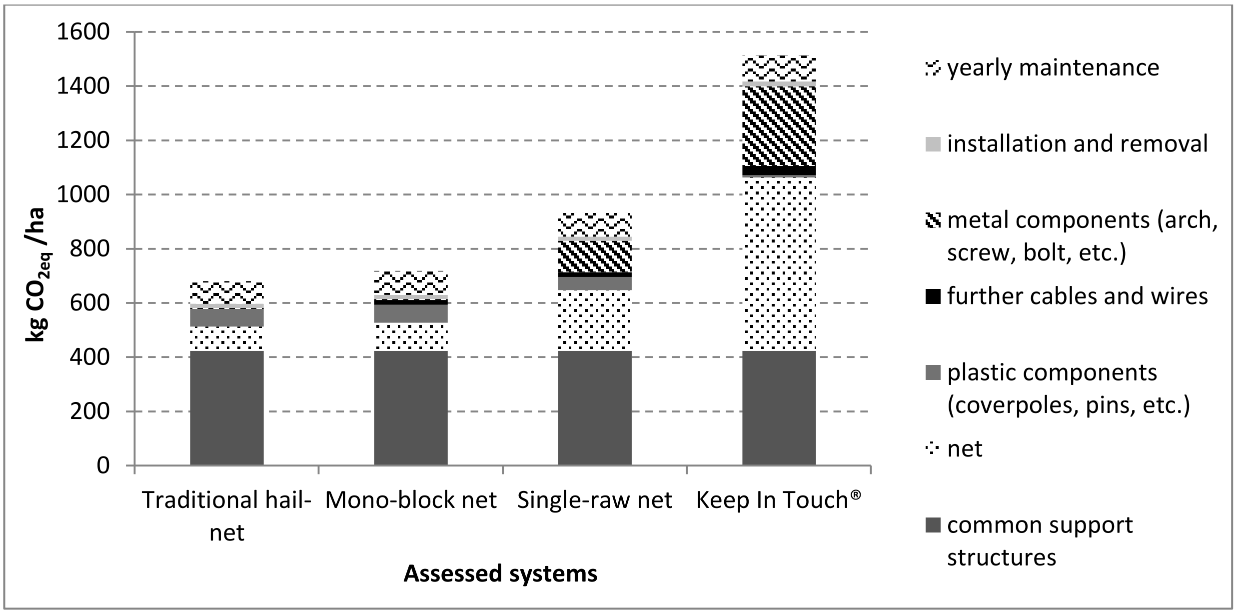

Figure 2: Contribution analysis to the CF of the different nets investigated. Values refers to the functional unit (FU=1ha per one year) and are expressed as kg of carbon dioxide equivalents (kgCO_2eq).

The GHG emissions of the pesticides treatment of Gala amount annually to 272.6kgCO_{2eq} /ha, and for Braeburn they amount to 310.4kgCO_{2eq}/ha. The mating disruption lead to a GHG emission of 32kgCO_{2eq} /ha per year.

Thus, the actual insects and pests management, including also the traditional hail-net, accounts totally to 924.44 kgCO_{2eq}/ha for Gala, and to 1022.26 kgCO_{2eq}/ha for Braeburn.

Discussion

Few papers in the international literature (Mouron et al. 2006, Kägi et al. 2008, Hayer 2010) include nets systems in the LCA assessment of apple production. However, they analysed only hail-nets, and they do not specify any technical data (such as how it is built, material used, etc.) or any information regarding their management. Kägi et al. (2008) showed that hail nets emit about 598.7 kgCO_{2eq}/ha per year, whereas in Mouron et al. (2006) it has been found that hail protection nets are highly energy related, but no figures regarding their CO_{2eq} emissions are reported.

This work provides a better understanding on the amount of material needed to build different nets systems and about their CF. Moreover, our findings underline the importance to include the supporting framework and the nets systems in the life cycle environmental assessment, since they can increase significantly the final and overall CF of apple production. Taking as an example the figure of climate change potential of the cultivation process phase (amounting at 5089 kgCO_{2eq}/ha) reported by Longo et al. (2017), where an organic apple plot of 5 ha in the Trentino Alto Adige region is assessed, the inclusion of the traditional net system would increase the climate change potential of 13.4%.

We would like to underline that, at this phase, it is not possible to forecast how many and which treatments can be avoided using the alternative nets. The agronomic experiences carried out within the research program of the Laimburg Research Centre doesn´t allow to generalized the results.

Even speculating that all the treatments can be avoided by the use of the nets, the CF figures in some cases seem to be very closed or even higher (such as in the Keep In Touch®) respect the actual situation (hail-net + plant protection spraying + mating disruption).

In order to promote sustainable techniques, several aspects should be considered: agronomic and economic aspects are essential, but environmental impacts should be taken into account too. The climate change potential is one of the most analysed environmental burden, but, in our opinion, also other environmental impacts should be considered such as aquatic, terrestrial and human toxicity, water and energy consumption, and impacts on the biodiversity. Moreover, an extensive installation of nets would inevitably impact the whole agro-ecosystem, changing the landscape and having implications also on the tourism and on the well-being of local inhabitants. Those are aspects that should be further investigated.

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