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Article

A Life Cycle Cost Analysis—Relevant Method Supporting the Decision to Establish an Apple Orchard in an Organic System

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Abstract: The life-cycle cost analysis is a method used to assess long-term economic efficiency among equivalent competing processes or products. The purpose of this paper is to investigate the nature and level of costs for an organic orchard located in Southern Romania, using a complex approach covering the entire chain of production, through its life span. The research results, based on a dynamic analysis and an integrated evaluation of the orchard's performance, were ranked on investment and operational costs and broken down into three categories (establishment, production, post-harvest, transport costs). The highest costs, representing 151,726 EUR/ha/20 years, about 52.72% of the total operational costs and 50.4% of the total farm costs/ha/20 years, were recorded in the exploitation stage. The scenarios for the sensitivity analysis considered different levels of average yields (40 and 60 tons/ha, respectively) with different rates of sold productions (85%, optimistic scenario; 70%, pessimistic scenario). The hot points identified at the production stage were the use of agricultural machinery, several pesticides, the costs of seedlings, anti-hail nets, plastic boxes, and labor costs, while at the post-harvest stage, there were those related to labor and energy consumption. The transport stage had important costs with respect to tractor operations and the track.

Keywords: orchard; apple; organic; costs; performance; Romania

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1. Introduction

1.1. General Considerations

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 agri-food 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 we noticed that 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, resource-efficient, 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 we considered 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 [17].

1.2. 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, we consider Argeș, Dâmbovița, 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 [24–27]. 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, we note the fact that 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, we have represented, 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 Argeș (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].

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), we have represented in dark color the Eastern regions in Romania where the largest quantities of apples are bought for consumption [36–38]. 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).

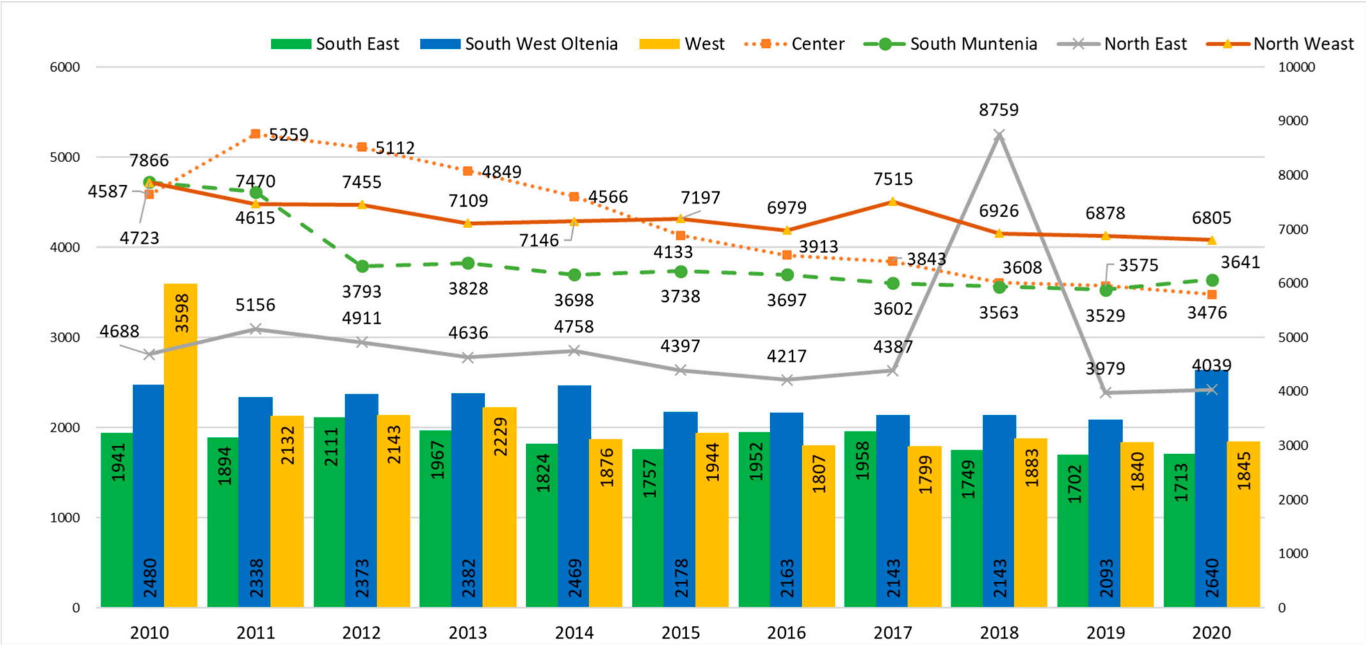


Figure 2. The number of trees, broken down by the eight counties of Romania.

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, we found that 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 [42].

2. Materials and Methods

2.1. General Approach of the Methodology

The LCCA (life cycle cost analysis) addressed in this work is one of the most used approaches in estimating the costs of a business. It is used to analyze and evaluate the total cost of a process, product, or service, starting with the costs of capital resources, acquisition costs, production costs, operation and maintenance costs, and, finally, the disposal costs of the analyzed product. Thus, the main purpose of the LCCA method is to estimate the overall cost of the examined process throughout its life cycle and subsequently to identify an alternative that will ensure the lowest costs, under conditions of optimal quality of the production process. It is recommended that this investigation be carried out at an early stage, so that cost reduction can be considered and operated on productively. The main challenge of an LCC analysis is to set out the monetary economic effects of the alternatives available at a specific moment. Through its complex approach, this method has thus become a useful mechanism in quantifying sustainability, by considering the economic impact of the design, execution, materials, and maintenance of the entire product, process, or service, and, at the same time, it identifies the strategies that can lead to the most effective options for the considered alternatives. The concept of a product's life-cycle management tends to support the investment decision-making process through the design of costs which arise in the long run [42] or through the efforts of continuous improvement to minimize negative environmental and socio-economic impacts [43]. In this sense, the stated costing system generates relevant information by supporting alternative decision making and by selecting production technology. Cost accounting, as an important source of information, should support management alternatives in order to ensure the competitiveness of the entities and to enable sustainable development. The costing system represents the segment of a broader concept, designed as life-cycle management, and, in this regard, the LCC provides significant information supporting alternative business decisions [44].

2.2. Database Used for the LCC Analysis

All the data used in this paper for the LCC analysis come from the experimental field of the Faculty of Horticulture, University of Agricultural Sciences and Veterinary Medicine of Bucharest, Romania. This apple orchard is located in the southern part of the country. The figures were collected by experts, encoded and processed in Excel files, then explored and examined though several tools of this software. The data regard the farm establishment costs, production costs, harvesting and post-harvesting costs, and transport costs, with each of them identified by the capital and the operational costs. The life span of the orchard was set for 20 years. The average yield considered was 40 tons/ha/year. The system boundaries lie from the establishment stage until the production transport from the field to the storage area. Our database was completed with details on the spring and fall calendar, which allowed us to make selections on costs based on the calendar.

2.3. Stages and Limits of the LCCA Method

In the Romanian agribusiness sector, the LCCA method is used quite frequently. In our case, the following steps were taken into account in the elaboration of this analysis: data collection and processing (data inventory); establishing the study interval (i.e., the life-cycle stages for which the study will be carried out), called system boundary; the identification of capital costs and operational costs; the unit of measure for the initial data (e.g., EUR/ha); the most accurate references for each stage and production process; the establishment of the functional unit of measure, the Functional Unit Cost (FUC, which, in the case of our study, is 1 kg of fresh apples); the presentation of the existing options, resulting from the sensitivity analysis; and, finally, the choice of the option that best fit the followed financial objective. The framework of this specific methodology, the LCCA, involves passing through several stages, the most important of which are the following:

- The goal and scope of the study, where the main purpose is stated.
- The life-cycle cost inventory, which concerns identifying and measuring the inputs and outputs for the system throughout its life span.
- The cost impact analysis: This is the stage where data are assessed and converted into relevant information. The impact analysis is performed within the system boundaries.
- Interpretation: The results from the inventory assessment are discussed. If an analysis of the sensitivity is demanded, then this should be conducted as a comparative analysis with the alternative options regarding the hot points identified in the system. Ideally, the results could be extended to other products or processes.

In this context, the literature [45], as well as the requirements and Guidelines for performing the LCC analysis [46] (e.g., ISO 15686-5/2017/15663), indicates the following methodological phases, which complement or reframe the above stages: * definition of the identified problems and alternatives, * cost analysis (detailing costs and their estimates), * economic evaluation and updating of future cash flows, * analysis of the break-even point, * identifying high cost contributors, * performing the sensitivity analysis, * presenting and comparing alternatives, and, of course, * recommending the best solution [47]. For these reasons, it can be appreciated that the LCCA is a particularly useful tool for decision making and for the evaluation of the economic performance of production systems, through the use of specific financial indicators, and, furthermore, in our case, for verifying the results of the fruit-growing technologies pursued. By providing financial data, several papers underline the level of indicators in order to support their results and state that the economic viability of the production models could serve as a complementary tool for indicating sustainability in the short- and midterm [48]. Thus, we underline the fact that the LCCA is an assessment of a product or service throughout its life cycle, generally from the cradle to the grave. From this point of view, the life-cycle cost analysis is recognized as an effective tool to assist in the selection of cost-effective decisions and should likely become a standard in cost evaluations. One impact of such an analysis aims to enable: the identification of the opportunities for improving a process during its lifecycle, the selection of the relevant indicators of its environmental performance and the adequate measurement techniques and the implementation of the eco-labeling scheme of products and the eco-declaration of products as elements of sales' promotion [49]. Also, regarding the method itself, we have added more information on profit computation and the discount rate used (2.5%), which was used for the recorded data. In order for us to analyze the data, Excel spreadsheets were used, which have some functionalities that can be adopted for a cost analysis. Following the methodological steps, in the figure below (Figure 4), the stages for a life-cycle analysis and the boundary system of an apple orchard production system are presented.

As life-cycle cost procedures are widely used for the economic evaluations of processes, the basic idea is to anticipate all future costs in order to obtain a life-cycle cost of a particular process. Repeating the calculations for a range of potentially interesting alternative processes allows for the selection of an optimum design which shows the least life-cycle cost [50].

The specific literature [51] indicates formulas for calculating the LCC. In this regard, we found the following relationship:

$$\mathrm{LCC} = \sum_{t=0}^{n} \frac{C_t}{(1+d)^t}, \tag{1}$$

where LCC = the lifetime cost of the product; n = the number of years within the study period; C_t = the relevant costs, including the initial and future costs from which the cash flows that can be obtained in year t are deducted (negative residual value); and d = the discount rate used to adjust cash flows and to bring them to a present value.

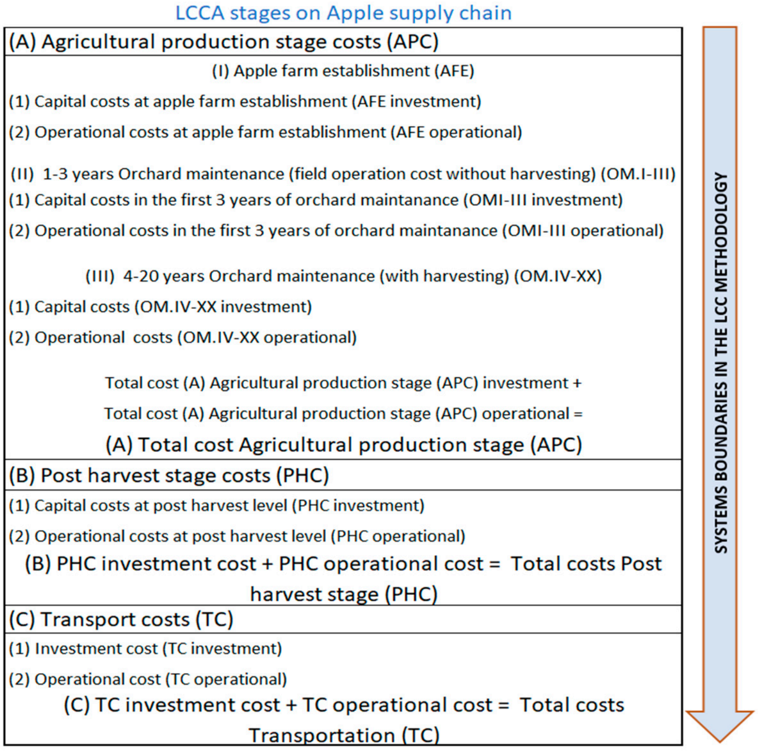


Figure 4. Simplified presentation of the main LCCA stages and the boundary system.

This method often requires an additional analysis, in the form of a sensitivity analysis. This is a technique used to determine the influence of major differences in the LCCA input parameters on economic outcomes. One of the variants used is for the most important input values to be set to certain limits (lower, upper, and average) or to impose a variability with a certain percentage, while all other input values remain constant, and then, the change in the results is analyzed. The interest for a sensitivity analysis is that it allows for the perception of the economic impact in the overall LCCA results. The specialized literature indicates that the cost sensitivity analysis of this method can be performed using applications such as Microsoft Excel Office 2019 or dedicated software with interfaces that ensure data entry, their processing, and obtaining specific results [52]. This is also the case of our article, where the sensitivity analysis consists of the identification of key points, i.e., those stages or elements in the process that present cost levels or values that can undergo adjustments (e.g., too high costs that will have to be adjusted) and for which simulations will be carried out to optimize the final result, in order to obtain a relevant impact for the pursued economic analysis. The system boundaries of our research were set from the apple orchard's establishment to field production and harvesting and then to the transportation to the storage facility. Consequently, the total LCC was calculated at the production stage, on the harvest stage, and on the transport stage. For the production stage, three main periods were determined: the apple orchard's establishment, the orchard's management in the first three years (without production), and the orchard's management in the years IV–XX (with economic production). The results obtained in the two scenarios were valuable in identifying the life-cycle cost outline, respectively, the hotpoints where a farm manager can actively interfere to optimize the costs. Also, different scenarios were run for testing "what if" hypotheses through the Microsoft Excel Office 2019 tool. For the construction of the different scenarios, we considered lower and upper limits of the capitalization of production on the market (70% for the pessimistic scenario and 85% for the optimistic scenario), and then the obtained economic results were analyzed. So far, the aim has been to maintain a level of benefit obtained that would cover the total capital and operating costs of the organic apple orchard for the entire planned operating period (20 years).

3. Results and Discussion

In approaching the LCCA methodology, we started from identifying the objective, recording data, establishing system boundaries, stages, and sub-stages of the process, and finally, calculating related indicators. Through the sequence of stages, the analysis of the economic viability of the system considered, namely, the apple orchard, was followed. Processing of the data and the presentation of the results were carried out by using advanced calculation tools and visual graphic representations provided by Microsoft Excel Office 2019.

According to the official data, Romania imports many apples from Poland and Turkey, which can also be found in the local permanent markets. In many cases, Romanian producers, due to the lower quality of their products, cannot comply with the requirements of the supermarkets, and, thus, they prefer to sell the apples they produce immediately after harvesting or to transform the fresh apples into juice or other secondary products [43]. In other papers, the LCC analysis on organic orchards obtained results that are clearly in favor of this production system due to its higher profitability, compared to a conventional culture system and considering the higher market price, guaranteed by certification [52].

3.1. Results on the Global Process

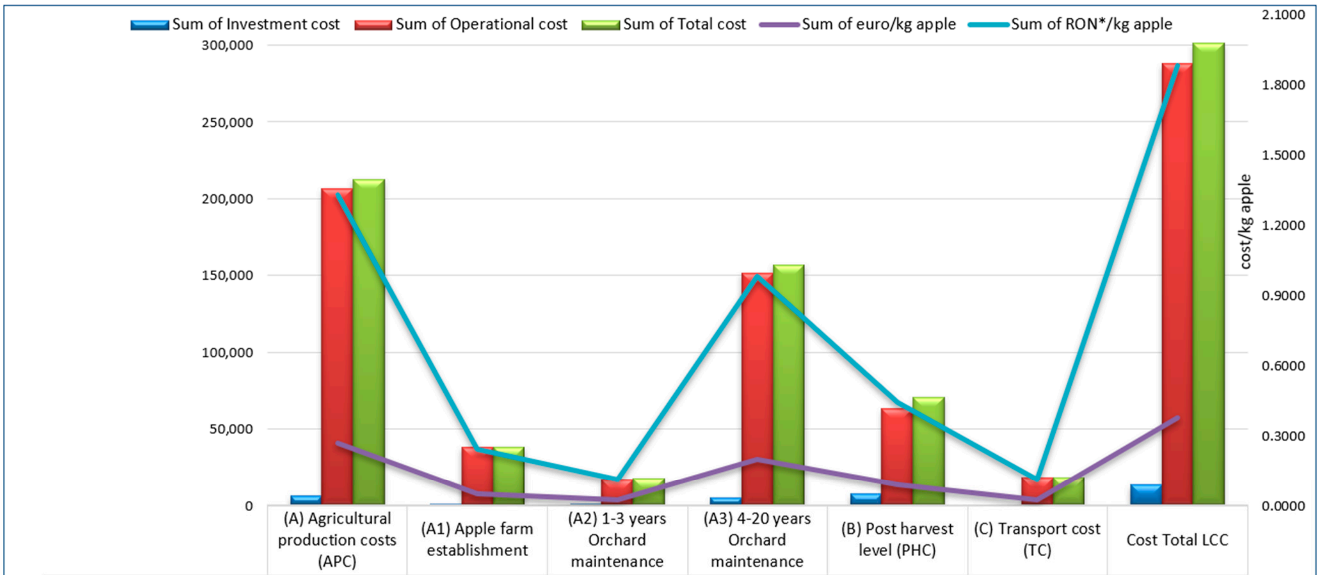
In Table 1 below, the main stages of the process of establishing and operating an organic apple orchard in the Southern area of Romania are presented. In the first section of the table, the capital and operational cost elements are revealed, expressed in euros, over the life span, at an average production of 40 tons of apples/ha, thus obtaining a total cost (LCC) of EUR 301,081. For these economic results, a series of costs were not considered, among which we note fixed costs (e.g., amortization and machinery insurance) or indirect production costs, such as rents, administrative costs, taxes, or subsidies.

Table 1. LCC and the level of the capital costs and operational costs for the three main stages.

Production Chain of Apple Orchard	Capital Costs (EUR)	Operational Costs (EUR)	Total Costs (EUR)	EUR/FUC, Share from the Total LCC	EUR/kg of Fresh Apples
(A) Stage: Agricultural production costs (APCs)	5929.7	206,608.4	212,538.1	70.59%	0.2657
(A1) Apple-farm-establishment costs (AFEs)	119.8	38,048.7	38,168.5	12.68%	0.0477
(A2) Orchard maintenance costs (first 1–3 years, without harvesting) (O.M.I–III)	763.0	16,833.7	17,596.8	5.84%	0.0220
(A3) Orchard maintenance costs (next 4–20 years, with harvesting) (OM.IV–XX)	5046.9	151,725.9	156,772.8	52.07%	0.1960
(B) Stage: Post-harvest costs (PHCs)	7375.9	63,321.8	70,697.7	23.48%	0.0884
(C) Stage: Transport costs (TCs)	-	17,845.5	17,845.5	5.93%	0.0223
LCC (Life-cycle cost)	13,305.6	287,775.7	301,081.2	100.00%	0.3764

Source: own processing, based on data from the experimental orchard of organic apples, Faculty of Horticulture, UASVM, Bucharest.

The matrix distribution of the results from the typology of costs (Table 1) is presented in order to be able to identify the weight of each type of cost (capital and operational) for the agricultural production cost, post-harvest cost, and transport cost categories, relative to the respective total stage or sub-stage. We can thus, state that operational costs from the production stage represent the vast majority of costs (97.21%), while capital costs from the same production stage represent the smallest share of the total cycle of production and exploitation of the orchard (2.79%). In total, capital or investment costs represent 4.42% of the total global cost, and operational costs represent the difference (95.58%). From the category of production costs, the sub-category of orchard maintenance costs, during the production period (years 4–20), covers the largest share (52.07% of the total category). The table also shows that maintaining the orchard during the first three years involves the allocation of 5.84% of the funds of the main category, the production stage. The costs from the post-harvest area and from the transport area represent 23.48% and 5.93%, respectively, of the total cost of the exploitation in the respective organic orchard. The last column of Table 1 reveals the total costs for the three main categories, which are 0.2657 EUR/FUC (production stage), 0.0884 EUR/FUC (post-harvest stage), and 0.0223 EUR/FUC (transport stage), respectively. Adding up all these costs leads to the total operating cost of the farm, calculated according to the LCCA method, which reaches 0.3674 EUR/FUC (1 kg of fresh apples). The weights of each category, from the total cost, are indicated in the last column. In the following figure (Figure 5), the results of the LCC analysis are presented. (Data source: own processing, based on data from the organic apple orchard, southern part of Romania).



	(A) Agricultural production costs (APC)	(A1) Apple farm establishment	(A2) 1-3 years Orchard maintenance	(A3) 4-20 years Orchard maintenance	(B) Post harvest level (PHC)	(C) Transport cost (TC)	Cost Total LCC
Sum of Investment cost	5,930	120	763	5,047	7,376	-	13,306
Sum of Operational cost	206,608	38,049	16,834	151,726	63,322	17,845	287,776
Sum of Total cost	212,538	38,169	17,597	156,773	70,698	17,845	301,081
Sum of euro/kg apple	0.2657	0.0477	0.0220	0.1960	0.0884	0.0223	0.3764
Sum of RON*/kg apple	1.3284	0.2386	0.1100	0.9798	0.4419	0.1115	1.8818

Figure 5. LCCA results on the cost performances in organic apple orchard. *RON is the Romanian national currency.

Therefore, an extract from a dynamic selection table on the apple supply chain is presented. This presentation allows us to select, from the results field, any element listed in the production process for which the investment and capital costs will be indicated, each of them with the initial cost expressed in EUR/ha and with the processed cost expressed in EUR/FUC/ha for the entire exploitation period of the organic apple orchard.

Next, in the figures below (Figures 5 and 6), some details are exposed regarding the different cost elements, from the production stage, and are presented in the form of a dynamic selection table, allowing for the expansion or contraction of the list of recorded costs, expressed in EUR/ha/20 years and in EUR/FUC/20 years/average yield, respectively.

LCCA Stages - APC Apple suply chain	Sum of Original data (€/ha)	Sum of Reprocessed data (€/1 kg fresh apple)
(I) Apple farm establishment (AFE)	**38,168.53**	**0.04771**
(1) Capital costs at apple farm establishment (AFEinv)	**119.79**	**0.00015**
1.1. Land preparation	52.08	0.00007
1.2. Planting	23.44	0.00003
1.3. Anti-hail support system and net	44.27	0.00006
(1) Operational costs at apple farm establishment (AFEop)	**38,048.74**	**0.04756**
1.1. Clearing (deforestation) - process	520.00	0.00065
1.2.1 Land preparation	210.00	0.00026
1.3. Planting	11,049.64	0.01381
1.4. Anti-hail support system and net	20,460.93	0.02558
1.5. Irigation system/1.5.1. Drilling/drilling operation	1000.00	0.00125
(II) I-III years Orchard maintenance (Field operation cost with out harvesting) (OM.I-III)	**17,596.76**	**0.02200**
(1) Capital costs in the first 3 years of orchard	**763.02**	**0.00095**
2.1. Prunning	36.46	0.00005
2.2. Weeds management	468.75	0.00059
2.3. Fertilization	23.44	0.00003
2.4. Pest and diseases	234.38	0.00029
(2) Operational costs in the first 3 years of orchard maintanance (OMI-III.op)	**16,833.73**	**0.02104**
2.1. Prunning	1619.92	0.00202
2.2. Weeds management	2203.50	0.00275
2.3. Fertilization	4309.78	0.00539
2.4. Pest and diseases	8097.68	0.01012
2.5. Irrigation	602.86	0.00075
(III) IV-XX years Orchard maintenance (Field operation with out harvesting) (OM.IVXX)	**156772.77**	**0.19597**
(1) Capital costs (OM.IV-XX.inv)	**5046.88**	**0.00631**
3.1. Prunning	265.63	0.00033
3.2. Weeds management	2656.25	0.00332
3.3. Fertilization	132.81	0.00017
3.4. Pest and diseases	1992.19	0.00249
(2) Operational costs (OM.IV-XX.op)	**151,725.90**	**0.18966**
3.1. Prunning	4776.15	0.00597
3.2. Weeds management	12,486.50	0.01561
3.3. Fertilization	24,150.88	0.03019
3.4. Pest and diseases	59,249.21	0.07406
3.5. Irrigation	3843.16	0.00480
3.6. Harvesting	47,220.00	0.05903

Figure 6. Table with dynamic selection; apple supply chain.

Based on the built pivot tables, a dynamic processing of the graphics was obtained, in the form of dashboards, by the help of slices (facility offered by Microsoft Excel Office 2019), for all the costs (capital and operational) related to each stage, expressed in Lei and in EUR/FUC.

3.2. Particular Results on the Specific Stages of the Process

Next, below in Figure 7, the results of data processing from the production stage are graphically presented, to which additional data were added regarding the costs and work execution calendars (autumn and spring schedule) from the global process of establishing and operating the apple orchard (source: own processing of information from the production stage, based on data from the experimental organic apple orchard in Bucharest).

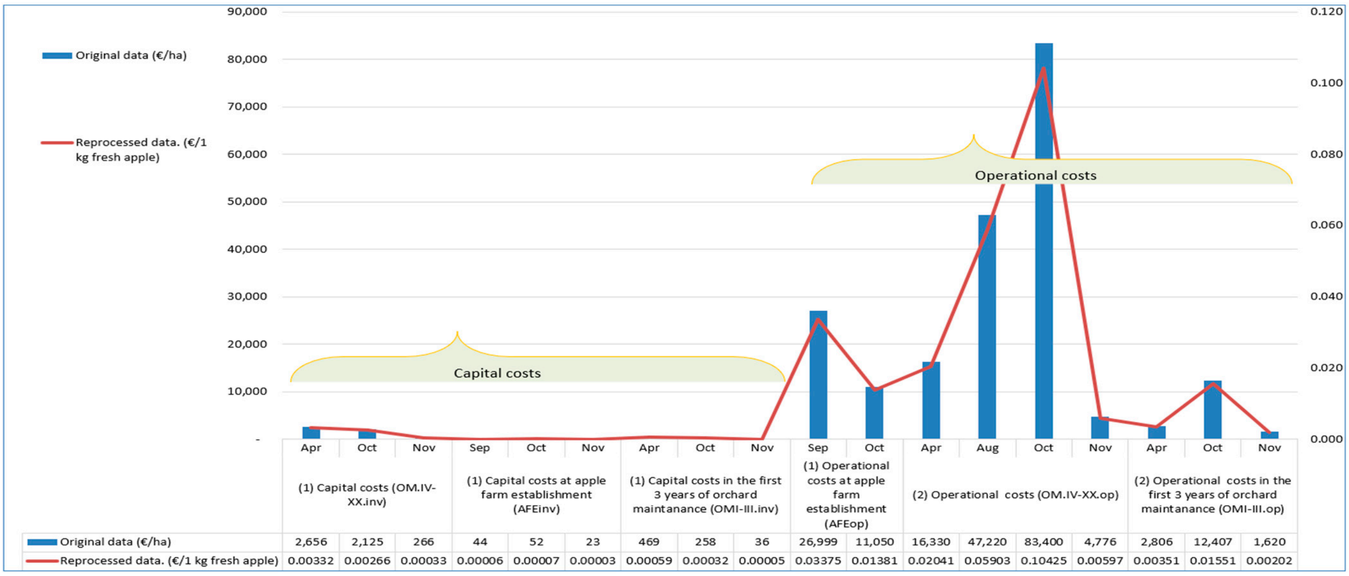


Figure 7. Data processing on the production stage in organic apple orchard.

Integrating the fall and spring calendars in the dynamic visual presentation of the results could be performed with the timeline Excel tools option. Thus, in the figure below (Figure 8), a dashboard in which information can be selectively obtained regarding the costs of the different periods of work performances, within the different stages or sub-stages of the production process in the orchard, as well as data regarding the month in which these works were carried out is presented.

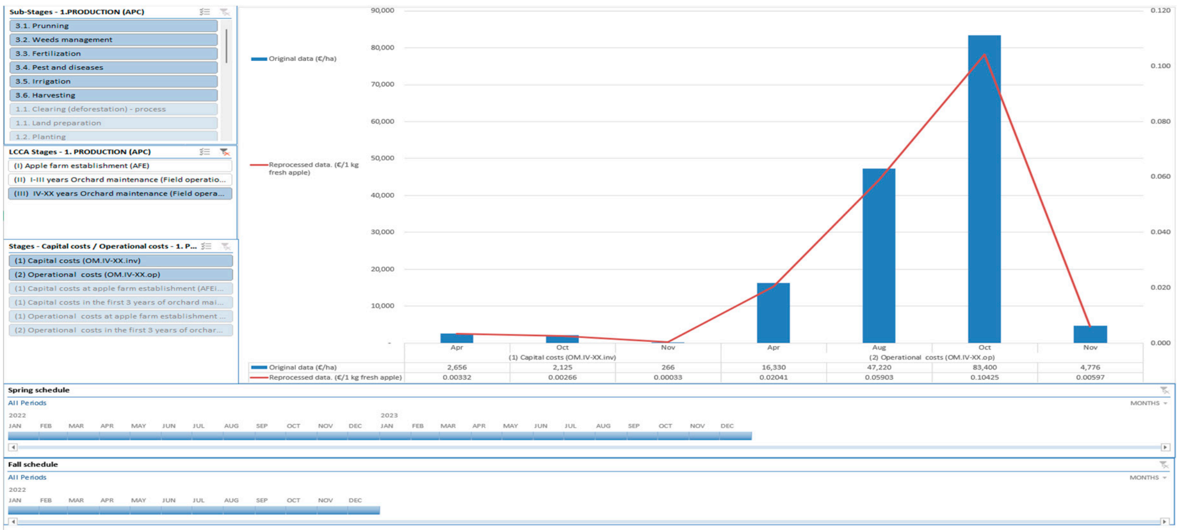


Figure 8. Dashboard with selection on type costs by slices and timelines after the dynamic selection criteria. Production stage.

Hence, in the below example, for the orchard maintenance sub-stage, years 4–20 (the period with harvesting), the related capital and operational costs are displayed (section b of the figure) for both timetables (autumn and spring), namely, 3.1, pruning; 3.2, weeds' management; 3.3, fertilization; 3.4, pests and diseases; 3.5, irrigation; and 3.6, harvesting. In the same way, it is possible to select any other stage or sub-stage, or any period from the registered calendars, for which the dashboard functionalities will display the related costs (capital and/or operating).

The second illustration below (Figure 9) presents the pivot tables which allow for the selective identification of the costs of certain sub-stages for the periods of the attached calendars or for the cost types (investment or operational).

LCCA Stages -PHC Apple suply chain	Original data (€/ha)
(1) Capital costs at post harvest level	**7,375.89**
3.1. Storage (SCi)	7,331.25
3.2. Packaging (PCi)	44.64
(2) Operational costs at post harvest level (PHCop)	**63,321.81**
3.1. Sorting (SCo)	25,496.00
3.2. Storage (SCo)	34,000.73
3.3. Packaging (PCo)	3,825.08

Figure 9. Dynamic table for the post-harvest stage, capital and operational costs, euro/ha.

An illustrative example on the interconnection of the presented results can be found in the two graphs below, which allow us to identify, scale, and graphically visualize the level of operational costs in the post-harvest stage (Figure 10).

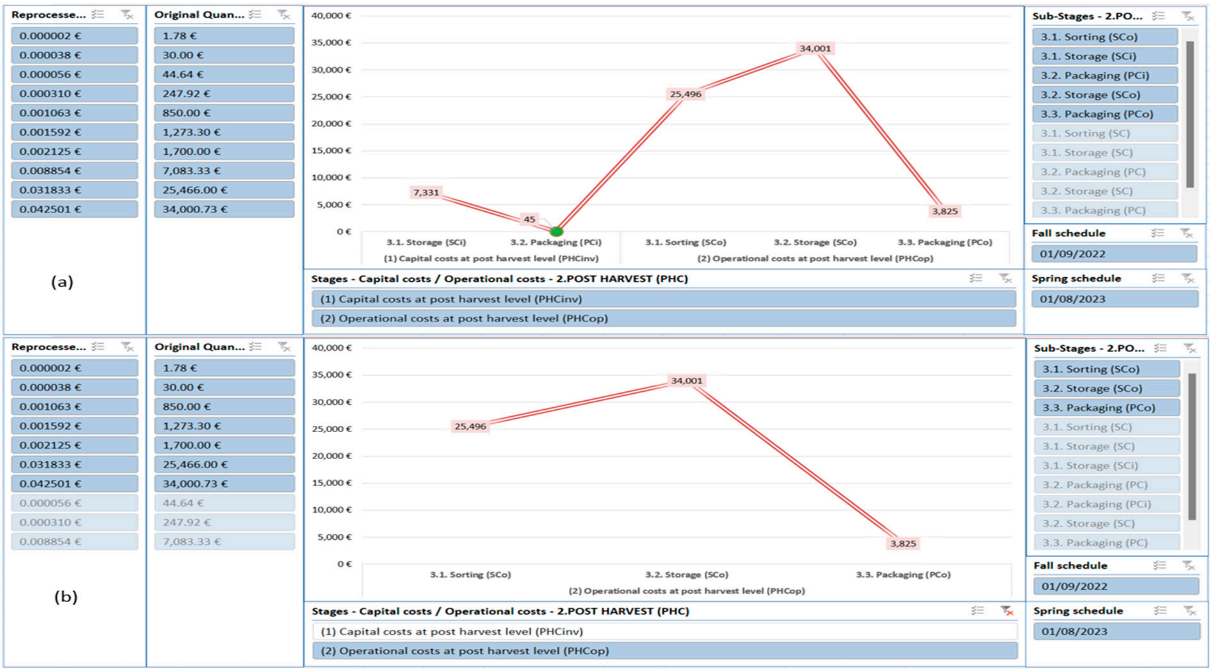


Figure 10. Selective processing and visualization of the costs in the post-harvest stage. (**a**) Entire post-harvest process; (**b**) Post-harvest process after selections of data with slice tools.

The data on the stage of transport, which is, in our case, the last stage of the analyzed process, are captured in the figure below (Figure 11), where the dashboard and the selection slices for the sub-stage of transport from the field to the warehouse are figured.

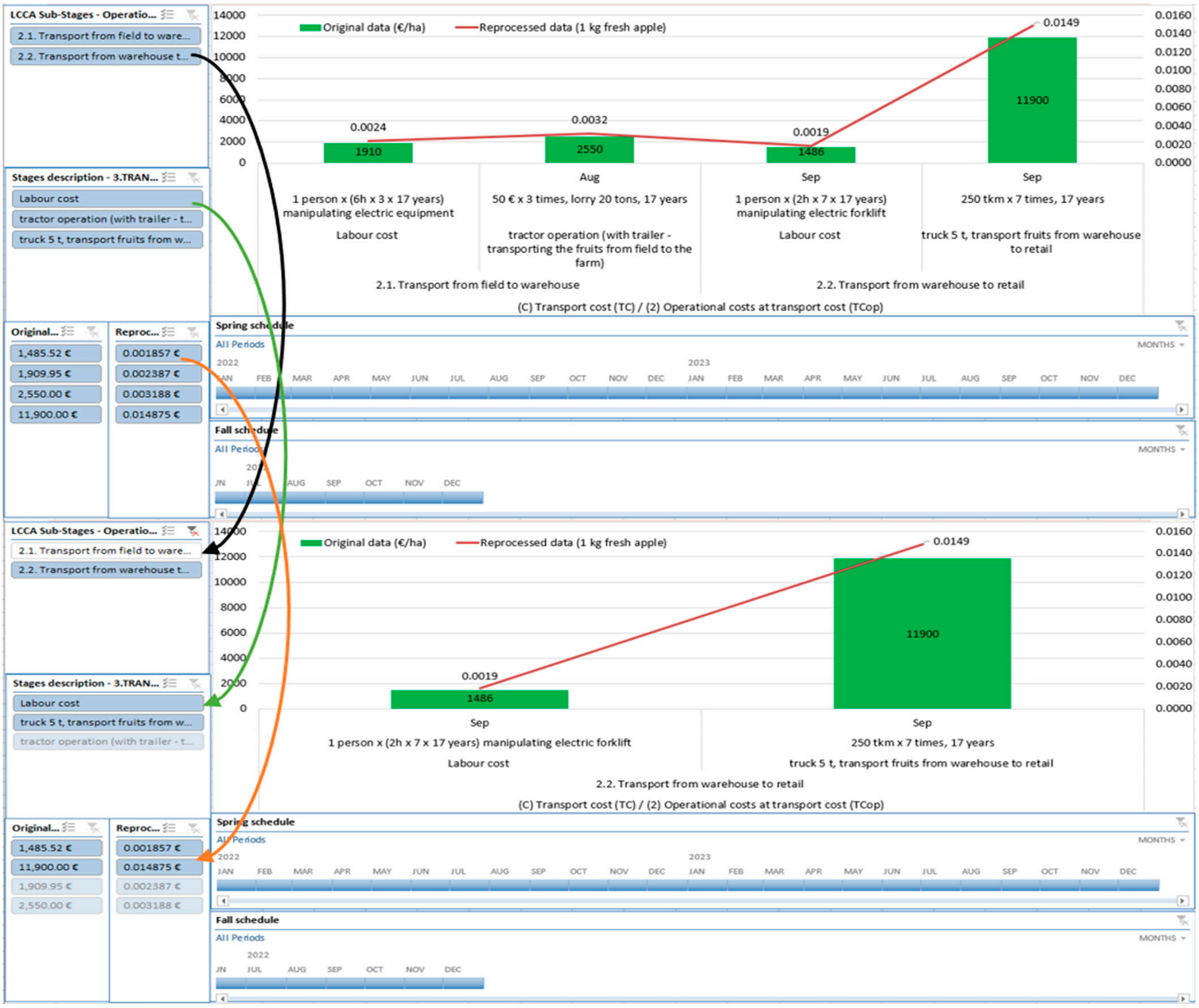


Figure 11. Dashboard and selection slices of the transport stage.

In the figure above (Figure 11), we detect the results after applying a filter on any element of the dynamic fields. In the second layer of the image, we spotted the scaling and graphical representation of the level in the operational costs for the transport stage from the field to the warehouse. Thus, the labor costs and the tractor operation costs are pointed out.

In what concerns the sensitivity analysis, we addressed elements regarding the level of capitalization of the production. This value is achieved by selling fresh apples on the market, for which we express the following notes. In this study, we considered a basic scenario in which 85% of the average yield (40 tons/ha/year) is used, and through the designed scenarios (considered that in the future, there will be conditions to increase the yield), we analyzed the economic indicators for a production of 60 tons/ha, in each of these two cases, having an optimistic scenario (a capitalization of 85% of the total production) and a pessimistic scenario (a capitalization of 70% of the total production). It is considered that the remaining 15% (optimistic scenario) and 30% of the production (pessimistic scenario), respectively, cannot be sold on the market, this representing, as may be the case, losses, transformations into a derived or alternative product (e.g., apple juice and jam), or apples introduced in a composting process, which in the end would represent a re-use in the orchard exploitation process as natural compost. In an exhaustive analysis, the level of capitalization of the production, the capacity, and the costs related to the storage spaces (which most of the time are quite limited) can be examined in detail and could change the results' frame. The table below (Table 2) illustrates the four scenarios presented above.

Table 2. Four economic scenarios for the ecological apple orchard in Bucharest, based on LCC analysis.

LCC (EUR/1 kg of apples) = 0.3764				
LCC (EUR/ha/20 years) = 301,081				
LCC (EUR/ha/year) = 15,054				
Market price EUR/1 kg of apples = 0.8500				
Indicators	S1 (85%)	S2 (70%)	S3 (85%)	S4 (70%)
Average production/ha (kg)	40,000	40,000	60,000	60,000
Orchard life span (years)	20	20	20	20
Total production/number of years of life span, kg	800,000	800,000	1,200,000	1,200,000
Annual production sold/ha/year, kg	34,000	28,000	51,000	42,000
Total production sold/ha/number of years of life span, kg	680,000	560,000	1,020,000	840,000
Value of annual production sold at market price, EUR	28,900	23,800	43,350	35,700
Value of total production sold at market price, EUR	578,000	476,000	867,000	714,000
Profit/ha/year, sold production, EUR	16,102	13,261	24,154	19,891
Profit/ha/20 years, sold production, EUR	322,048	265,216	483,072	397,824

Source: own processing, based on data from the experimental organic apple orchard, Faculty of Horticulture, UASVM, Bucharest.

Thus, the level of the annual production sold and the profit per hectare per year and for the entire period of the exploitation of the organic apple orchard are presented in absolute values. The profit recorded per hectare, related to the sold production, is a gross profit, obtained by subtracting the costs of the production from the value of annual production sold (at the market price) at the same level of capitalization. For this computation, the taxes, fees, and other charges were not counted.

The figure below (Figure 12) helps us to comparatively identify the four scenarios with different levels of production and with different average returns. Meanwhile, within the sensitivity analysis, we tried to determine what would be the required level of production from the two previously presented pessimistic scenarios (70% share of production capitalization), in order to find a solution for obtaining the same level of the benefits as in the optimistic scenarios (when 85% of the production was sold). This was facilitated by Excel 2019 Microsoft's use of the "What if Analysis" section.

The results can be found in the table below (Table 3), from where it can be easily identified that an average production of 48.5 tons, with a capitalization of 70%, would ensure a profit of 322,000 EUR /ha/20 years, as in the case of the first scenario, S2.1, where a production of 40 tons would be recorded, with a share of 85% in the sold production. For the second case, S4.1, an annual average production of about 72.8 tons/ha would be needed to achieve a profit similar to scenario 3, S3, where the production reached 60 tons and the production was sold at a level of 85%. A graphical representation of the two scenarios, S2.1 and S4.1, is provided in the figure below (Figure 13).

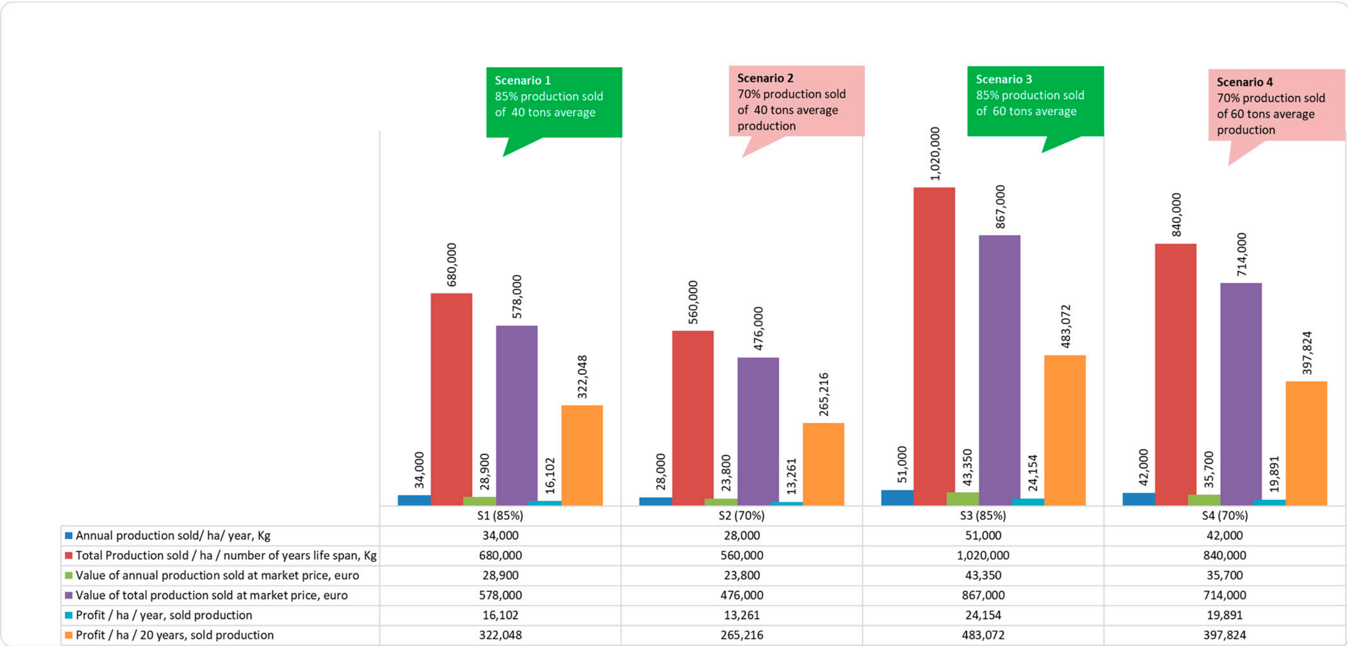


Figure 12. Visual representation of the four scenarios.

Table 3. Scenarios on the financial indicators, using "What if Analysis".

Indicators	S2.1 (70%)	S4.1 (70%)
Average production/ha (kg)	48,564	72,846
Orchard life span (years)	20	20
Total production/number of years of life span, kg	971,284	1,456,926
Annual production sold/ha/year, kg	33,995	50,992
Total production sold/ha/number of years of life span, kg	679,899	1,019,848
Value of annual production sold at market price, EUR	28,896	43,344
Value of total production sold at market price, EUR	577,914	866,871
Profit/ha/year, sold production, EUR	16,100	24,150
Profit/ha/20 years, sold production, EUR	322,000	483,000

Source: own processing, based on data from the experimental organic apple orchard, Faculty of Horticulture, UASVM, Bucharest

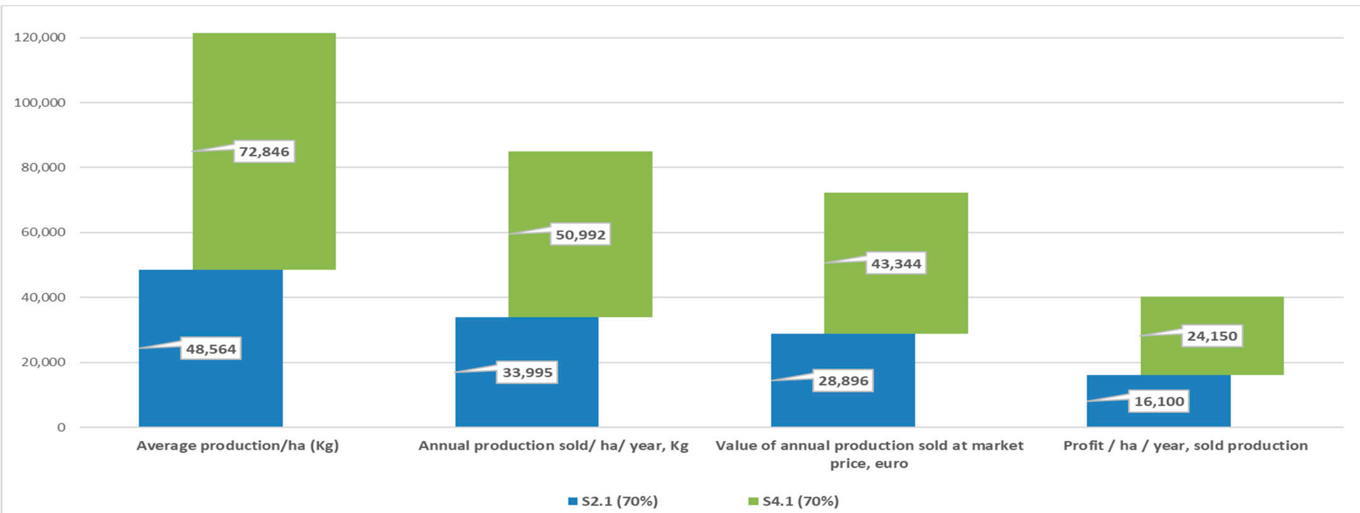


Figure 13. Graphical representation of the four scenarios on the average level of production and the profit.

In this figure, the level of the four economic indicators can be identified: average production, annual production sold/ha/year, value of annual production sold at market price, and profit/ha/year, considering a market price of 0.850 EUR/1 kg of fresh apple.

4. Conclusions

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. However, we acknowledged the limitations of our research design, especially those related to the restrictions of the methodology applied. Moreover, further research should consider a specific investigation that explores a refined economic approach to the organic apple orchard's costs by describing the options for selecting the best parameters which concern the production cycle for a long period of time. For such an investigation, the special features of apple production technics should be identified, and practical recommendations on how they can be improved should be delivered. The LCCA is a method that allows for obtaining reliable results by the degree of data detail needed and by the scope of the lifetime covered for the studied process. Meanwhile, it also has the advantage of limiting or extending the reference period and the limits up to which the system is analyzed. The time period considered can be examined from the first step in the establishment of the apple orchard until its termination, at the limit of the period for normal exploitation, depending on the cultivated varieties and the desire to maintain it. In our case, for an apple orchard operated in an organic system, the LCC analysis 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.

Regarding the three main stages in the farm's exploitation process, we can state, according to the LCC analysis, the fact that the predominant costs are the operational ones, especially those in the production stage (97.21% of the total cost in the main stage). In terms of capital costs, the post-harvest stage is the most expensive (10.43%); the lowest allocation of financial resources was made for the plantation establishment costs. Meanwhile, for the transport stage, we have no capital costs at all in our case, particularly for the orchard, within the boundary system chosen. Even so, the transport operational costs represent only 5.93% of the total LCC, followed at a very long distance by the post-harvest costs at 23.48% of the total LCC cost. The highest costs, representing 151,726 EUR/ha/20 years (52.72% of the total operational costs and 50.4% of the total farm costs/ha/20 years) were recorded in the orchard exploitation stage, in the operational category. At the same time, the scenarios in the sensitivity analysis considered different levels of average productions (40 tons and 60 tons, respectively) and different degrees of production utilizations (85% in the optimistic scenario and 70% in the pessimistic scenario). The hot points identified at the establishment and exploitation stage were the costs related to the use of agricultural machinery, certain pesticides and insecticides, the costs of seedlings, anti-hail nets, plastic boxes, and labor costs. At the post-harvest stage, the most important costs were those related to labor costs and energy consumption for storage capacities. The transport stage had important costs with respect to tractor operations and the track for carrying the fruits. The LCC calculated was 0.3764 EUR/FUC (1 kg of fresh apples). Taking into consideration a level of 85% of the production sold on the market, for 0.8500 EUR/kg (market price), the annual revenue of the farm was evaluated at 28,900 EUR/ha. The calculated profit/ha/year was 16,102 EUR, this means that for the whole period of the farm's exploitation (20 years), the total profit was approximated to be at about 322,000 EUR/ha. Of course, the overall approach in this paper could be improved, and we acknowledge that this study will be completed with a deeper analysis of the financial indicators, in which will provide more information about the real dimensions of the money cashflow, net present value, payback period of the investment, etc. However, in presenting such a large amount of economic information and extensive results, the LCCA methodology should receive greater attention from stakeholders and from the academic research field, especially in order to reduce the environmental burden of food and farming systems.

We have also stressed that, mainly in organic systems, pests and diseases have to be regarded in correlation with fertilization operations. Meanwhile, the system of subsidies can be a very motivating element for the conversion of farms into ecological systems, especially as it is known that, in Romania, organic fruits generally come from exports (e.g., Italy), and, therefore, there is room for expansion and potential on the domestic market. At the same time, the processing of organic fruits (juice and jam) can have an important place in the chain of the valorization of organic productions. We can then appreciate that a substantial food retail market, the fastest growing in the EU, is an important argument to focus all efforts on the further development of trade.

The cost-effectiveness issue is a key component to frame the orchard costs. The LCCA balances initial investment costs with the long-term expense of owning and operating the farm. By comparing the life-cycle costs of various design configurations, it is possible to identify the most cost-effective system. As practical management cost-control strategies, we note the operational stages where manual work is involved and, consequently, the costs are very high. At the apple farm level, the biggest costs come from pests and diseases, fertilizations, harvests, and weed management. There are some alternatives to be implemented, but these are not always easy to do. Namely, for pests and diseases, there is the option to use composts, thus increasing the immunity of the plant and resulting in a smaller number of treatments. For the fertilization operations, in the case of organic farms, there is a recommended alternative to optimize costs by introducing an external composting platform, and, thus, the compost becomes a fertilizer during the year, omitting the need to use commercial fertilizers. At the harvest level, the largest amounts come from labor costs. At the moment, there are advanced robots to facilitate mechanized harvesting at a very high yield, but they are not yet serial products, with affordable prices at the farm level. Another cost management approach regards weed management, where, in the orchard investigated in this paper, this is considered as mechanized management, and where it already optimizes the costs for a sustainable system. Still, there are other alternatives to be used, such as the implementation of a system with cover crops (between rows) and grassy strips per row (e.g., *Trifolium repens*) to reduce the number of passes with machines through the orchard to a maximum of 3–5 passes. We can also introduce more biological treatments (using the system predators—weedy strips), thus improving efficiency and decreasing costs. Additionally, as a special condition for organic productions, it is recommended to store the products in separate areas, far from those of conventional products, if this is ever the case. In conclusion, for this specific issue regarding the LCC analysis, we recommend further investigations.

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Data Availability Statement: The data used in the Introduction section are available at www.insse.ro and www.https://ec.europa.eu/eurostat/data/database. Data used for the LCC analysis are unavailable due to privacy restrictions.

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

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