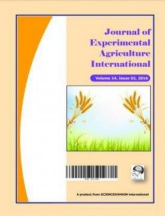

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Feasibility and Economic Risk of Programmed Pruning Cycle in Arabic Coffee

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Authors' contributions

This work was carried out in collaboration between all authors. Authors DCB and SJF designed the study, conducted the experiment in the field and managed the writing of the manuscript. Authors KMV and CMM performed the evaluations of the parameters analyzed in the study. Author DFB performed the statistical analysis. Authors ACVF and NJP managed the writing of the manuscript. Author PMS managed the bibliographic searches. All authors read and approved the final manuscript.

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ABSTRACT

Coffee crop represents a great economic importance in Brazil, in which Arabica coffee represents a great part of the national production. However, the average yield of Arabica coffee is low, which reduces the profitability of the activity. Pruning systems can regain vigor and increase productivity. The system most adopted by coffee farmers is "recepa" (cutting off the orthotropic branch at 0.8 m above ground), which has not resulted in efficient reinvigoration. It is believed that the implementation of new systems, such as programmed pruning cycle, can improve the productivity of Arabica coffee. However, the economic impacts and risks associated with this type of pruning are

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still unknown. The objective of this study was to determine the feasibility and financial risk of the use of programmed pruning cycle compared to traditional Arabica pruning. A financial viability of programmed pruning cycle without Arabica coffee was determined by calculating the Net Present Value and the Internal Rate of Return. Using the sensitivity analysis, to identify the items with the greatest impact on the project. Finally, the financial risk of this technique was determined by the Monte Carlo method. The technical coefficient used for the elaboration of cash flows and is available by the Center for the Development of Agribusiness and the Capixaba Institute for Research, Technical Assistance and Rural Extension. The price data are available from the Coffee Trade Center of Vitória-ES and the Capixaba Institute for Research, Technical Assistance and Rural Extension. The reference year of the data of this work is 2017. A programmed pruning cycle is more economically feasible compared to traditional pruning. It was possible to identify the most sensitive items in pruning systems. The use of programmed pruning cycle of Arabica non-coffee is a practice with zero risk and economic yield.

Keywords: Coffea arabica; pruning management; financial analysis; production costs.

1. INTRODUCTION

Coffee is one of the most valuable primary products in world trade and represents one of the most important agricultural activities in Brazil. Coffee cultivation is present in almost all of the Brazilian territory, with 2,209,097 hectares of cultivation and production of 49.7 million bags of coffee in the year of 2016 [1].

Among the cultivated species, Arabica coffee (*Coffea arabica L.*) and Conilon (*Coffeacanephora* Pierre) are the most economically important in Brazil. Arabica coffee accounts for 79.35% of the planted area, and 81.1% of the country's total coffee production [1]. Although it is the most cultivated species in Brazil and it has a high productive potential, the species present low average productivity, about 21.66 bags benefited per hectare in 2016 [1].

Low productivity may be related to the management that has been used in the crop. One of the most important practice management is pruning, since the coffee farmers accept this management and it is accessible, also it is responsible for the maintenance of productive capacity; recovery of weakened plants; correction of problems related to plant architecture; disease severity control; increased crop longevity; and it contributes to reducing the biennial production [2,3,4].

The traditional pruning used in the crops caused a decrease in productivity in the following year, resulting, in some cases, the total absence of production (zero harvest). [2] reported that the most commonly used types of pruning in Arabica are skeletonization pruning (the plagiotropic branches are cut about 30 to 40 cm from the stem); “recepa” (the stem are cut 40 to 60 cm from the ground); and the “decote” (the apex of the plant are cut at varying heights of 1.60 to 2.60 m). However, these pruning systems represent negative points that hinder cultural dealings in culture. Skeletonization causes changes in the canopy structure, making manual harvesting difficult. As well as in the “decote”, making harvest more difficult and causes super lateral shoot branches, making it difficult for light to enter the base of the plant; and in the “recepa”, the phenomenon of 'zero harvest' occurs in the year following the pruning practice.

Skeletoning is a more efficient pruning system compared to others, but it is not used by small farmers who only use manual operations because of the technical difficulty involved in this process, and also because of the difficulty faced in the manual harvesting process, since this pruning changes the plant architecture making manual harvesting difficult.

For farmers who use mechanization, scaffolding becomes feasible to ease of the operation. In addition, there is a decrease in the production cost that can compensate for the low productivity in the pruning year. In the specific case of the mechanized harvesting operation, in relation to the manual, cost reductions of up to 67% may occur, reflecting higher yields for the farmer [5,6].

In order to implement an efficient pruning system that meets the demand of family farmers, [7], evaluating a new pruning system for Arabica coffee, programmed pruning cycle, verified

increase of productivity, reduction of biennial production, no occurrence of zero and increase of manual harvesting yield of the plants, when compared to pruning traditional pruning.

The programmed pruning cycle consists of 12,000 to 15,000 orthropic stems per hectare, by selecting the ideal number of stems per plant as a function of spacing. Parallel to the selection of the stems, the plagiotropic branches that have reached 70% or more of their production are removed. The stems remain in the plant for three or four harvests, and from that point about 50 to 75% of them are eliminated, in order to allow light to enter the central part of the plant, causing auxin photodegradation and promoting the emission of vigorous shoots. The selections of buds of the base of the plant that will compose the new aerial part are selected during the next three or four cycles of production. The remaining rods will be removed after the next harvest [8,9,7].

However, there is no information about the economic viability of this type of pruning; which in spite of raising crop productivity, increases some production costs, such as farm labor related to pruning and cutting.

[10] verified that in the last two decades the demand for researchers on production cost, profitability and competitiveness in the productive sector of coffee has grown. It is noteworthy the need to carry out studies that verify the economic viability of this new technology. Therefore, the purpose of this study was to determine the feasibility and economic risk of using programmed pruning cycle compared to traditional pruning in Arabic coffee, aiming at family coffee farmers that do not have mechanization in the *Espírito Santo* mountain region.

2. MATERIALS AND METHODS

2.1 Economic Viability Evaluation

The Net Present Value (NPV) and the Internal Rate of Return (IRR) were used as indicators of economic result, according to [11]. These indicators have as an advantage the effect of the time dimension of monetary values and are, in general, the most used. The NPV transfers instantly all expected cash variations, discounting them at a certain interest rate, and adding them algebraically, according to the following equation:

$$NPV = -I + \sum_{i=1}^{n} \frac{CFt}{(1+K)t}$$

Since *NPV* is the Net Present Value; *I* is the capital investment at date zero; *CFt* represents the return on date *t* of cash flow; *n* is the project review period; and *K* is the minimum rate for the investment, or capital cost of the investment project, which is in the study was equal to 10%, which represents the return of capital applied with monetary correction in the savings account.

The IRR of a project is the rate that makes the NPV of the investment cash flow null. It makes the present value of future profits equivalent to the expenses incurred with the project, thus characterizing the rate of return on invested capital, and can be expressed by the equation:

$$0 = -I + \sum_{i=1}^{n} \frac{CFt}{(1+IRR)t}$$

Cash flows are monetary values that represent the inflows and outflows of resources and products per unit of time, which make up a proposal or an investment project. They are formed by inflows (effective revenues) and output flows (effective expenditures), whose differential is called net flow [12]. In order to reflect the real economic potential of the alternatives tested, all prices used in the economic analysis, whether of products or inputs, are represented by real values collected in the region of the study in 2017.

2.2 Sensitivity Analysis

In addition to productivity, other elements that affect cash flow are likely to vary, such as input and output prices. It is difficult to predict at what levels the prices of these items will be in the future, in the years that make up the project horizon. In order to estimate the impact of any variations in the prices of these items on the project results, the sensitivity analysis method is used.

Sensitivity analysis consists of measuring to what magnitude a prefixed change in one or more project variables changes the final result. This procedure allows us to evaluate how changes in each of the project variables can influence the profitability of the investment [13].

The basic procedure to perform a sensitivity analysis is to: choose the indicator to be sensitized; determine its expression in function of the chosen parameters and variables; obtain the results from the introduction of the parameter values in the expression; print variations on one or more parameters and see how and in what proportions these variations affect the final results of the project.

Thus, for the sensitivity analysis of the present study, an unfavorable 10% variation in the prices of inputs and products were considered, and the effects on the Internal Rate of Return of each one were observed.

2.3 Economic Risk Analysis

To evaluate the risk involved in the various systems, the Monte Carlo Method technique was used. The basic principle of this technique is the relative frequency of occurrence of the event of a certain phenomenon tends to approximate the probability of occurrence of this same phenomenon when the experiment is repeated several times assuming random values within the established limits [14]. Examples of using this technique to approach risk in agricultural activities can be found in several studies, such as [15,16,17,18].

Given the impossibility of studying the probability distribution of all variables, the best alternative is to identify, through sensitivity analysis, those that have the greatest effect on the financial result of the project.

In view of the difficulty involved in identifying the probability distributions of each of the most relevant variables, it is common to use the triangular distribution, in which was used in this study. This distribution is defined by the most probable or mode average level, by a minimum level and a maximum level, which is important when a person does not have sufficient knowledge about the variables.

Using the Excel program, the probability distribution for each of the variables is proposed, in this case the triangular distribution. By generating random numbers, values are obtained for these variables, resulting in several cash flows and, consequently, several results indicators for the project. By repeating this procedure a significant number of times, the frequency distribution of the project indicator is generated, which allows to gauge the probability of success or failure.

2.4 Data Source

The study area took place in the northwestern region of the state of *Espírito Santo*, at 634 m altitude, with a climate of type Am (tropical humid), average temperature of 21.4°C, average annual rainfall of 1260 mm and rugged topography.

For the study, a system of rainfed production was considered in non-motorized declivable areas in a crop with a life cycle of 24 years using two maneuvers in relation to pruning. The first one is related to tradition pruning used in the region, in which the plants are cultivated to grow wildly, and cut after the 8th year. After harvesting, the shoots are allowed to grow wildly until the 16th year, when they are re-fed and remain growing wildly until the end of the life cycle of the crop (24th year). In this system there is a zero crop in the 9th and 17th year, and a reduction in productivity in the 10th and 18th year, since the sprouts from the collection are still in the process of growing, due to the collection performed in the 8th and 16th year.

The second management refers to the programmed pruning cycle for Arabic coffee, in which the plants are renewed without zero harvest; because there is the permanence of at least one productive rod in the plant. Renewals, in this case, occur after the 7th, 14th and 21th years, providing the formation of vigorous shoots that will compose the new stems in the next productive period. In the programmed pruning cycle annual elimination of the plagiotropic branches is not very productive, which raises labor costs by pruning and cutting. The information about the performance of programmed pruning cycle in coffee is based on [8,9,7].

While elaborating the technical coefficient matrices of the respective production systems, a concept was used by [19], which defines the set of agricultural practices, practices or techniques carried out in the conduction of a culture, in a more homogeneous way, by representative groups of farmers. The technical coefficients for the preparation of the cash flows and the information attributed to each of them were obtained through information provided by the Agribusiness Development Center [20] and by interviewing researchers and extension agents of

the Capixaba Institute of Research, Technical Assistance and Rural Extension (INCAPER). In addition, part of the information that composes the yield and the harvest yield of the programmed pruning cycle were obtained by the results found by [13]. The price data received by the farmers were collected by the daily quotations of the product, done by the Coffee Trade Center of Vitória-ES. The data of this study refer to the year of 2017.

3. RESULTS AND DISCUSSION

3.1 Evaluation of Economic Viability

In traditional pruning, the NPV was positive only at discount rates lower than 3.61%, different from what occurs when programmed pruning cycle is used, in which NPV is positive at a rate of 15.30% (Fig. 1).

Through the data related to NPV, it is possible to verify that pruning represents a great economic impact on the coffee crop. If a minimum rate of the attractiveness of 12% is considered, coffee crop managed with traditional pruning using "recepa" becomes unfeasible, since this management generates an IRR of only 3.61%. On the other hand, the implantation of programmed pruning cycle is feasible, since it generates a IRR of 15.30%, about 3.3 percentage points more than the minimum rate of attractiveness. This result occurs due to the increase of the productivity and absence of the 'zero harvest' phenomenon provided by this innovative type of pruning, the cycle pruning cycle. On the other hand, in traditional pruning, there is no return in the year after this practice due to zero harvest, thus justifying the low IRR.

When it is sought to implement new management techniques in agricultural production systems, the economic study of the production cost is important for decision making; since it helps the investor with an indication of the choice of the production system to be adopted and followed in order to which obtains better economic results [21]. In the present study, the economic study reveals that the new pruning system is more efficient than traditional pruning in the productive system that covers the reality of family coffee farmers in the mountain regions, providing important information for coffee farmers who fit into such realities.

3.2 Sensitivity Analysis

Through a sensitivity analysis, after an unfavorable 10% variation in input and output prices, there was a greater sensitivity of the IRR to changes in the coffee price, followed by the land price. Then they had an impact on profitability, the cost of labor, fertilizers and grain drying.

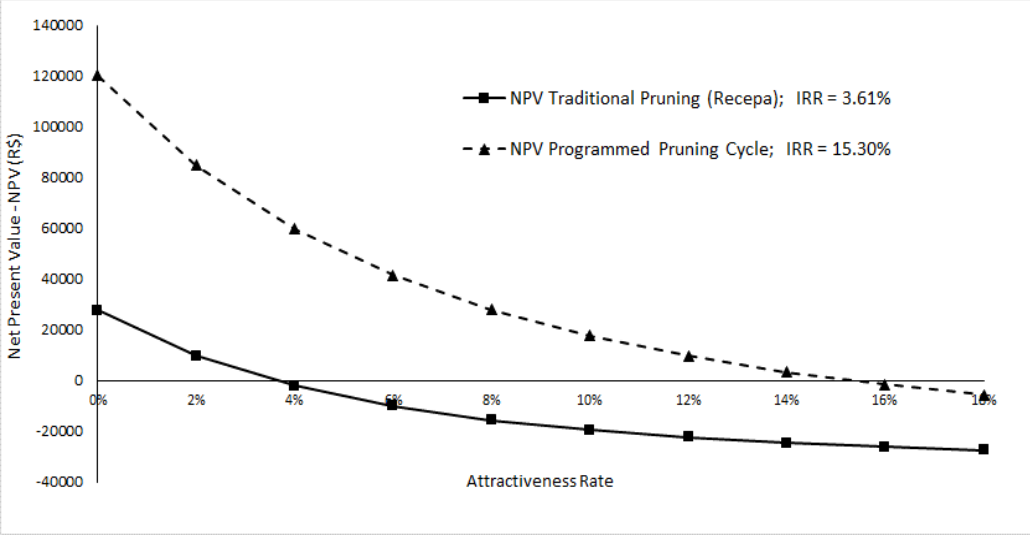

Fig. 1. Net present value (NPV) with a common planning horizon as a function of the different attractiveness rates, and internal rate of return (IRR) for Arabica Coffee crop conducted with two pruning operations

It can be observed that in both types of pruning the variable "Product Sale" was the one with the greatest impact on IRR. Thus, the 10% decrease in the coffee benefited price would reduce the IRR of 4.67 and 4.09 percentage points for the coffee planted with the programmed pruning cycle and with the traditional pruning, respectively.

From the sensitivity analysis, the items that affected the financial results of each type of pruning in the Arabica coffee crop were classified in order of importance. For programmed pruning cycle, in addition to "Product Sale", the most economically relevant items are: "Land Purchase", "Total farm Labor", "Nitrogen-N", "Drying and Processing" and "Potassium -K_2O. For traditional pruning, in addition to the "Product Sale", the most important items would follow the following order: "Total farm Labor", "Nitrogen-N", "Land Purchase", "Drying and Processing" and "Potassium -K_2O.

The order of importance of each item in the financial results may be different among the pruning systems, although the value invested in these items have been equal. This is because the sensitivity analysis compares the value of the item to the net revenue of the project. Therefore, the impact of a certain item is linked to the net revenue of the project

Considering that the net from programmed pruning cycle were higher than those of traditional pruning, it has been shown that the increase in the purchase value of a certain item has a lower impact on the IRR than the programmed pruning cycle when compared to traditional pruning.

The items indicated by the sensitivity analysis are, among all items in the cash flow, the ones that most impact the economic viability of the project, i.e., negative changes in the prices of these items may make the project unfeasible, as well as, positive changes may increase financial viability.

According to [22], the high production cost, decisively influenced by the scarcity and high cost of labor, is one of the main problems faced by mountain coffee farmers today, reflecting in the one observed in the present study, in which the coefficient of labor in the traditional pruning system was one of the most important items in total cost.

It is possible to observe that the farm labor represents a greater economic impact in the traditional pruning than in the programmed pruning cycle. Therefore, the programmed pruning cycle changes the architecture of the plants and according to [7], is one of the reasons for increasing manual harvest yield. It can be affirmed that the practice of pruning among the other items demands greater labor.

Within the work item, practices with greater relevance are the harvesting, pruning and stripping. Deforestation is a manual process and is, therefore, a problem, especially for large coffee farmers who have automated cropping techniques, since it would be necessary to hire a large number of employees, who often have little knowledge on the activity and increase the production cost [23,24]. In programmed pruning cycle, there is a decrease in the emission of shoots due to the self-shading exerted by the plant, a fact that can corroborate the reduction of labor costs in this pruning system.

3.3 Economic Risk Analysis

Even though programmed pruning cycle in Arabica coffee seems to be a viable activity, there are uncertainties mainly in the price paid for the product. One of the purposes of the economic evaluation of projects is to reduce the great risk assumed in the decision-making, so that the farmers know the margin of safety of the results of the analysis before making his/her final decision.

Sensitivity analysis, which considers the influence of each variable on the project results, is the first step in dealing with risks. However, several variables can fluctuate simultaneously. Therefore, it is important to have a sense of the probabilities of occurrence of adverse situations involving the most important variables of the project, as well as their consequences on the financial results.

Therefore, the accumulated probability distribution of the NPV of the different pruning managements, obtained by means of Monte Carlo Method, is expressed in Fig. 2. It is known that the information used in the evaluation of projects are always important for the future of the variables values which form the cash flow and, therefore, are estimates that can led to errors. With this analysis, it is possible to estimate the probability that the project will become unviable, given the risks that the projections adopted in the cash flow will not be done with the implementation of the project.

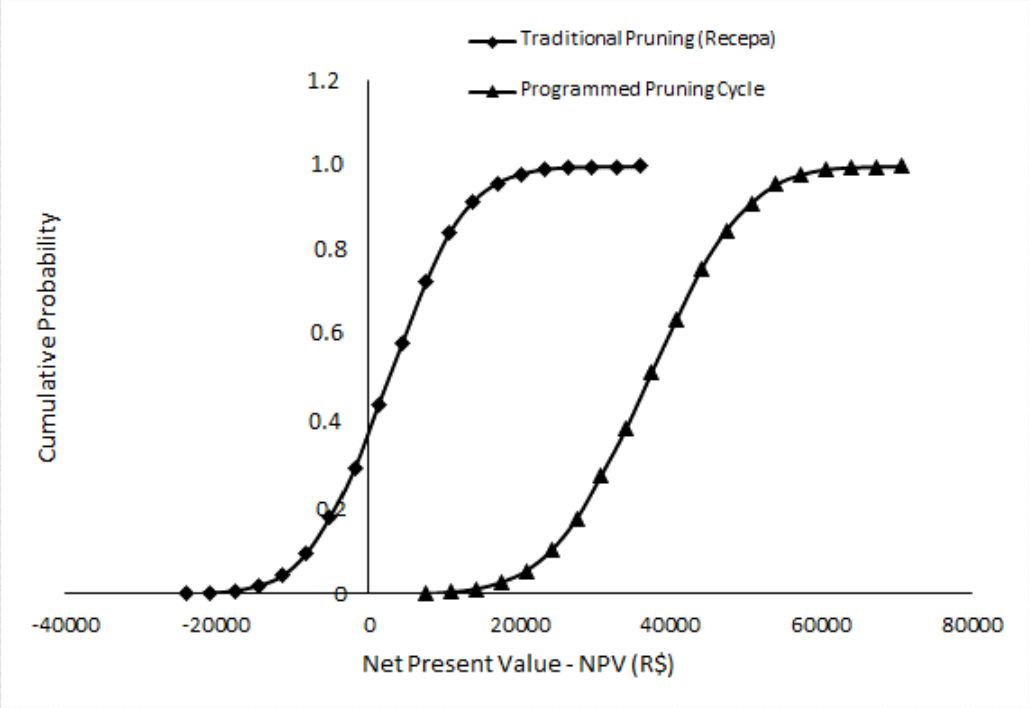

Fig. 2. Cumulative probability distribution of the net present value (NPV) obtained by Monte Carlo method of the cultivated Arabica Coffee planted with two pruning managements

The risk analysis uses the most economically important items to estimate the cumulative probability of NPV being negative by changing the values in these items. The greater the cumulative probability of NPV being negative, the greater the economic risk. In programmed pruning cycle there is no probability of negative NPV occurrence, so the risk is zero.

It can be observed from the Monte Carlo Method that when using programmed pruning cycle, the NPV probability is negative, at attractiveness rate of 10% it is null, in other words, this pruning system besides being economically feasible presents greater stability and investment certainty for the coffee farmers. Another very important item, labor, is reduced in programmed pruning cycle, and consequently, there is a decrease in the total cost and the economic risk involved. In relation to traditional pruning, it is observed that there is a 30.5% probability of NPV being negative. Therefore, considering the possible fluctuations in the prices of the most important items for the project results (defined in the triangular distribution), the probability that, under traditional pruning, the activity becomes unviable under less favorable market conditions is relatively high.

In addition to ensuring greater income stability and lower risks to family coffee farmers, programmed pruning cycle in Arabica coffee crop presents great diffusion potential, since it is easy to be understood and carried out, and also because this pruning is already done and well accepted in Conilon coffee crop. Therefore, it is recommended the practice of programmed cycle pruning in Arabica coffee, since it increases the productivity of the crop and guarantees income and permanence of family farmers who do not have mechanized operations in the activity.

4. CONCLUSION

For the discount rates considered and under the study conditions, programmed pruning cycle is less likely to obtain negative net present values, thus being more economically viable than traditional pruning, for family coffee farmers that do not have mechanization.

The sensitivity analysis indicated for the programmed cycle pruning the most economically relevant items that are: "Product Sales", "Land Purchase", "Total farm labor", "N-Nitrogen", "Drying and Processing" and "Potassium-K_2O". For traditional pruning, in

addition to the "Product Sale", the most economically relevant items are: "Total Workforce", "N-Nitrogen", "Land Purchase", "Drying and Processing" and "Potassium-K_2O ".

The economic risk associated with programmed pruning cycle in Arabic coffee is zero, for family coffee farmers that do not have mechanization.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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