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Sustainable Management of Coffee Production in the Cerrado Mineiro: The Contribution of Kaolin to Commercial Crops

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Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
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ABSTRACT

The coffee culture occupies a prominent role in the national context, and it should be noted that the planting of coffee in full sun in Brazil began after the liberation of slaves with the reduction of labor at low cost. In general, the degree of luminosity is the main factor responsible for coffee production because it affects the vegetative and floral buds, which later become the fruits. There are ways to mitigate the loss of productivity caused by climatic adversities, specifically the increase in air temperature and excessive solar radiation. In this context, the present work aimed to discuss the application of kaolin in commercial coffee crops with rural producers in the cerrado of Minas Gerais, as a sustainable agricultural production practice. For this, a field research was carried out with sixteen coffee farmers who grow Arabica coffee (*Coffea arabica L.*), in full sun, in the Cerrado biome of Minas Gerais, and who spray the mineral kaolin during the production management of the crops. It can be observed that the farmers interviewed seek to understand and apply some kind of sustainable management for the crop and that most see the application of kaolin in a positive way, being necessary, however, to implement environmental education projects that deal better with this topic among coffee growers in general.

KEY WORDS: Sustainability. Coffee farming. Climate Change.

1 INTRODUCTION

The consolidation of Brazilian agribusiness, based on coffee farming, is closely related to biotic and abiotic factors. The set of these factors, when in unbalance, can cause significant losses in productivity and quality of products produced in the field (ASSAD; MAGALHÃES, 2014).

The productivity and taste of coffee, as well as intensity of pests and diseases, are related to the behavior of the climate, particularly temperature and humidity (EMBRAPA, 2019). The most suitable regions for the cultivation of Arabica coffee of high quality and productivity, are the mountain regions, located at an altitude above 1200 m (BUNN *et al.,* 2015) and average annual ambient temperature between 18°C and 22°C (CAMARGO, 1985).

In Brazil there are six coffee producing states, headed by Minas Gerais which is responsible for more than 50% of the total produced, over a cultivation area of more than 1 million ha and occupying more than a hundred thousand farmers (EMBRAPA, 2020). Studies on the impacts of climate change and coffee plantations indicate an increase of approximately 0.25°C every decade, concomitantly with a reduction in the annual rainfall accumulated during the flowering and ripening periods of the beans. This set of adverse climatic events, caused a reduction in productivity above 20%, particularly in the Southeast region, notably Minas Gerais, the largest coffee producing and exporting state in Brazil, so the climate risk translates into risk of reduced production and increased social vulnerability of coffee growers (ILYUB *et al.,* 2020).

Scientific studies highlight the sensitivity of the coffee plant under adverse weather, specifically, instability in the rainfall and air temperature regime, thus, more than 90% of coffee plantations, already installed, would be compromised if there is an increase of 6°C in the current average air temperature (ASSAD; MAGALHÃES, 2014).

There is tacit evidence that climate change has already begun, and also the impacts on coffee production, and other key global crops (LOBELL; SCHELENKER; COSTA-ROBERTS, 2011). In 2014 the state of Minas Gerais, the largest coffee producer in the country and responsible for a quarter of total production, experienced a period of severe drought, accompanied by highs, motivating trade speculators, to anticipate price hikes (COOKE, 2016). The physiological

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

behavior and productivity of all *Coffea spp* crops depend on the fertilization of flowers, the birth and filling of the grains. In the period of prefloration and also in the initial phase of the coffee bean (chumbinhos with size between 4.0 mm and 6.0 mm in length) the presence of low relative humidity and, simultaneously, temperatures in the range between 20ºC and 23ºC cause dehydration of floral buds, known as "floral abortion" (sterile flower), and fall of "chumbinhos", influencing significant losses in productivity (MATIELLO; FERREIRA, 2016).

The concern with land occupation and the environmental impacts of human actions can be observed in world conferences on the environment. Presented and approved at the United Nations General Assembly in 1983, the Brundtland Report made explicit the concerns with the consequences of promoting economic growth. In it, sustainable development is defined as: "that development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (CMMAD, 1991, p. 9).

This report supported the need to rethink development so that it could promote current and future human progress (GUERRA, 2010). Thus, the production system, analyzed through the lens of environmental sustainability, should devote efforts to increase production considering other important aspects, such as the biome, the health and longevity of crops, the reduction of biennial impacts and the reduction of the impacts of soil depletion (KHATOUNIAN, 2001). It is worth noting that Brazil, the fifth largest country on the planet, has a total area of 851.57 million hectares, with use and occupation in different ways.

Agriculture and cattle raising activities occupy 255.47 million hectares, of which 21.2% are for native and cultivated pastures, 1.2% are covered with planted forests, and only 7.8% are used for various crops. 562.03 million hectares, or 66% of the entire national territory, is theoretically occupied by integral conservation units, untouched native vegetation and indigenous lands, which is why Brazil is recognized as the country that preserves the most native areas, compared to other nations (EMBRAPA, 2019).

Considering the coffee agribusiness and the main production regions, all rural properties have, on average, a percentage of the area dedicated to the preservation of native vegetation above the minimum established by the Brazilian Forest Code (CFB). In Minas Gerais, the figure is 34%; in Espírito Santo, 33%; São Paulo, 22%, and in Bahia, 45% of the areas dedicated to preservation (EMBRAPA, 2019). The evolution of the Brazilian legal system driven by the International Conferences on the Environment within the United Nations Organization currently imposes on the coffee grower a more rational and sustainable posture in coffee cultivation (REZENDE; CAMPOS, 2017).

The effect of afforestation provides thermal comfort to the coffee plantation and has beneficial effects on the soil because it promotes a change in the microclimate, influencing the physiological processes of the coffee plant. It then becomes a strategic alternative to the climatic adversities, especially the change in temperatures.

In coffee cultivation, climatic adversities cause direct impacts, in the reduction of productivity and indirect impacts, generating economic instability especially in rural communities, which depend for their livelihood on the edaphoclimatic conditions for the good performance of crops. Climate change is an imminent threat to the integrity of the coffee growing system in Minas Gerais in the long term (VIEIRA, 2007).

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

2 OBJECTIVE

In this context, the present work aimed at analyzing and discussing the contribution of kaolin to commercial coffee crops in terms of sustainability and environmental protection, based on the application and analysis of questionnaires applied to coffee growers whose properties are located in the Cerrado region of Minas Gerais.

3 METHODOLOGY

This work is characterized as descriptive research, which includes the observation of the facts recorded and analyzed without any form of manipulation of the researcher (PRODANOV, FREITAS, 2013). It is also exploratory research, given that the objective of this research is to provide more information about the subject of investigation (PRODANOV, FREITAS, 2013; GIL, 2008).

As for the technical procedure of data collection, it is classified as field research. In the field research phase, sixteen individual interviews were conducted among the known universe of sixty-five coffee growers who cultivate Arabica coffee (*Coffea arabica L.*), in full sun, in the Cerrado biome of Minas Gerais, and who have been spraying the mineral kaolin during crop production management for at least two consecutive harvests, as a sustainable alternative for the protection of plants against excess solar radiation and high temperatures, as an innovative and affordable alternative to replace the shading of coffee by the canopy of native trees.

The sample is intentional, also known as "judgment sample", and is part of the non-probability sampling group. It is a type of sample that demands greater participation and involvement from the researcher in choosing the elements of the population that make up the sample (FLICK, 2009). The choice of this type of sampling is based on the fact that the kaolin mineral used in the management of full sun coffee farming, the object of this research, was recently introduced in the Brazilian market (EMBRAPA, 2016). Therefore, the number of farmers-users of kaolin, compared to the universe of coffee growers in Brazil, is limited (RODA *et al.*, 2020).

The sixteen rural properties that make up the sample are located at an altitude between 900m and 1,150m above sea level, ideal for coffee cultivation, within the Cerrado Biome of the state of Minas Gerais, considered the second largest biome in both South America and Brazil (EPAMIG, 2011).

The interviews were conducted in October and November 2021, after approval by the Research Ethics Committee of PUC-Campinas (No. 4.992.909 issued on September 23rd, 2021).

4 RESULTS

On the 16 farms which were visited, the use of kaolin as a coffee protector was an adopted practice. This would suggest that this was a group of farmers particularly aware of the challenges of environmental preservation in coffee cultivation. When asked, all, in different ways, recognized themselves as responsible for environmental preservation. It is possible that the concept of environmental preservation, that is, of integral protection of the environment

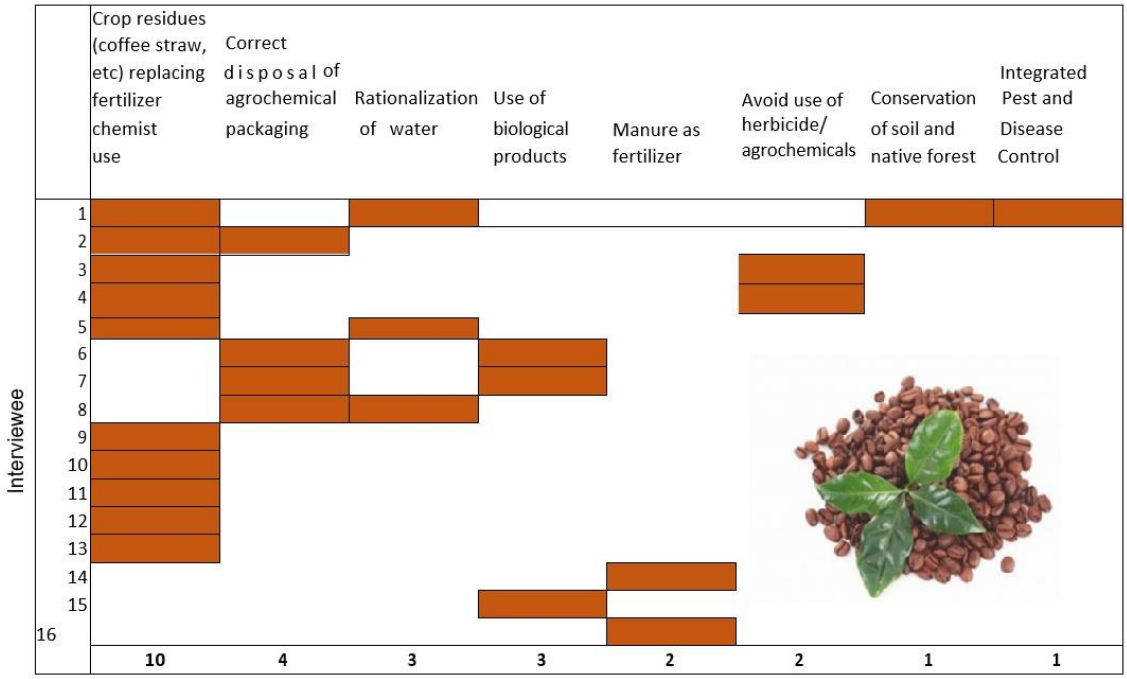
Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"
ISSN 1980-0827 – Volume 19, Number 5, Year 2023

from anthropic actions, was used in different ways, inappropriate by the farmers. It is likely that they were thinking about environmental conservation, i.e., they were considering the sustainable use of natural resources.

To this end, the vision of environmental sustainability was investigated. For 15 respondents "It is the use of natural resources, such as soil and river water, enough to produce coffee and thinking about leaving it to my descendants. Only one respondent defined it as "the use of natural resources, such as soil and river water, as much as necessary to increase coffee production, even if it is very intense.

It can be observed that the participants were aware of the importance of environmental sustainability of their own actions, even if, in front of the pressure of production, they may resort to intensive use of soil and water. The question about environmental sustainability then focused on the description of practices that they adopted, Figure 1 allows us to observe that the most frequent practice, in 10 of the 16 farms, is the replacement of chemical fertilizer by residues from other crops, such as coffee straw. The correct disposal of chemical product containers, mentioned by 25% of the interviewees, confirmed the relevance of having legislation that disciplines the correct handling and disposal of empty containers of pesticides (Law 9974 of 2000). It is noteworthy that only one respondent mentioned the integrated control of pests and diseases.

Figure 1 - Vision on sustainable practices that can be adopted in coffee production



Source: Own elaboration, 2022.

The same figure highlights the disparity of knowledge and actions among farmers. Only one of them reported the adoption of four different sustainable practices. Seven respondents suggested two practices and 50% of the participants only one. The free responses to these

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

questions highlighted the need for environmental education actions that promote the dissemination of knowledge of additional techniques that promote environmental sustainability, in addition to the importance of environmentally friendly legislation.

In general, it can be said that in relation to the management of the coffee crop there are practices that can mitigate losses in productivity caused by climatic adversities, specifically the increase in air temperature and excess solar radiation. This is the tree shading system under the canopy of native or cultivated trees, widely observed in Costa Rican coffee cultivation (ICO, 2017).

The Brazilian coffee grower has little tradition in growing coffee in shaded tree systems, however, there is research dedicated to the Agroforestry System (SAF) that endorses the possibility, successfully, of the practice in some regions, which offer suitable soil and climate conditions (MOURA *et al.,* 2018).

In tropical regions, the use of afforestation promotes the reduction of ambient temperature, driving improvement in flowering and reduction of the rate of floral abortion (DA MATTA *et al*., 2007). Thus introducing this concept within sustainable practices for height becomes interesting and promising.

In this way, kaolin can be treated as an ecologically appropriate input for the management of commercial crops, presenting itself in the form of processed and purified rock powder is a product of low environmental impact, non-toxic to the environment and living beings. Sprayed on the plants in mixture with water, after evaporation it forms a microscopic film of mineral adhered to the surface of the plant, which performs the function of heat stress reducer, specifically in those parts of the plant that are exposed to solar radiation and high air temperatures, reducing burns, contributing to the increase of production and the improvement of the quality of the fruits (MPHANDE *et al*, 2020; SHARMA; REDDY; DATTA, 2015; SMEDT; SOMEUS; SPANOGHE, 2015; GLENN; PUTERKA, 2005).

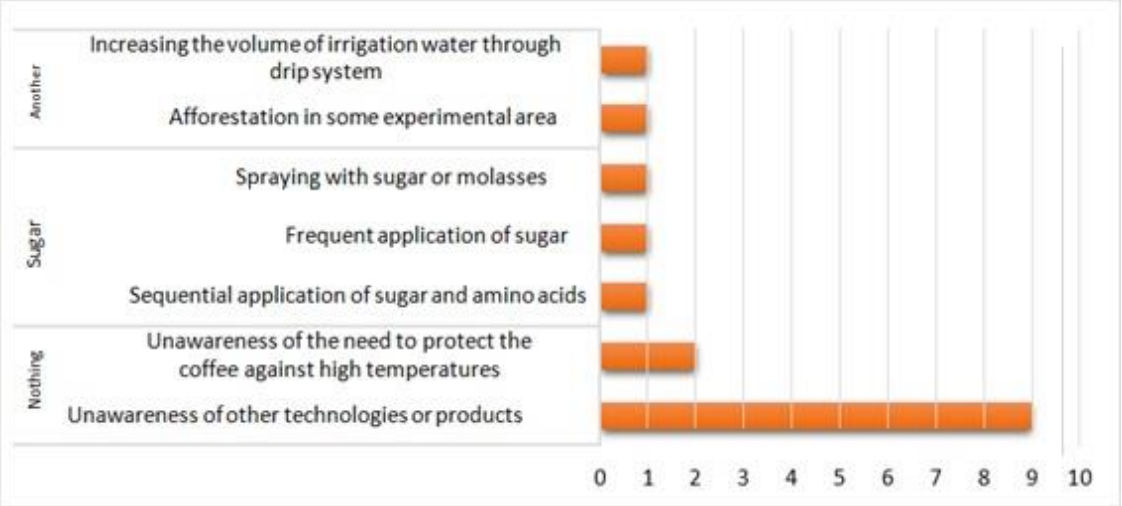
Chemically inert, kaolin (Al4 Si4 O10 (OH)8) has a soft texture, high hygroscopic capacity, and a wide pH range. This mineral, commonly found in white color, does not undergo dilatation, is non-abrasive, and has low thermal and electrical conductivities; therefore, it is a raw material widely used as a pigment, and as an inert to reinforce the load in product formulations (GLENN; PUTERKA, 2005).

Scientific publications prove the efficiency of kaolin in various crops, since the mineral particle film that forms with its spraying on plants reflects solar radiation, reduces heat accumulation, reduces oxidative stress, reduces water loss by transpiration, promoting abiotic stress relief, unfolding in improvement of the functioning of physiological, morphological and biochemical mechanisms of the plant (BRITO *et al.*, 2019).

When the farmers in the sample of this study were asked about mitigating actions against high temperatures, before the adoption of kaolin, eleven interviewees stated that they did not take any measures, either because they were unaware of appropriate technologies or because they were unaware of the need to protect crops from high temperatures (Figure 2).

Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"
ISSN 1980-0827 – Volume 19, Number 5, Year 2023

Figure 2 - Mitigating actions against high temperatures and solar radiation



Source: Own elaboration, 2022.

One practice, stated by three farmers, was the application of sugar. One of them stated that it is a "Technology that I learned in South Africa and used on the crops in Hawaii, but it doesn't even compare to kaolin. I used it as an improvisation to reduce abiotic stress". According to another interviewee sugar increases "the speed of uptake of leaf fertilizer and thus the plant is more nourished and therefore more resistant to temperature stress." Another option chosen to help the plant was to increase drip irrigation. Finally, only one of the interviewees resorted to planting trees that could shade the coffee plantation, as shown in Figure 2.

A study conducted at the experimental station of the Empresa Brasileira de Pesquisa Agropecuária de Minas Gerais (EPAMIG) revealed that the parts of the coffee plant exposed to the sun suffer damage to the cell structure due to the high degree of chlorophyll degradation, (MOUTINHO-PEREIRA *et al.,* 2009). Aware of the importance of protecting fruits and leaves, respondents mostly evaluate very positively the use of kaolin (Figure 3). It is worth noting that the benefits recognized in protecting the leaves slightly outweigh the benefits in protecting the fruits. In the latter case, approximately 8% expressed dissatisfaction with the product.

Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"
ISSN 1980-0827 – Volume 19, Number 5, Year 2023

Figure 3 - Evaluation of the effects of kaolin

Source: Own elaboration, 2022.

Processed, purified and formulated kaolin is classified as a non-hazardous, non-flammable, odorless agricultural input, free of any type of chemically synthetic ingredient,thus, due to this set of characteristics it is classified in Brazil as an agricultural input exempt from the obligation of registration for marketing and use, both by the Ministry of Agriculture, Livestock and Supply (MAPA), as well as by the National Health Surveillance Agency (ANVISA) and the Brazilian Institute of Environment and Renewable National Resources (IBAMA), agencies that regulate all types of agricultural inputs in Brazil (CGAA, 2014).

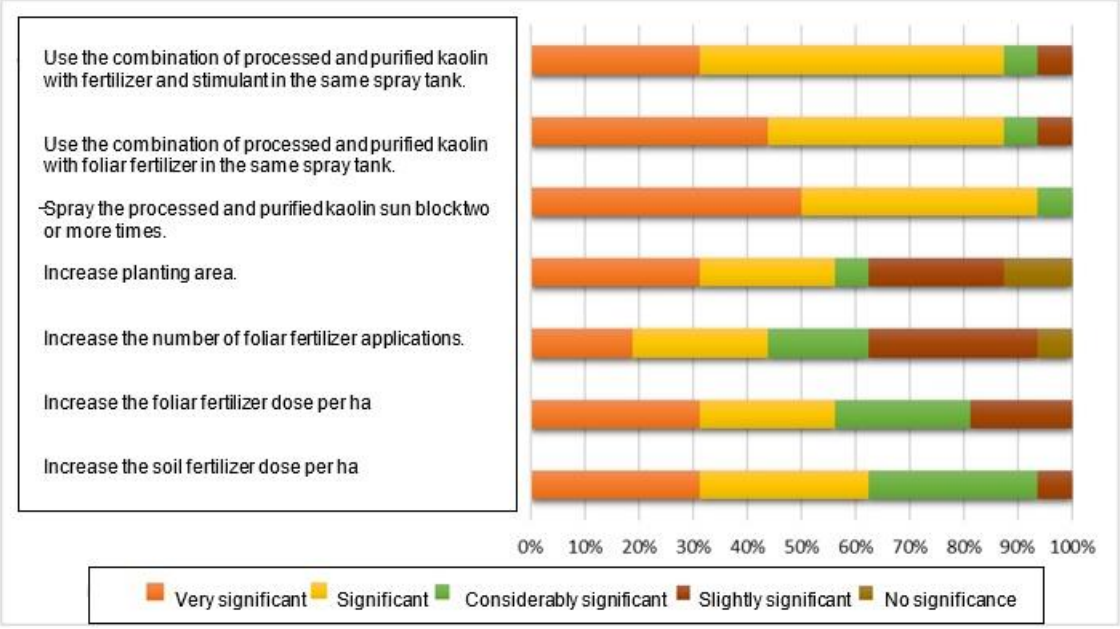
After pulverization, the kaolin forms a mineral particle film on the surface, which provides relief from abiotic stress, due to the reduction of water loss by transpiration, increase of the water rate in the plant, and improvement of stomatal conductance. These changes positively influence the biochemical, morphological, and physiological mechanisms of the plant, promoting as a consequence, a greater sanity to the leaves and fruits, besides the reduction of chlorosis or burns, caused by oxidative stress (BRITO *et al.*, 2019).

Field studies show that the parts of plants exposed to full sun protected after kaolin spraying, when compared to non-covered plants, presented an average reduction of 4°C, generating greater thermal comfort (KHALED; HAGAN; DAVENPORT, 1970). In the same study, the authors affirm that due to the formation of the kaolin film on the leaves, a 25% reduction in the transpiration rate of the plants was also observed.

Finally, once the use of kaolin had been evaluated, knowing the impacts of high temperatures on farming, and aware of the importance of adopting sustainable practices, there was an interest in knowing what actions were being planned to increase coffee production, as presented in Figure 4.

Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"
ISSN 1980-0827 – Volume 19, Number 5, Year 2023

Figure 4 - Possible actions to increase production



Source: Own elaboration, 2022.

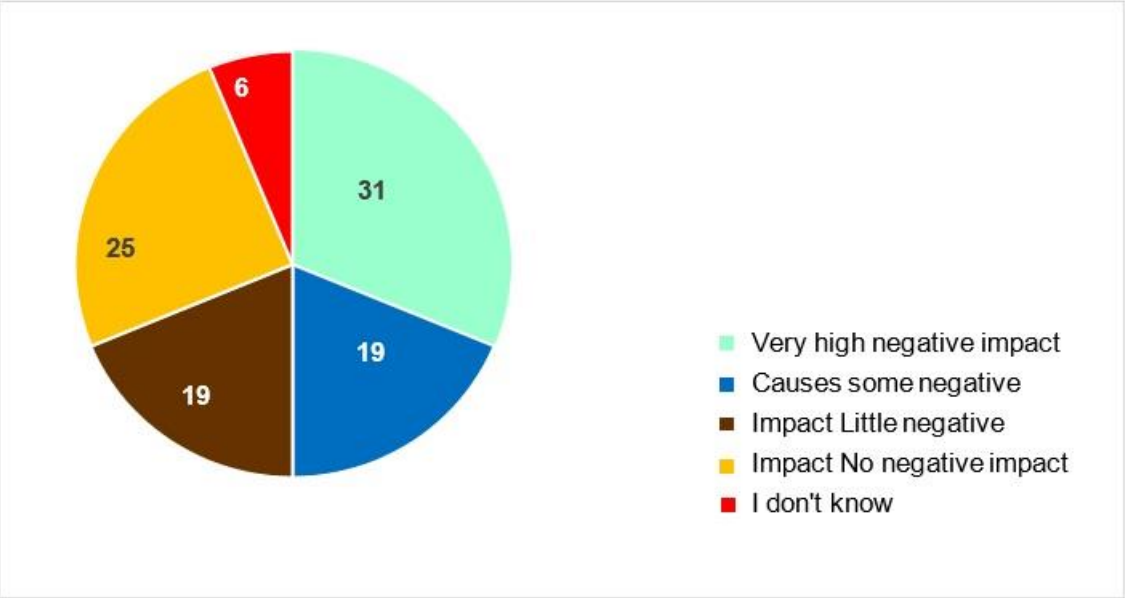
In general, dealing with agricultural crops, the kaolin mineral film to be effective, should have some desirable characteristics such as: 1) Neutral pH (inert); 2) Diameter less than 2 μm; 3) Formulated to provide uniformity of spreading in order to form a uniform film; 4) Sufficiently porous so as not to interfere with the gas exchanges of the leaves; 5) Allow the transmission of photosynthetically active radiation (PAR), exercising, to a certain degree, the function of reflecting agent or filter of ultraviolet radiation (UV) and infrared radiation (IR) (GLENN; PUTERKA, 2005). The use of kaolin, alone or with fertilizer, is recognized as an important or very important option by more than 90% of the respondents. The totality emphasizes the importance of the use of kaolin, alone. However, about 30% emphasize as very important to increase the planting area, or to increase the use of fertilizer.

Commercial coffee plantations cultivated in full sun, which received pulverization of the processed kaolin, evaluated under unfavorable climatic conditions, proved to be more productive compared to plants without protection due to the thermal comfort of the plant (ABREU *et al.*, 2020; GLENN *et al.*, 2001). Coffee plants exposed to temperatures above 23ºC, without forest shading, tend to have a higher rate of flower abortion, inducing the plant to produce more leaves and fewer beans (DE CAMARGO, 2010).

The contradiction between recognizing the importance of one's own actions in the conservation of the environment and choosing to increase production by expanding the area was investigated through the question about the evaluation of the environmental impact of leasing new areas for coffee planting. Figure 5 summarizes the answers, where one can observe that 31% recognize the very high negative impacts of this decision, on the other, 44% point to little or no negative impact.

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

Figure 5 - Environmental impact assessment of leasing new plantation areas



Source: Own elaboration, 2022.

Field research results pointed out that coffee crops protected with processed kaolin produced more perfect coffee fruits, with larger size, resulting in increased productivity (ABREU *et al.*, 2016; SANTINATO *et al.,* 2016). Another study found a 28.4% increase in bean quality and that each kg of coffee bean dried in coconut, with kaolin protection, yielded 0.635 kg compared to 0.594 kg from the area harvested without kaolin (ABREU *et al.*, 2017). Coffee plants protected with Surround® WP produced 94 60 kg bags per hectare, compared to 91 bags from plants without protection (ABREU *et al.*, 2017).

5 CONCLUSION

In general, the results obtained with the present work allowed us to conclude that:

a) The farmers interviewed recognized the importance of caring for the environment, however, they believed they had to choose between increasing production or promoting environmental conservation;

b) By analyzing the results of the interviews, it can be observed that the participants were aware of the importance of applying concepts of environmental sustainability in their own actions, even if, faced with the pressure of production, they could resort to intensive use of soil and water;

c) On the 16 farms analyzed, the farmers were already using kaolin, and most of the interviewees were aware of the importance of protecting fruits and leaves by using the product;

d) In this sense, the interviewees, for the most part, evaluated the use of kaolin positively;

e) It is worth highlighting the need to adopt environmental education actions that promote the dissemination of knowledge of additional techniques that promote environmental sustainability, in addition to the importance of the application of legislation favorable to the protection of the environment on rural properties.

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

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ISSN 1980-0827 – Volume 19, Number 5, Year 2023

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