A Bio-dynamic Agriculture Model based on Rock Dust: A Case Study in Alto Alegre, Roraima, Brazil

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Abstract— *The success in the use of rock dust as a non-chemical fertilizer, being a great vitoria of biodynamic agriculture, has led to an interesting amount of investigations, mainly with a highly theoretical bias, often without discussing common trade-offs in agriculture such as the fact that the larger soil breathing increases the problem of potential carbon loss and the highest sodium concentration increases the problem of the risk of soil sodification.*

Researchers found that the correction of soil nutritional deficiencies can also be achieved with the application of finely ground rock types such as natural phosphates, gypsum, mafic and ultramafic rocks e mais recentemente as silicate rocks, and more recently silicate rocks, due to their abundance and the ease with which they can be found in the form of fine residues from the moulding process in the canteras. The idea of these researchers is that the carrier rocks are full of nutrients, particularly K, Ca and Mg, and therefore laboratory tests are not necessary.

In other words, most researchers avoid joint analysis (rocks and soils), in particular geochemicals and mineral analysis, because the easiest part of the work is to show, through literature reviews, the great advantages of sostenible fertilizers, in particular as regards highly degraded soils, putting special emphasis on strong soil remineralization and soil pH balance, in contrast to the high cost and harmful impact of chemical fertilizer industry on Global Global Warming, in proportion similar to fuel fuels.

In addition they do not consider rock dust as a Biodinamic Homemade fertilizer. The difficulty of cooperatives engaging in the acquisition of crushing machines depends on a closer relationship with agricultural entitles to analyze both rocks and soils (compatibility examination) besides the union among farmers for formation in this "novelty" and subsequent construction of crushing machines in their own farms.

For this reason, the research question is how culture relates to knowledge and intelligence in order to know what type of culture we have to build for effective Bio-dynamic agriculture.

Therefore, this work brings two research models that feed each other.

In addition to the Culture-Knowledge-Intelligence (CKI) model, this article presents a Bio-dynamic Agriculture model, a mature way of better using the resources available on the farm itself. The study concluded that this model is useful for small farmers to learn, through cooperatives, home-made farming practices, such as rock dust as a new fertilizer mixed or not with cattle manure.

Keywords— Family farming, cooperatives, knowledge management, cultural intelligence, local solutions.

I. INTRODUCTION

1.1 Soil remineralization using rock dust:

In addition to the benefits outlined in the abstract, rock dust has been shown to increase the cation exchange capacity (Anda et al., 2015) and water-holding capacity of sandy soils (Kahnt et al., 1986). However, many rock dusts are either inefficient or contain potentially toxic elements in harmful levels. As a result, the effectiveness of applying finely ground rocks to tropical soils largely depends on their chemical and mineralogical composition, soil deficiencies, and the specific requirements of the crops being grown (van Straaten, 2017).

This advantage of rock dust over chemical fertilizers is particularly evident in highly weathered soils found in tropical regions, where traditional soluble fertilizers may be expensive or unavailable (Swoboda, Döring, & Hamer, 2022). An analysis by Swoboda, Döring, and Hamer (2022) of 48 crop trials demonstrated the potential of rock dust as an alternative source of potassium (K) and a multi-nutrient soil amendment for tropical soils, while the benefits for temperate soils remain unclear. Positive outcomes were particularly observed with mafic and ultramafic rocks such as basalts and rocks containing nepheline or glauconite. Among various silicate rock powders (PRS), basalt powder stands out. Basalts, being igneous rocks with a mafic composition, are rich in magnesium (Mg) and iron (Fe) silicates and have a basic pH. These rocks also provide essential nutrients for plant nutrition, including phosphorus (P), potassium (K), calcium (Ca), and several micronutrients (Swoboda, Döring, & Hamer, 2022).

Viana, Caetano, and Pontes (2021) describe a technique that combines intermediate doses of basalt powder with larger doses of cattle manure. While various methods are used, the most effective approach was found to be the combination of rock dust with another type of fertilizer. Da Silva et al. (2017) emphasize that integrating rock powders with organic materials that support biological activity can influence the mineral alteration process. However, there is limited knowledge on how materials affect the dissolution of ground rocks, particularly basalt rock powder.

During composting, the nitrogen cycle plays a crucial role in determining compost quality (Hoang et al., 2022). This article will discuss strategies for mitigating nitrogen loss. Some researchers, however, present findings without thorough research, such as lab tests or real-world farm applications. Ramos et al. (2022) suggest that combining organic fertilizers with rock powder can meet the nutritional needs of both macro and micronutrients, with application costs of rock powder being significantly lower (<60%) and having long-term fertility benefits. Specifically, corn and bean plants grown in soils enriched with basalt dust yielded up to five times more than crops without basalt dust (Conceição et al., 2022).

Similarly, Bauwhede et al. (2024) report that rock dust helps reduce nutrient leaching by providing a slow, sustained release of nutrients into the soil. However, this depends on the mineralogy of the rock, soil acidity, and the testing methodology. Grecco et al. (2016) highlight that the low processing costs and the need for alternative fertilizers support the practice of using ground rocks on soil. Nevertheless, studies on this subject are limited, and the nutrient release rate remains unclear as different rocks react differently to weathering, influencing nutrient availability.

Dos Santos et al. (2016) explain that nutrient release from rock dust occurs more slowly compared to chemical fertilizers. While this slow release is an advantage in some cases, it can also be a disadvantage, as it extends the process and requires larger quantities of material to be applied to the soil.

Lopes-Assad et al. (2006) found that the fungus Aspergillus niger is effective in solubilizing phosphate rocks through the production of organic acids. In the treatment with Aspergillus niger, pH fluctuated over time, with increased acidity leading to higher potassium (K) solubilization rates. However, when treating alkaline ultramafic rocks with Aspergillus niger, the acidity decreased, resulting in a reduced K solubilization rate.

To counter soil acidity, it is common practice to lime the soil with calcium and/or magnesium carbonates (such as calcite and dolomite). These minerals react with hydrogen ions released by the soil water, as well as carbon dioxide and aluminum in the form of hydroxide, thereby mitigating aluminum toxicity (Goulding, 2016).

The application of rock dust depends significantly on the crop being cultivated. Some crops, such as lettuce, require a high concentration of nutrients in the short term, and therefore, basalt may not be ideal for these situations.

Hanish et al. (2024) found that applying up to 100g of basalt filler powder to both tested soils did not result in any significant increase in lettuce yields. The yields observed without soluble fertilizer (averaging 50g per pot of lettuce) were nearly four times smaller than those achieved with fertilizer treatments. Lettuce cultivation requires high doses of soluble inputs to meet the crop's nutritional demands within its short production cycle. As a result, basalt powder, with its low nutrient concentration, was unable to fulfill the crop's short-term needs.

Guimarães et al. (2020) found that banana orchards fertilized solely with mineral sources produced higher fruit yields compared to those fertilized with organic-mineral sources. However, the organic-mineral fertilization resulted in lower soil acidity and higher availability of phosphorus (P) and potassium (K). It was also observed that excessive potassium in the soil could cause nutritional imbalances in the plants, potentially reducing their productive potential. Consequently, further studies on banana fertilization strategies are necessary to improve nutritional balance.

It is important to approach the overestimation of rock dust as a fertilizer in Brazil with caution, as noted by Viana, Caetano, and Pontes (2021). They acknowledge that rock dust holds significant potential for Brazilian agriculture but is still underexplored. More research is required, particularly focusing on the agronomic effectiveness of rock dust when combined with animal manure (Viana et al., 2021).

According to Organicospro (2018), a well-known type of ground rock is limestone, which is rich in calcium carbonate (calcite limestone) or calcium magnesium carbonate (dolomitic limestone). In contrast, basalt powder is rich in silicate minerals that provide silicon to the soil—a crucial nutrient for promoting plant health and boosting productivity. These and other examples underscore the role of basalt powder in restoring degraded and leached soils, stimulating soil biology, and enhancing overall production. Some advantages of biomineralization include:

- Replenishing nutrients in weak and impoverished soils
- Reducing acidity over time
- Improving soil structure by enhancing oxygen content
- Lowering chemical fertilizer costs
- Increasing seed germination
- Enhancing the growth of roots and plant aerial parts
- Thicker stems and bark
- Creating a protective leaf film against diseases, wind, and frost
- Increasing durability post-harvest
- Providing a greater quantity of nutrients

Batista (2016) applied basalt rock powder in varying quantities, with and without the addition of limestone, to soil samples. In samples with limestone, potassium levels increased compared to those without limestone, and the pH was higher. Soil pH correction was less pronounced when limestone was not included in the treatment. It is important to note that soil re-acidification is a slow process, and superficial reapplication of limestone is sufficient to correct it. The study concludes that while soybean yields showed a modest but positive response to limestone reapplication (an average yield increase of 252 kg ha^{-1} $year^{-1}$), corn yields were less affected (Hammerschmitt et al., 2021).

Among the aluminosilicate minerals found in rock dusts (RDs) are orthosilicates (e.g., olivine), inosilicates (e.g., pyroxenes like diopside, amphiboles like hornblende), tectosilicates (e.g., orthoclase, plagioclase, nepheline, leucite), and phyllosilicates (e.g., biotite and muscovite) (Calabrese et al., 2022; Swoboda et al., 2022; van Straaten, 2006). RDs can serve as an alternative to conventional liming, but unlike lime, they have a lower acid-neutralizing capacity (ANC) and release their alkalinity more gradually. Additionally, they provide a range of nutrients, including calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), and sulfur (S) (De Vries et al., 2021; Ramos et al., 2022; Swoboda et al., 2022).

Swoboda, Döring, and Hamer (2020) found that several rock modifications significantly improve the agronomic effectiveness of silicate rock powders (SRPs). Enhanced weathering of SRPs could also sequester substantial amounts of CO_2 from the atmosphere, and supplying silicon (Si) could enhance plant resistance to a broad spectrum of biotic and abiotic stresses.

More research is needed to fully understand the use of silicate rock powders (SRPs) when combined with limestone, chemical fertilizers, or animal manure. Particularly, studies should focus on the type of rock, the type of soil, the crop being cultivated, and the application quantity, as illustrated in Figure 1 below:

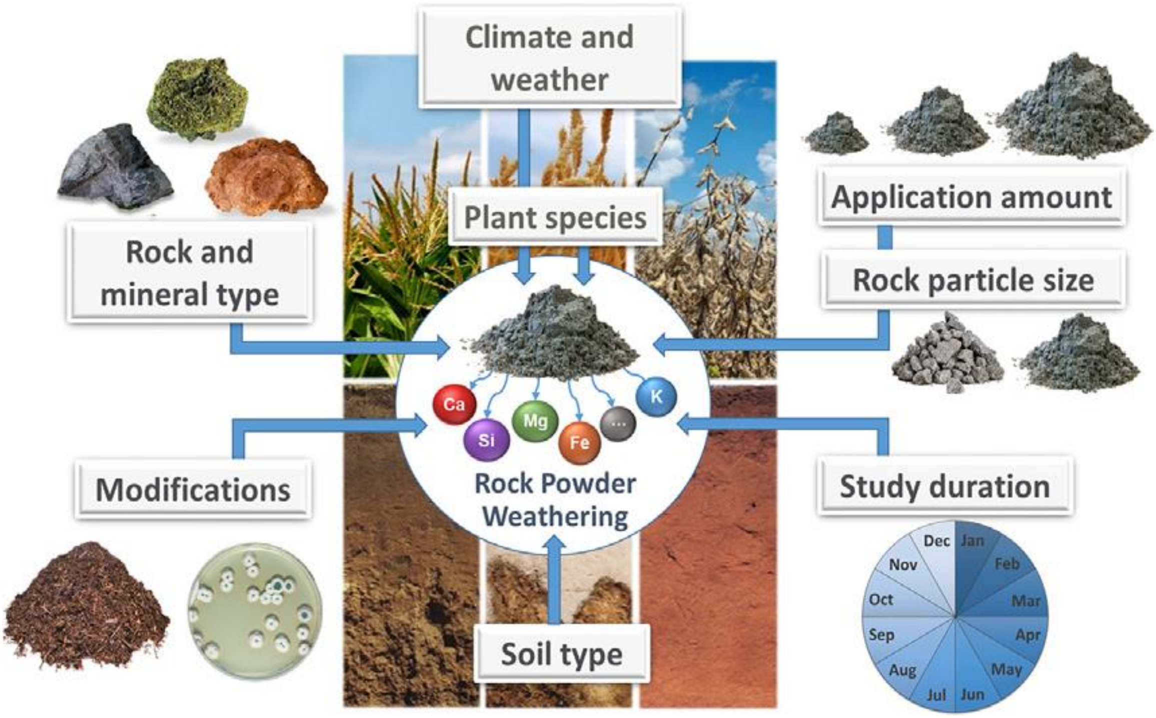

FIGURE 1: Factors influencing the use of silicate rock powders - SRPs (Swoboda Döringb & Hamera, 2022)

Bergmann and Holanda (2014) explain that when considering the use of a rock as a soil remineralizer, it is essential to investigate these processes through petrography. This method enables the identification of minerals, their texture, crystallization order, grain size, and overall integrity. Additionally, the materials added to the soil must meet strict criteria, including limits on harmful or potentially harmful elements, such as toxic heavy metals, and components that could contribute to soil salinization or introduce inert minerals that may degrade soil structure, such as sodium and quartz compounds.

1.2 Best practices and lessons learned from bio-dynamic agriculture:

An excellent alternative to industrial agriculture, which is also in decline due to excessive mechanization, chemical manipulation, herbicide use, and neglect of environmental conservation, is bio-dynamic agriculture.

Bio-dynamic farming goes beyond organic farming by adopting a holistic, ecological, and ethical approach to farming, gardening, food, and nutrition. It is a way of living, working, and relating to nature and our vocations, fostering awareness of the uniqueness of each landscape and the inner development of individuals, as well as the collective growth of the community.

Common practices in bio-dynamic agriculture include striving for self-sufficiency in energy, fertilizers, plants, and animals; organizing activities around the natural rhythms of the environment; utilizing a diverse range of plants, fertilizers, and animals in a healthy manner; approaching work with seriousness, precision, order, and attention to detail; and maintaining punctuality in executing tasks (Paull, 2011).

Campbell and Watson (2012) and Raupp (2001) found that soil improvement in bio-dynamic agriculture is achieved through proper humus management. This includes applying well-fermented manure and organic fertilizers, practicing effective crop rotation, ensuring good soil functioning, implementing protective measures such as windbreaks, and using cover crops, green manures, and diversified crops instead of monocultures. Mixed cultivation is also emphasized to allow plants to support each other.

Boicean & Dent (2020) suggest that crops that deplete the soil, such as corn, potatoes, cabbage, and cauliflower, should alternate with crops that replenish the soil, such as legumes (peas, beans, clover, etc.). Additionally, deep-rooted crops should be alternated with shallow-rooted crops, and those requiring fertilizers should be paired with those that can thrive without them.

In line with bio-dynamic practices, FAO (2021) reports that sustainable agricultural practices can reduce damage to ecosystems and ensure food production despite challenges like climate change, extreme weather, droughts, and other disasters. These practices also contribute to the progressive improvement of land and soil quality.

1.3 Study on the Potential for the Use of Rock Dust in Roraima:

A noteworthy study on soil balancing in Roraima was conducted by Bergmann and Holanda (2014) as part of the broader project Geodiversity of the State of Roraima: Geology Program of Brazil (2014). The diverse soils, combined with climatic factors, terrain, and management limitations, allowed for the identification of six geographical units based on their potential for soil use and occupation in Roraima.

The most suitable area for soil balancing is the basic rock region (composed of Diabase, Basalt, and Gabro), which is dominated by vertical changes and includes red argisols, red oxisols, vertisols, chenosols, and nitisols. In Roraima, soils with low natural fertility and high acidity prevail, posing significant challenges to agricultural use. However, eutrophic soils, found in limited areas, have higher agricultural suitability and are more intensively used, though they still suffer from low technology adoption, as they are located in remote or rural settlement areas.

The lack of proper infrastructure also restricts productivity in Roraima, as the road network is insufficient for the timely delivery of supplies and efficient production flow. Additionally, labor is often underqualified, and public investments are lacking. Despite these challenges, the state's equatorial location provides favorable climatic conditions for agriculture, allowing most crops to yield better results compared to other Brazilian regions. Overcoming these challenges is crucial for economic growth, social inclusion of indigenous communities, and sustainable development. Sustainable agricultural practices, including rock balancing, play a key role in addressing these issues.

Agriculture in Roraima is mainly practiced in the La Sabana region, where various soil types, such as canosols (yellow, red-yellow, and red), argisols (red and yellow-red), and neosols (hydromorphic quartarene and organic, fluvic, and surface litholic), dominate. These soils are characterized by low base saturation, low cation exchange capacity, and high acidity. In particular, levels of interchangeable phosphorus are very low, requiring constant pH correction.

The most fertile soils in the state are found in the basic rock regions: the Pedra Preta Sill in the Uiramutã region, the volcanic rocks of the Apoteri formation near Nova Olinda, and the area around Taiano. The best areas within the basic volcanic rock domain are located in Vila do Taiano (northwest Roraima), Sierra de Nova Olinda (central Roraima), and near the indigenous community of Flechal in Uiramutã. These regions feature soils derived from basaltic rocks from the Apoteri formation, including red oxisols, organic slopes, and chernosols, along with nitisols associated with diabases, diorites, and gabbros of the Pedra Preta threshold. These areas exhibit a pronounced relief with strongly wavy topography under forest cover.

Figure 2 shows a taian diabase sample, collected in the municipality of Alto Alegre, and with strongly positive phosphomolibdate test.

FIGURE 2: Samples of diabase from Taiano (municipality of Alto Alegre) with strong positive phosphomolybdate test.

In addition to the municipality of Alto Alegre, in the municipality of Iracema, the presence of rare earth minerals, niobio, barium and phosphate are cited.

In Brazilian family agriculture, rock powders are used in consortium with waste of organic origin (animal manure and green fertilizer), and the farmer frequently produces their inputs through the composting process (possible thanks to a series of microorganisms), which allows increasing the efficiency of nutrient extraction.

The N is generally provided by the practice of green fertilizers, and plants such as Tithoniadiversifolia (honey flower) are also used, capable of adding K in proportions of up to 4.3% in leaves and ground stems added to the compost (Palm et al., 1997

Apud van Straaten, 2007) For such success it is important to consider the use of rock powders within the soil-plastic system, which includes the entire microbiota of the soil. and particularities of plant roots extraction systems (Mundstock, 2013).

According to investigation indicative results, rock dust can be applied to any crop, in particle sizes that range between 0.105 and 4.0 mm, similar to limestone, by casting or use of machines. The amounts vary according to the ground and the cultivation in question, oscillating between 0.5 and 8 tons/hectare. Due to its already established use and performance in agronomic trials, it can be affirmed that in Brazil, the volcanic rocks of basic composition of the Serra Geral formation (basaltos and diabasas of the southern, southeast and central-west regions) have good potential for balancing combined with the fact that they are often available as fine crushers. While these rocks have relatively low silica contents, they have high contents of CA, mg and faith that are associated with mineral structures with lower resistance to solubilization, being able to make them available in the short term, when added to the ground in the correct grain size.

Alkaline rocks, being rich in K, in addition to having volcanic terms with microcrystalline matrix, are very suitable for use in soil remineralization.

In Brazil, a Poços de Caldas phonolite is the only rock to date authorized for commercialization as adequate for use as an alternative to potassium chloride (KCL), a imported soluble fertilizer widely used in Brazilian agriculture (Cortes et al., 2009).

It is also important to note that the use of these rocks does not exclude the analysis of oligoements, to quantify micronutrients and potentially harmful elements (Bergmann and Holland, 2014).

1.4 The problem of excessive imports of chemical fertilizers in Brazil:

The rock dust brings to the plants a greater collection of elements. In addition to macronutrients P, k, calcium (ca), sulfur (s) and magnesium (mg), depending on the rock used, essential micronutrients can be offered, such as zinc (zn), copper (cu), iron (faith), manganese (mn), molybdenum (mo), boron (b), cobalt (co) and nickel (ni). In high solubility monoements fertilizers, the contribution is mostly limited to nitrogen (N), P and K macronutrients, although there are currently complex fertilizer formulas containing CA, Mg, S and micronutrients (mainly B and Zn). However, the negative aspect refers to the high solubility of the nutrients present in this type of input for Brazilian climatic conditions.

Thus, soil remineralization techniques are considered alternative routes to fertilize exhausted soils due to the loss of nutrients. Its importance is great in countries such as Brazil, which imports around 65% of the raw materials necessary to manufacture fertilizers and presents a worrying demand projection on production in this sector, which is expected to reach 83% in 2025 (Bergmann and Holland, 2014).), as shown in Figure 3.

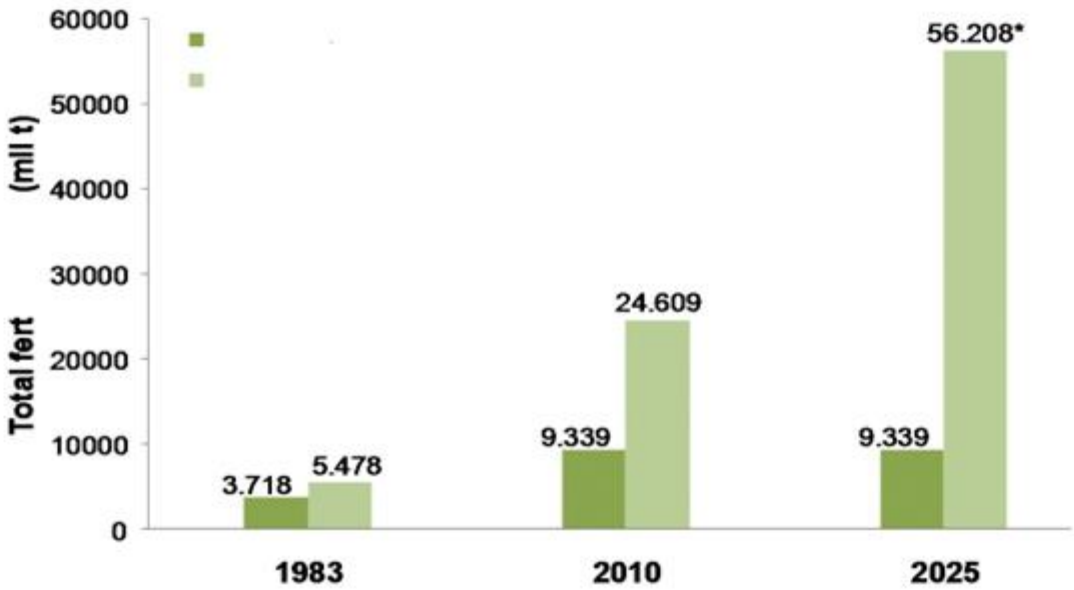

FIGURE 3: Production and demand graph of fertilizers in Brazil. Adapted from Martins (2013).
Source: ANDA (2011). Mbagro Project.

According to Goulart et al. (2023), the Novos Campos region in Roraima is home to magmatogenic phosphate mineralizations associated with the anorthosite-manager-chanockite-shanite (AMCG) association. Additionally, the region features magmatichydrothermal phosphate deposits and minerals containing rare earth elements (ETR) linked to alkaline volcanic-reputonic complexes. The Gabroanorthosite units of the AMCG Mucajaí association are identified as the most significant phosphate resource in the region.

Brazil's heavy dependence on fertilizer imports makes the country vulnerable to fluctuations in the international market, such as exchange rate variations, changes in trade policies, and logistical challenges. These factors could disrupt the consistent supply of fertilizers that Brazilian farmers rely on, potentially compromising agricultural production and food security. Fertilizer imports involve long distances and necessitate adequate infrastructure for transportation, storage, and distribution. High logistics costs, including maritime transport, storage, and internal distribution, contribute to the increased final price of imported fertilizers. This, in turn, negatively affects the economic viability of imports, making products more expensive for farmers and reducing their competitiveness. The high fiscal burden, including ICMS taxes on fertilizer imports, further impacts the Brazilian agricultural sector and food security, ultimately leading to higher food prices for consumers.

In response to this issue, the Brazilian federal government introduced the National Fertilizer Plan (PNF) in November 2022, aimed at reducing the country's dependency on fertilizer imports. The plan is intended to guide the fertilizer sector through 2050. However, cultural factors continue to constrain the sector, with farmers remaining reluctant to adopt biodynamic (homemade) practices. Small-scale farmers face challenges due to a lack of education on alternative methods, while medium and large-scale farmers are already accustomed to the importation of chemical fertilizers.

Moreover, there is a lack of legislation or government initiatives that facilitate access to non-chemical fertilizers, such as the construction of rock crushers, soil physico-chemical studies, and access to scientific research from Embrapa, the Geological Service of Brazil (SGB), and other related institutions.

Law No. 12,890, passed on December 10, 2013, regulates the inspection and control of the production and marketing of fertilizers, correctors, inoculants, biofertilizers, remineralizers, and substrates for plants. It establishes important guidelines for these products' use in agriculture.

Regulatory Instruction No. 39, dated August 8, 2018, outlines definitions, requirements, specifications, guarantees, product registration procedures, authorizations, packaging, labeling, fiscal documentation, advertising standards, and tolerances for mineral fertilizers intended for agriculture.

The Ministry of Agriculture, Livestock and Supply (MAPA) has standardized the production, registration, and marketing of remineralizers, commonly known as "rock dust." This ground and sifted rock is used to enhance the physical and chemical quality of soil. While it differs from common fertilizers in solubility and concentration, both types of fertilizers offer complementary effects. With the new legislation, consumers can now verify the quality of these products, which will be officially registered with MAPA.

Regulatory Instructions 5 and 6, published in the official gazette on Monday (14), establish several requirements for manufacturers to ensure the provision of quality and safe products. These regulations also outline the rules that must be followed during the registration process.

The regulation of remineralizers represents a valuable alternative for Brazilian farmers, who already depend on limestone and mineral fertilizers to restore soil fertility. This long-standing demand from the sector, particularly among organic producers who avoid mineral fertilizers but are open to using "rock dust," has now been addressed through new legislation, as noted in the Official Gazette of the Union.

II. RESEARCH METHODOLOGY

This study uses the literature review methodology in an integrated way to better understand the impact of culture on knowledge and intelligence.

Snyder (2019) states that literature review as a research method is more relevant than ever. Traditional literature reviews present a careful menu of thoroughness and rigor and are carried out on an ad hoc basis rather than following a specific methodology.

In the article, it will be argued that the potential for theoretical and practical contributions using the literature review as a method will be advanced to clarify what a literature review is, how you can use it, and what criteria should be used to assess its quality.

Of course, there are some guidelines for conducting literature reviews that suggest different types of reviews, such as narrative or integrative reviews (e.g., Baumeister & Leary, 1997; Wong, Greenhalgh, Westhorp, Buckingham, & Pawson, 2013), systematic reviews and meta-analysis (e.g., Davis, Mengersen, Bennett and Mazerolle, 2014; Liberati et al., 2009; Moher, Liberati, Tetzlaff and Altman, 2009) or integrated reviews (e.g., Torraco, 2005). There have also been some intentions to develop specific guidelines for business or management research (e.g., Palmatier, Houston, and Hulland, 2018; Tranfield et al., 2003).

This article carries out an integrated review of the literature on silicate rock powders (SRPs), biological fixation of nitrogen, Culture, Knowledge management and Organizational Intelligence.

Integration occurs not only in the literature review itself, as the intersection between these concepts is demonstrated through different sources, but also through the two research models in which the constructs are present.

2.1 The Culture – Knowledge- Intelligence model:

Kroeber (1949) asserts that what distinguishes humans from animals is culture. Since humans transcend their organic limitations, culture becomes an accumulative process, with each individual building upon the experiences of those before them, thereby contributing to the cultural development.

- Culture, rather than genetics, shapes behavior and dictates actions.
- Humans age in accordance with the cultural norms of their society. Their instincts are partially suppressed due to the extensive "evolutionary process" they undergo.
- Culture is a cumulative process, forged from the historical experiences of past generations. This process either restricts or encourages an individual's capacity for creative or non-creative action.

Building upon these foundational concepts, the Culture-Knowledge-Intelligence (CCI) model is developed, as depicted in Figure 4.

The premises of the CCI model are:

a) Culture is composed of the beliefs, values, assumptions, and traditions of a society (SCHEIN, 2010). (ii) The central thesis is that for education to achieve its objectives, the curriculum must be restructured or reformulated around the four pillars of learning: learning to know, learning to do, learning to live together, and learning to be (SMITH, 2018). (iii) The three pillars of intelligence are: prediction, strategy, and action (ROTHBERG AND ERICKSON, 2004).

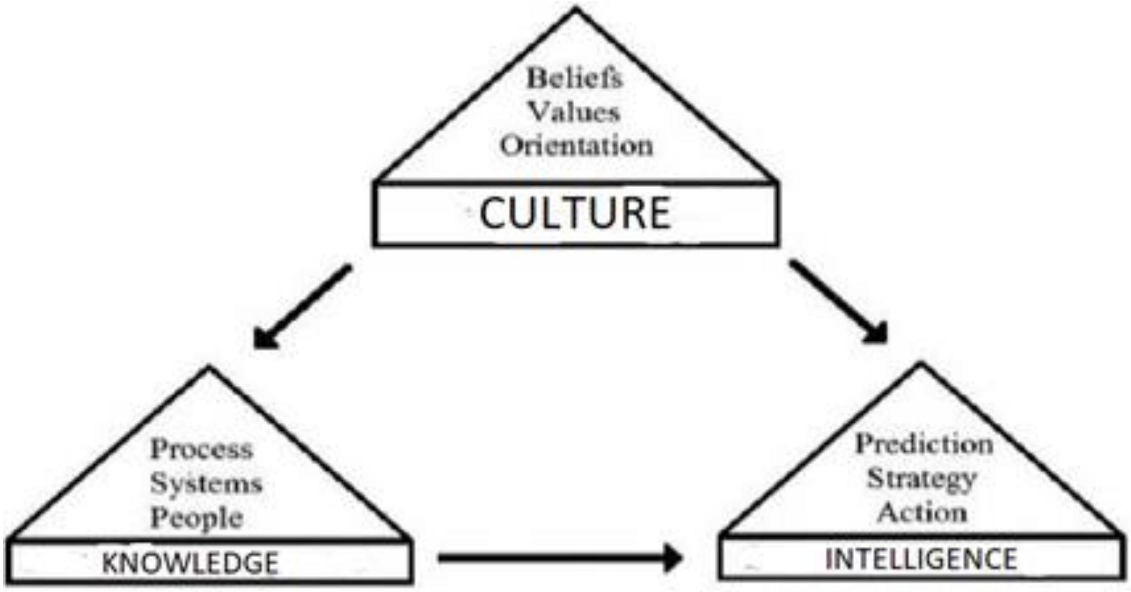

FIGURE 4: The Culture-Knowledge-Intelligence Model (adapted from Choo, 1998)

The CCI model is based on three hypotheses (Table I):

TABLE 1
ASSUMPTIONS OF THE CCI MODEL

Hypotheses	Sources	Results
Cultural has a positive impact on Knowledge	Leidner et al. (2006), Deal and Kennedy (1982) and Tweed and Lehman (2002) suggest that the way in which individuals perceive, organize and process information and the way in which they communicate with others and the way in which understand, organize and generate knowledge and solve problems, is related to culture.	SUPPORTED
Cultural has a positive impact on intelligence	Culture, more than genetics, determines behavior and determines its actions (KROEBER, 1949). Umuteme et al.(2023) posit that factors such as values, norms, beliefs and practices embedded in organizational culture significantly shape the overall project environment and affect team dynamics.	SUPPORTED
Knowledge has a positive impact on intelligence	Rothberg and Erickson (2004) maintain that knowledge is static and, ultimately, only has value if people use it (intelligence)	SUPPORTED

III. BIO-DYNAMIC AGRICULTURE MODEL

Due to their ability to create and apply collective knowledge, cooperatives have achieved surprising results in the local and national development process.

Silva et al. (2006) identified that 60 agricultural cooperatives showed a significant increase of profit in 130%.

Cooperative institutions can be found in various sectors of the economy, such as agriculture, health, credit, transport, education, etc. Of these sectors, the one with the best structure and to which great national and international importance is given is agriculture.

The idea of creating cooperatives in rural areas has enormous potential for the formation of social capital, as it promotes actions that aim to bring together not only the group of cooperative members but also the local community.

Figure 5 shows the Bio-dynamic family farming model.

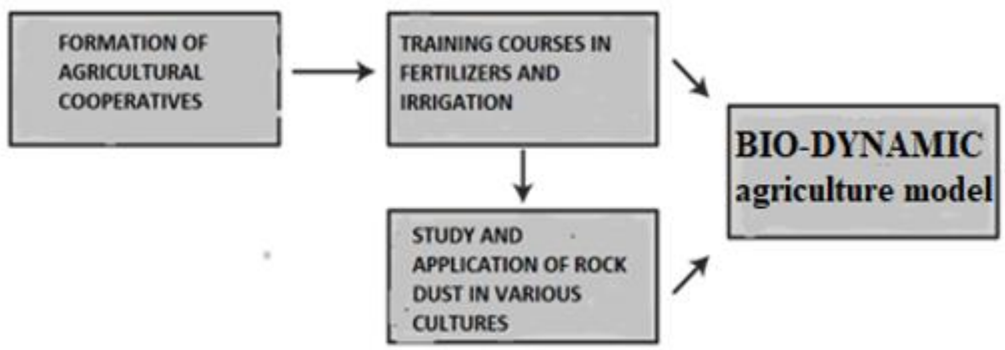

FIGURE 5: Bio-dynamic family farming model.
Fuente: Author, 2024

This Bio-dynamic agriculture model emphasizes that agricultural cooperatives are the foundation for this type of farming. However, for farmers to be motivated to unite and address their challenges, there needs to be a supportive culture that embraces training opportunities, especially on topics like fertilizers, which were discussed in the previous section. Thus, offering training courses, particularly on the use of rock dust, serves as a key foundation for the development and sustainability of Bio-dynamic agriculture.

Moreover, the Bio-dynamic model highlights that shifting the culture of small family farmers positively influences knowledge management practices within cooperatives and aids in the development and execution of the Farmers' Technical and Financial Assistance Plan (intelligence).

IV. CONCLUSION

Bio-dynamic agriculture relies on a mature cultural shift, as it encourages farmers to develop solutions based on the natural resources available on their farms. This article conducted a literature review on rock dust and biological nitrogen fixation to explore how such a culture can be cultivated. The article also proposed two interconnected models: the Culture-Knowledge-Intelligence model and the Bio-dynamic Agriculture model, which emphasize the creation and sharing of knowledge through cooperatives.

The study revealed the need for further research to address the challenges associated with dissolving silicate rock powders (SRPs) in various crops, considering both the quality and quantity of this material. There is also potential for exploring combinations of SRPs with limestone, animal manure, or even chemical fertilizers.

All of this research takes place in a collaborative setting between farmers and researchers, facilitated by cooperatives. Hence, it is crucial to understand the impact of culture on knowledge and intelligence in building a strong cultural foundation to apply relevant knowledge effectively.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization, Methodology, Data curation, Writing- Original draft preparation, Visualization, Investigation, Validation, Writing- Reviewing and Editing.

CONFLICTS OF INTEREST

We have no conflicts of interest to disclose. All authors declare that they have no conflicts of interest.

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