Scientia Horticulturae 229 (2018) 233–239

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Research Paper

Carbon footprint and profitability of two apple cultivation training systems: Central axis and Fruiting wall

Elisabet Vinyes[a,*], Luis Asin[c], Simó Alegre[c], Carles M. Gasol[a,b], Pere Muñoz[d]

[a] Sostenipra Research Group, Universitat Autonoma de Barcelona (UAB), 08193 Bellaterra, Barcelona, Spain
[b] Inèdit Innovació S.L., Research Park of UAB, UAB Campus, 08193 Bellaterra, Spain
[c] Institute for Research and Technology in Food and Agriculture (IRTA), 25198 Lleida, Spain
[d] Department of Agri-Food Engineering and Biotechnology, Barcelona School of Agricultural Engineering (ESAB), c. Esteve Terradas, 8 08860 Castelldefels, Spain

ARTICLE INFO

Keywords:
Life cycle assesment
Carbon footprint
Fruit emissions
Sustainable farming
Apple production

ABSTRACT

The study compares two apple training systems. Central axis and Fruiting wall, to provide useful environmental information to fruit producers, and also to detect the emission differences between them in terms of Carbon footprint. The data used in this study were directly collected from apple orchards located in Catalonia nine years of real agricultural data are available. The functional unit to performance the analysis is to produce 1 kg of apple fruit.

According to results, in both systems, the Fertilization stage was identified as the main contributor to Carbon footprint (44%). The impact of the use of machinery and the infrastructure involved in orchard production are important factors to be taken into account when training systems are compared, because depending on the yield the emisisons per kg of fruit produced may increase. The Central axis system has Carbon footprint values of 0.207 KgCO2eq; and the Fruiting wall system, 0.195 KgCO2-eq. Thus, the Central axis system has 6% higher values.

The economic results reveal that the Fruiting wall system is more profitable than the Central axis. This greater profitability is based on higher production and lower cost of pruning and hand thinning during the period of full production. Both factors compensate for the higher costs of planting and management in the early years.

1. Introduction

World population increase is generating a demand for agricultural products, as well as intensive consumption of natural resources, water and energy etc., with a major environmental impact that contributes strongly to climate change. The 2007 IPCC report estimates that the direct impact of agriculture is about 10–12% of global anthropogenic greenhouse gas emissions. Fruit production is considered an agricultural sector with low environmental impact, compared to the herbaceous crops sector and other foods (Cerutti et al., 2011b; Frey and Barrett, 2007; Martínez-Blanco et al., 2011).

Numerous environmental tools are available to evaluate the environmental impact of a process or product. The *Life Cycle Assessment* (LCA) method has proved a useful tool for evaluating the environmental damage of this kind of agricultural activity (Martínez-Blanco et al., 2011; Milà i Canals, 2003). LCA is a compilation of the inputs, outputs and potential environmental impact of a product system throughout its life cycle (ISO14044 20). In this methodology the environmental impact is expressed in different impact categories. LCA is also suitable for measuring a product's or process's Carbon footprint. The CF is defined as: the sum of greenhouse gas emissions and removals in a product system expressed as CO_2 equivalents, based on a *Life Cycle Assessment* using the single-impact category of climate change (ISO 14067:2013).

Environmental information on food products is becoming increasingly available and accessible to society, fostering movements of both producers and consumers towards more sustainable production and consumption. To develop sustainable environmental management, it is important that food producers analyse the main environmental indicators of their production processes, in order to detect the critical environment-related points and improve them. Note that farmers play a key role when environmeltal analisys is done in agricultural products, as they have first-hand information about the activities involved (Torres et al., 2016).

Catalonia is the Region of Spain with the highest apple production, 54% of total Spanish apple production and 46% of its total cultivated area (MAGRAMA, 2013). Given the importance of apple cultivation in Catalonia, this study aims to perform an environmental analysis and to calculate the Carbon footprint (CF) of two different apple cultivation

* Corresponding author.
E-mail address: elisabet.vinyes@gmail.com (E. Vinyes).

https://doi.org/10.1016/j.scienta.2017.10.046
Received 2 June 2017; Received in revised form 26 October 2017; Accepted 31 October 2017

Table 1
Environmental fruit studies published and periods considered.

Fruit	Country	Period	Initial stages	References
Orange	Spain	1 year	No	Sanjuan et al., 2005
Apple	Switzerland	4 years	No	Mouron et al., 2006
Apple	New Zeland	2 years	No	Milà i Canals et al., 2006
Strawberry	Uk, Spain	1 year	No	Williams et al., 2008
Citrus (products)	Italy	1 year	No	Beccali et al., 2010
Orange	Italy	1 year	No	Clasadonte et al., 2010b
Peach	Italy	1 year	No	Clasadonte et al., 2010a
Nectarine	Italy	1 year	No	Cerutti et al., 2010
Apple	Italy	1 year	yes	Assomela, 2012
Kiwi	Greece	1 year	yes	Zeus, 2012
Apple	France	1 year	No	Alaphilippe et al., 2013
Apple	Italy	1 year	yes	Cerutti et al., 2011b
Apple & Peach	Spain	10 years	Yes	Vinyes et al., 2016

systems, Central axis and Fruiting wall, in order to detect the emission differences between the two and to provide environmental information to help fruit producers find the best practices to reduce CO_2 emissions in the fruit cultivation process. The study also includes a simple economic evaluation to compare the viability of the two systems of cultivation.

The data used in this study were directly collected from apple orchards belonging to the Catalan Institute for Research and Technology in Food and Agriculture (IRTA). According to previous work (Vinyes et al., 2016), the main impact in the entire fruit production cycle is detected at the agricultural stage (37–40%), so in this study only the agricultural stage was examined, storage and distribution stages were excluded, also there is a lack of quality data in this stages.

To emphasize that, other environmental studies of fruit have been published, but not using multiyear perspective analysis, many studies only considerer data from one or two productive years (Table 1), and do not includes impact of orchard initial stages (planting and soil preparation). So the novelty of this study is multiyear approach been used according, as well as including orchards establishment stages, and also using real orchards management data. Caution should be taken when the studies are based only in a single year, or results related to mass, because unproductive years could increase impacts value on the results, whereas over productive years could decrease them.

Another innovation of this study is that two apple formation systems of the most common apple orchards have been analysed, if there are differences not only at productive level but environmental level. Table 1 shows diferent fruit studies published and the information of period and satges considered.

2. Materials and methods

2.1. Carbon footprint (CF)

The CF is defined as: calculation of the amount of greenhouse gases (GHG) emitted into the atmosphere over the life cycle of a product, service or organization, expressed in kilograms of carbon dioxide equivalent: kg CO_{2eq} (PAS 2050:2008BSI, PAS, 2008PAS 2050:2008). The ISO14067 (Carbon Footprint of Products Requirements and Guidelines) publication harmonized the method of CF calculation by unifying the different existing impact assessment models. ISO 14067:2013 defines CF as: “the sum of greenhouse gas emissions and removals in a product system expressed as CO_2 equivalents, and based on a life cycle assessment using the single impact category of climate change”.

In this study, to calculate the CF of the two apple cultivation systems, the LCA approach, following ISO 14044:2010 and ISO 14067:2013, was used, to find how the two systems compared and how the infrastructure involved and the multiyear approach affected results.

2.2. Life cycle assessment (LCA)

The LCA is defined by ISO standard (ISO14044:2010) as the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle. LCA analysis considers four main steps: aim and scope, inventory analysis, impact assessment and interpretation of results. The end results are dependent on the systems’ boundaries and the functional unit (FU), which is the unit to which the results of the LCA are related and is subsequently used for the communication of the LCA results.

Given the aim of this study, at according to 2 Section 2.1, only the CHG impact category was taken into account. The calculation method used was Recipe Midpoint H. Calculations were performed with the SimaPro 8.1 software, together with the ecoinvent Centre database 3.1. According to Milà i Canals et al. (2006) and Cerutti et al. (2011a), a mass-based functional unit is adequate when analysing only the agricultural stages of the life cycle of fruit for descriptive purposes. Therefore, in this study the functional unit was defined as “cultivation of 1 kg of apple”.

2.3. Economic assessment

To define which system, Central axis or Fruiting wall, is most profitable, a simple economic study examined the real production data for every year of the trial. The economic study was not intended to establish the cost of production of 1 kg of apple, but to compare the two assay systems.

The economic analysis includes the following points at current prices: the installation of drip irrigation and fertirrigation, the cost of labour, the costs of machinery acquisition and use, and the rental of specialist machinery. It also includes insurance for crop losses due to bad weather, annual costs of management and administration and the payment of taxes.

Nine years of production were taken into account, allowing for changes in the life of the plantation. The Planting costs, such as soil preparation, fertilization, materials, labour and interest generated during the first year, were included.

For the economic analysis the following indicators were used:

- IRR (Internal Rate of Return): Annual average profitability of the plantation.
- NPV (Net Present Value): All annual balances generated by the investment were updated by the discount rate.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t} - C_0$$

Where:

Ct = net cash inflow during the period t
Co = total initial investment costs
r = discount rate, and
t = number of time periods.

The analysis includes the following costs:

– Installation of drip irrigation system
– Costs of manual work
– Running costs of machinery
– Costs of machinery acquisition
– Rental costs of specialist machinery
– Cost of insurance for crop losses due to bad weather
– Annual costs for management of other work