Life Cycle Cost Analysis for an Apple Orchard

Subjects: Horticulture

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The life-cycle cost analysis is a method used to assess long-term economic efficiency among equivalent competing processes or products. It is accepted that the role of the organic farming system is to produce fresh and authentic agri-food products and, at the same time, to protect and conserve the environment. For an apple orchard operated in an organic system, the life cycle cost analysis (LCCA) was performed within a system boundary, starting from the establishment stage of the orchard until the transportation stage, from the field to the warehouse and from the warehouse to retail stores for a 20-year life span of the orchard.

orchard apple organic costs performance Romania

1. Introduction

With an increasingly dynamic global system, the perspectives of the agri-food sector are not only determined by climatic conditions, the limited nature of resources, and the level of digitization but also by new technologies and consumer preferences. In order to meet the growing demand for affordable and healthy food, policy makers will need to implement measures and strategies that encourage socio-economically and ecologically sustainable agrifood systems, ensuring, at the same time, a sustainable economic return. Today, environmental management practices and attention are not only focused on addressing emissions and waste from production processes but are shifting to analyze product life cycles and their impact on the environment. Global environmental impact assessment tools such as the life cycle assessment (LCA) and the life cycle cost analysis (LCCA) are successfully applied by companies and research institutions to identify, investigate, and calculate the environmental effects of a product through its life cycle. The LCCA, also known as "whole cost accounting" or "total cost of ownership", is a methodology for evaluating the economic performance of a process over its entire life span, balancing between the initial monetary investment with the long-term-associated expenses of the ownership and operational costs. The LCCA is a method that addresses the economic component of sustainability, by evaluating the initial investment costs and the recurring operational costs of the various existing options that may occur throughout the entire life of a product or service. The analysis of some potential scenarios can be performed under conditions of similar benefits but with different financial resources. Thus, the aim of this research is to identify a framework for selecting the best information to be used for the LCCA method in organic apple production systems and to decide on the key elements that determine the best option for establishing and exploring an organic orchard in the southern part of Romania. This study covers a detailed investigation with the help of the LCCA method, which can be very useful in horticulture for specialists in the apple sector looking for a financial approach for orchards.

The food production and agri-food systems are currently diversified and highly sophisticated, using new technologies and methodologies such as the LCA (life cycle assessment) and the LCCA (life cycle cost analysis). The limits of these methodologies and their specific procedures can contribute to a differentiation in the application of the methods used in fruit production systems, which sometimes conduct to different results, as indicated in the literature ^[1]. Even though the LCCA is a tool under development for analyzing the economic sustainability of products or services, this concept is less utilized in the agriculture sector ^[2]. The literature also notes that uses of the life-cycle cost analysis (LCCA) in the development of a wide range of technological solutions are present, while the evaluation focuses on identifying hotspots and potential design improvements. In the substantiation of this research, papers from the literature specifically describing the LCCA method were tackled. In this respect, there are limits and particularities of the LCCA method that have been presented under different approaches, which are sometimes introduced together with the life cycle assessment (LCA) method. So far, there is a wide range of examinations on the products and processes that have been taken into consideration in the specific literature.

While the LCCA is a decision support tool and there are papers indicating a certain number of platforms that offer support for the LCCA method ^[3], it is also known that the life-cycle cost analysis, together with the life-cycle assessment and the social life-cycle assessment, is a decision tool that leads to sustainable decisions and investments ^[4]. On the apple research side, there is a study where the aim of the paper was to identify the apple consumer profiles in Romania ^[5], besides the fact that there are authors that stress the importance of understanding cost distributions along the supply chain regarding both investments and operating costs, so that could facilitate decision making ^[6], and there are studies that present statistics of the information regarding the results of the LCCA method ^{[7][8]}. Meanwhile, it is worth mentioning that those studies that cover the LCCA methodology very well show that by-products would not only contribute to profitability but would also be a source of raw materials that would avoid the use of resources and processes in the production of other products ^[9]. In a similar paper ^[10], the LCA and LCCA methods were used to shape technical options for wastewater treatment and by-product recovery, with a focus on identifying hotspots and potential design improvements. Also, the specific literature commonly presents comparative studies between conventional and organic methods ^{[11][12]}. Along with this kind of research, there have been challenges addressed to the field telling of the limited water resources and the effects of climate change ^[13], and this could also be an issue in the case of apple orchards.

On the other hand, the literature also presents studies based on the LCCA method ^[14] focusing on the food waste issue and underlining that this has become a global problem due to its impact on the environment. Analyzed together with the economic perspective, the life-cycle cost method (LCCA) has become an appropriate tool for assessing sustainability. Other pragmatic approaches to these methods also target food waste, which has become a global problem due to its impact on the economy and the environment. Appropriate ways of preventing, valorizing, and managing food waste could mitigate or avoid these effects.

Together with these methodologies that have become a benchmark in recent years, there is also the concept of circular economy. The circular economy (CE) is a pillar of the European Green Deal and is an increasingly important area of EU external action, including the EU international cooperation and development policy ^[15]. Within the EU Circular Economy Action Plan (CEAP), a powerful policy steering to guide EU diplomacy and international

cooperation is provided by communicating the EU's ambition to lead efforts at the global level, while contributing to the Policy Coherence for Development. Thus, it aligns the CE with the context of the economic transformation promoted by the Green Deal, underlining the ambition to promote the transition to a climate-neutral, resourceefficient, and circular economy globally. These approaches, together with the measures developed and the implementation of sustainable solutions, are all the more urgent, as studies show the imminence of the deterioration of natural space and the speed at which the entire planet is affected. In this context, the life cycle cost analysis (LCCA) has become an appropriate method for assessing the total cost of ownership by taking into consideration all the costs of acquiring, owning, and disposing of a process. It is useful when the project alternatives fulfill the same performance requirements, but differ with respect to capital costs and operating costs, thus, the option which maximizes net savings is selected ^[16]. The LCCA is especially useful when project alternatives that fit the same performance challenges but that differ with respect to capital costs and operational costs must be confronted when selecting the approach that increases savings. The alternatives were related to the storage and processing capacity of fresh apples, and consequently the weight of the amount of fruit sold on the market for fresh consumption. As one of the purposes of this method is to support and ease the extensive application of life-cycle costing (LCC) among agribusiness operators, farms can make more cost-effective decisions in their activities. In this sense, there was a complex approach to the LCCA method, together with the LCA (life-cycle assessment), that was carried out for identifying the main hotspots and for selecting the alternative scenarios closest to the ideal solution through the multicriteria method, the latter allowing for the achievement of synthetic indices for a two-dimensional sustainability assessment $\begin{bmatrix} 17 \\ 17 \end{bmatrix}$.

2. Apple Sector in Romania

For a better understanding of the analysis carried out in the present study, technological particularities of planting and maintenance of apple orchards are presented. The apple (Malus domestica) is very widespread in Romania. In this country, the apple culture is characteristic of hilly areas, where there are numerous fruit-growing areas [18][19]. Among the counties well known for apple cultivation, the researchers consider Arges, Dâmbovita, Vâlcea, Prahova, Buzău, Suceava, Iași, Maramureș, Bistrița, Sălaj, and Mureș. In Romania, the apple areas occupy approximately one third of the total area of the orchards, which places it in second place, after the plum species ^{[20][21]}. Both international and Romanian varieties are divided into three groups: summer varieties, autumn varieties, and winter varieties [22][23]. Apples have special biological characteristics, being among the fruits that retain their freshness for a long time, can be transported over long distances, and can be consumed at any time of the year [24][25][26][27]. This fruit has, in its composition, a series of nutrients and important elements, such as sugars, vitamins (A, B1, B2, and C), iron, phosphorus, calcium, and magnesium, with their quantities being higher in the peel than in the pulp ^[28]. Among the particularities of apple tree growth and fruiting, the apple has a relatively small trunk and a wide wreath ^{[29][30]}. Depending on the vigor of the varieties used, apple trees can be planted in intensive orchards (500-1250 trees/ha) or super-intensive (over 1250 trees/ha) orchards. Less often, they can be planted on a rugged terrain or in the pre-mountainous area, with densities of 300–400 trees/ha, where specific varieties are used [31]. Regarding the climate and soil requirements, the apple grows well in areas where average annual recorded temperatures are between 8 and 11 °C. Apple trees have moderate light requirements: they prefer sunny areas, but they can also grow in semi-shade conditions ^[32]. Establishing an orchard begins with choosing and preparing the land. At the time of planting, the trees must be in vegetative rest and the soil must not be frozen. The best time to plant is autumn, after the leaves have fallen ^[33]. Harvesting must be performed at the optimal time for each apple variety. The handling and transport of the fruits is carried out in varied types of packages, in order to maintain the quality of the products and to reduce the time from harvesting to conditioning. Fruits can be stored in boxes, in dark and cool spaces for 3–4 months, at temperatures between 0–4 °C with an air humidity of 80–85%. The transportation stage refers to two major phases. The first constitutes the phase of transporting the fruit from the orchard to the place of storage, where the sorting and selection of the fruit can take place, especially for those that are to be stored for a longer period of time. The second phase refers to the transportation of the fruit from the storage place to the retailers ^{[34][35]}. In particular, for the framing of the apple sector in Romania, in the figure below (**Figure 1**), a map from 2020 with the counties where the highest average apple productions are obtained (kg/tree). Thus, it can be identified that the south–southeast part of the country is considered an orchard basin with important productions (source: own representation based on ^[36], made with data from public databases ^{[37][38]}).



Figure 1. Map of Romania. The Romanian counties with the highest apple productions.

The abbreviated letters in the figure above represent the code of the counties in Romania (e.g., the ones highlighted red in the selection area there are Argeş (AG), Dâmbovița (DB), Prahova (PH), Teleorman (TR), Giurgiu (GR), Călărași (CL) and Ialomița (IL) counties). Next, in the figure below (**Figure 2**), there is a visual presentation of the dynamics in number of apple trees in Romania (figures are expressed in thousands) ^[37].



Figure 2. The number of trees, broken down by regions, in Romania.

Being a country with important apple productions, reaching about 25–35 kg/apple tree (total production 570 thou tons apples in 2021 ^[38]), Romania also records a relatively high consumption, with, on average, about 30–35 kg of apples/inhabitant/year.

Thereby, in the figure below (**Figure 3**), the researchers have represented in dark color the Eastern regions in Romania where the largest quantities of apples are bought for consumption ^{[36][37][38]}. These counties are Vrancea (VN), Galați (GL), Buzău (BZ), Brăila (BR), Tulcea (TL), and Constanța (CT) and have been identified as areas where the quantities of apples for consumption recorded the highest values in Romania (about 3–4 kg of apples/month/person).



Figure 3. Map of Romania. The counties with the highest apple fruits consumption.

Organic agriculture is a major contributor to the sustainable development of the sector, to the development of economic activities with an important added value, and to the increase of interest in the development of a sustainable rural space. Romania is an important agri-food producer and exporter, where the current population number is about 19.2 million inhabitants, being the largest market in South-Eastern Europe and, thus, offering many opportunities in food retail. The sales of organic products in Romania are estimated at just under EUR 100 million (up from EUR 41 million, in 2016), which is, in Europe, one of the lowest values per capita. However, the domestic market for organic products is growing, especially in big cities. The main long-term trading partner in the field of organic farming is Germany, as well as other EU member states. The most important trade relations with countries outside the EU are with Turkey, for imports, and with the United States of America, for exports. All the large state research institutions that conduct agricultural research have a branch that deals with the ecological sector (e.g., the Research Institutes for Horticulture in Bacău, Pitești, and Vidra și Buzău). The organic apple production sector in Romania has increased in recent years. In 2019, according to Eurostat, in Romania, there were 3296 hectares of apple orchards in the conversion stage or eco-period of which 1868 were organic. The average yield of these orchards is 6.8 tons per hectare, and, in total, 12,653 tons of apples were obtained. An increase in the area of organic apples is expected, due to the increase in prices and demand. The large number of individual farms, which record a much lower yield than commercial ones, is an obstacle in increasing the potential of organic apple farms in Romania. Overall, about two thirds of all orchards are more than 25 years old (mostly in extensive and intensive production systems). In organic production, the share of old orchards is estimated at three

quarters. The 2020 figures for organic apples indicate a production of 11,250 tons (2020) of fully certified apples and 18,000 tons in 2021. Particularly, if the farmers manage to sell their fruit to the big supermarkets, their products are not always identified as organic ^[39]. Moreover, the reason for many farmers to convert existing apple orchards to organic ones is clearly the subsidy scheme. Thus, 620 EUR/ha is paid annually during the 3 years of conversion as well as 442 EUR/ha/year for the maintenance of the organic orchard, provided that the farm has a minimum of 1 ha of certified land to receive these subsidies. The total amount of subsidies paid by the Romanian government in 2021 reached EUR 92 million, an increase of 25% compared to 2020. In fact, the development of organic farming has always been closely linked to the subsidy system. The subsidy system will be revised, which could be a turning point for the development of organic apple productions in Romania. Still, it seems that the apple is not a focus crop for organic developments by the Romanian government, as well as for research and extensions, so limited growth is expected. In order to produce ecologically, there are strict rules that must be observed (e.g., the use of genetically modified organisms is prohibited, as well as stimulators and growth regulators, etc.). The objectives, principles, and norms applicable to ecological production are part of the community and national legislation. In Romania, the control and certification of organic products is currently ensured by private inspection and certification bodies. They are approved by the Ministry of Agriculture and Rural Development (M.A.R.D., based on the criteria of independence, impartiality, and competence, established, in Government Order no. 895/2016 for the approval of the Rules regarding the organization of the inspection and certification system, the approval of inspection and certification bodies and the supervision of the activity of control bodies). The approval by M.A.R.D. of the inspection and certification bodies is necessarily preceded by their accreditation, carried out by a body of qualified individuals for this purpose. As part of the campaign to promote organic agriculture in the European Union, at the initiative of the General Directorate for Agriculture and Rural Development of the European Commission, a website www.ec.europa.eu/agriculture/organic/home ro (accessed on 18 April, 2023) was created with the main objective of informing the general public about the ecological agriculture system as well as establishing a starting point for carrying out promotional campaigns in different Member States. The list of control bodies approved by M.A.R.D. for the control and certification of organic products on the territory of Romania is in accordance with the provisions of art. 34 of Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 regarding the organic production and labeling of organic products and repealing Regulation (EC) no. 834/2007 of the Council and the provisions of the Order of the Minister of Agriculture and Rural Development no. 312/2021 regarding the organization of the control and certification system, including the approval of control bodies and the supervision of their activity in ecological agriculture [40]. Thus, as was previously stated, the tree-growing sector is considered to be an important supplier of food and raw material for industries worldwide. Meanwhile investment costs affect the economic efficiency of orchards, as well as the production costs and incomes [41]. Regarding the apple consumption in Romania, based on some studies, this is differentiated mainly based on age, and it usually depends on the origin of the fruits, as well as the variety, the form, and the reason of consumption $\frac{[42]}{}$.

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