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SUMMARY

QUANTITATIVE GENETIC IMPROVEMENT IN AUTOGAMOUS PLANTS: APPLICATION OF RECURRENT SELECTION

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Aristeu Antonio Lourenco Costa[1], Raimundo Filho Freire de Brito[2], Nicolas Oliveira de Araújo[3], Ana Izabella Freire[4] and Filipe Bittencourt Machado de Souza[5]

ABSTRACT
The text addresses genetic improvement in plants that reproduce by self-fertilization, focusing on characteristics such as productivity, resistance to pests and diseases, and fruit quality. Recurrent selection is highlighted as a strategy to increase genetic variability and improve the effectiveness of selection over consecutive cycles. In the study described, two soybean cultivars adapted to the target region are artificially crossed in a greenhouse, with the objective of creating a segregating population. The breeding method used is SSD (Single Seed Descent), which facilitates the obtaining of homozygous lines by reducing the time required for this and requires less space, and the populations are conducted in environments such as greenhouses.

Keywords: Genetic gain. Genetic variability. Quality of the fruit.

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INTRODUCTION

OBJECTIVES

To improve genetic gain in traits of interest, such as productivity, resistance to pests and diseases, fruit quality, among others, in plants that reproduce by self-fertilization. Recurrent selection is an efficient strategy to increase genetic variability and allow selection to be more effective over consecutive cycles.

MATERIAL AND METHODS

GENOTYPES USED AND HYBRIDIZATION

Two commercial soybean cultivars recommended for the target region of the breeding program will be used to form the segregating population. The two cultivars should show good productivity and resistance to the main diseases of the crop. The P1 and P2 parents will be artificially hybridized in a greenhouse through emasculation of the female flower and brushing of the pollen-supplying anthers on the stigma of the emasculated flower. In greenhouse conditions, where the environment is more favorable, an average of 70 to 80% of success of the crosses performed are obtained (Borém, 2001). Thus, 20 crosses will be carried out, with the expectation of obtaining approximately 15 seeds in total. These F_1 seeds will be planted in a greenhouse, to obtain seeds for the next generation.

BREEDING METHOD USED

The breeding method used will be SSD, which essentially consists of harvesting a seed from each plant of the F2 generation, using only one seed as a parent in the next population. After reaching the required level of homozygosity, each progeny is kept in mixture. In this method, the segregating population is conducted in environments that are not representative of the conditions under which they would be grown commercially (Fehr, 1987). The main characteristic of this method is the reduction of the time required to obtain homozygous lines, since the processes of evaluation and selection of genotypes only begin after obtaining the homozygous lines, and thus, several generations can be conducted in one year (Borém, 2001). One of the advantages of the method is that it requires only a restricted area for the conduction of segregating populations (Ramalho et al., 1993), such as greenhouses.

CONDUCTION OF THE SEGREGATING POPULATION

The segregating population will be conducted in a greenhouse and the seeds obtained will be sown in 3.0 L pots, where up to six plants can be grown. 5 holes will be made in a circle and one in the center, all deep, where a seed of each plant of the segregating population will be placed per hole, originating the generation F3,0 cm2:3. 90% germination will be considered in each generation, so 1500 F2 seeds will give rise to 1350 F2 plants. This process will be repeated until the F4:5 generation, when 1020 plants were randomly harvested individually giving rise to the F5:6 families. These will be planted in the experimental area of the Federal University of Lavras in a 32x32 lattice design with two replications, together with 4 controls. Each plot will consist of a row of two meters with spacing of , sowing 20 seeds/m. From this generation, 221 F 5:7 progenies will be selected0,5 m, which will be planted the following year in 3 locations (Lavras, Lambari and Patos de Minas), in a 15x15 lattice design with 3 replications and 4 controls. Each family will be planted in two rows of with spacing, sowing 20 seeds/m. Of these, the 20 best will be chosen based on the joint analysis of grain yield. These families will be evaluated in a randomized block design, in the same locations mentioned above, with plots of 2 rows and 3 replications, using the same controls, from where the five best will be selected to participate in the Cultivation and Use Value Trials (VCU).3 metros0,5 m4 metros

Table 1. Scheme for the management of soybean segregating populations

Generation	Year	Quantity	Local
P1 x P2	1		Greenhouse
F1	1		Greenhouse
F2	1	1500 seeds	Greenhouse
F2:3	2	1350 plants	Greenhouse
F3:4	2	1215 plants	Greenhouse
F4:5	2	1093 plants	Greenhouse
F5:6	3	1020 progenies	Field – Lavras
F5:7	4	221 progenies	Field – Lavras, Lambari, Patos
F5:8	5	20 bloodlines	Field – Lavras, Lambari, Patos
F5:9	6	5 strains	VCU

STATISTICAL ANALYSIS

Grain yield data (g/plot) will be obtained, and analysis of variance will be performed initially by location, using the following statistical model, considering all effects, except the mean, as random:

$$Yijk = m + ti + qk + bj(k) + ej(ik)$$

where :

Yijk: value observed in the plot that received treatment i, in block j, within the repetition k;

m : overall average;

Ti: Treatment effect I (i=1,2,3,...,1024)

qk : effect of the repetition k, where (k = 1,2 and 3) for $F_{5:7}$

$BJ_{(k)}$: effect of block j (j = 1.2,...,32), within the repetition k

$ej_{(ik)}$: experimental error associated with observation Y_{ijk}

For the analysis of individual variance of the evaluation data of the F5:8 progenies, the following statistical model will be used:

$$Yijk = m + t_i + r_j + e_{ij}$$

Yij: value observed in the portion that received treatment i, in repetition j;

m : overall average;

Ti: Treatment effect I (I = 1,2,3,...,24)

rj : effect of repetition j, being (j = 1,2 and 3)

eij : experimental error associated with observation Y_{ij}

Subsequently, the joint analysis of variance will be performed, with the adjusted average data of each location, using the following statistical model considering all effects, except the mean, as random:

$$Yio = m + ti + lo + (tl)_{io} + \bar{e}io$$

where :

Yio: production of treatment i, on-site o;

m : overall average;

Ti: Treatment effect I (i=1,2,3,...,1024)

lo : effect of the location o, being (o = 1,2 and 3)

$(tl)_{io}$: effect of the interaction of treatment i with site j;

ēio : medium error.

From the analysis of variance, the components of genetic variance, phenotypic variance and heritability in the broad sense will be estimated, as performed by Raposo (1999). The Realized Gain with the Selection (GRS) will also be obtained using the following expression:

$$GRS = GS_j / m_j$$

where :

GSj: is the performance in generation j of the families selected in generation i, minus the overall average of individuals in generation j;

MJ: the average of the selected families in generation J;

With the estimate of the GRS , the realized heritability will be obtained, using the expression similar to that presented by FEHR (1987), that is:

$$h2ij = [GRS] / [ds_{(\%)}]$$

where:

GRS: Realized Gain with the Selection already detailed above;

$DS_{(\%)}$: is the selection differential, that is, the average of the families selected in generation I minus the general average of the families of this generation divided by the general average of the families of generation I;

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USE OF RESIDUE FROM THE PROCESSING OF BOVINE BLOOD IN PASTURE FERTILIZATION

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ABSTRACT

Pasture in Brazil is of great importance for Brazilian cattle farming, due to its wide practice, but the current scenario of pastures is one of degradation. Due to the urgency of correcting it, fertility correction is extremely important. Chemical fertilization is commonly used for this purpose, however, due to the finite character of many of these sources, sustainable alternatives are sought. The use of agro-industrial waste, as long as it has a chemical composition of interesting agronomic interest and ease of transport, because, under these conditions, the use of these wastes becomes cheaper and allows environmentally correct disposal for these wastes that are often discarded in a harmful way. The meatpacking industry represents a major generator of organic waste, due to the high number of units in Brazilian territory. The blood generated from the red line is used to make blood meal, widely used in animal nutrition, and from this processing a waste is generated, which is treated and discarded under application in the soil.

Keywords: Fertilization. Fodder. Nitrogen.

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INTRODUCTION

Soil is considered a base ecosystem for any type of production system, whether for agriculture or livestock. Pastures make up about 20% of the country's area that is destined for agriculture (MOUZINHO et al., 2022). Its wide use is due to the fact of expressive animal production, exclusively on pasture in Brazil.

However, forage production in Cerrado regions suffers from challenges related to abiotic factors, especially the soil issue, since they are characterized by low natural fertility, with reduced levels of nutrients such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), in addition to low water retention capacity due to low levels of organic matter (HUNKE et al., 2015; BECK et al., 2018).

In this way, to get around this situation, it is necessary to replace nutrients via chemical fertilizers. Fertilization of pastures is necessary in order to increase the capacity of pasture use in grazing systems (BATISTA and MONTEIRO, 2008). However, inorganic sources naturally have a high acquisition cost and, with the global crises caused by the pandemic scenario associated with wars, impact on exorbitant increases in the acquisition of these fertilizer sources, which can harm food security and the economic viability of the production system (ALLAM et al., 2022). According to Silva et al. (2011), it is important to use alternative fertilizers that present viable costs and sufficient supply, thus creating a new source of nutrients to be used in pastures, such as industrial waste.

According to Armstrong (2006), in a large part of human activities, waste is generated such as garbage production, sewage treatment, industrial treatments, among others, so the use of organic waste as a source of nutrients in crops is an important alternative for sustainable reuse of waste generated daily in the country.

An example of industrial waste widely produced in the country is that of the meatpacking industry, generated through the slaughter of animals with bloodletting. The blood from slaughter is processed to be used in animal feed, fertilization and by the pharmaceutical industry (ROCHA MARIA, 2008).

According to Brito and Santos (2010), the use of animal waste as a source of nutrients is an important alternative for preserving the environment, and slaughterhouse waste contributes to the addition of macro and micronutrients to the soil.

DEVELOPMENT

PASTURE SCENARIO IN BRAZIL

Brazil stands out on the world stage in terms of meat production, being one of the largest producers and largest exporter in the sector. Much of the production is based on pastures, as it is a practical and economical way to supply food to ruminants.

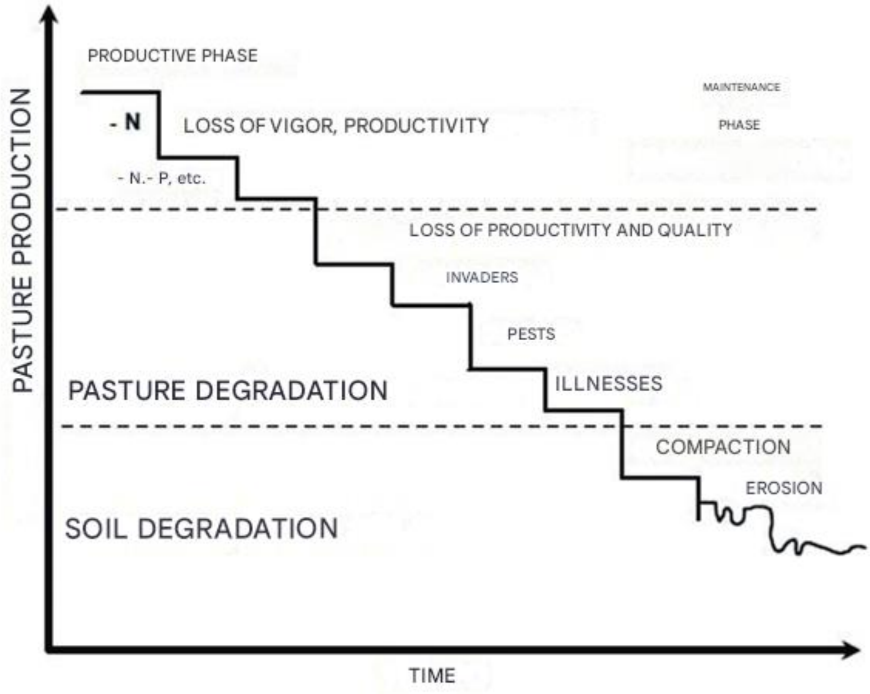
In the characterization of pastures managed and implemented in Brazil, *Uroclhoa brizantha* cv Marandu is widely used. *Uroclhoa* comes from tropical Africa that has excellent adaptation in Brazil due to its agronomic characteristics, having good acceptance by producers and its use is observed throughout the country. It is a perennial grass that has resistance to leafhoppers, high regrowth capacity, tolerance to drought, fire and cold, with better development in places whose temperature can vary between 20° and 30°C, and in relation to soil fertility it presents medium to high requirements (JUNIOR et al., 2015).

The productivity of Marandu grass varies around 8 to 20 t $^{ha-1}$ of dry mass per $^{ha-1\ year-1}$ and can be recommended for sheep, buffaloes, goats and cattle for breeding, rearing and fattening, with good acceptability to rotational grazing strategies, silage techniques and hay production (SILVA et al., 2024). However, forage production in Cerrado regions suffers from challenges related to abiotic factors, especially the soil issue, since they are characterized by low natural fertility, with reduced nutrient contents, in addition to low water retention capacity due to low levels of organic matter (HUNKE et al., 2015; BECK et al., 2018), which is one of the causes of pasture degradation.

Peron and Evangelista (2004) reported in the early 2000s that approximately 80% of the pastures cultivated in the Cerrado presented some stage of degradation, compromising in addition to productivity the quality of the forage. However, this scenario has been changing over time. In the case of severely degraded pastures, there was a significant reduction, from 46.3 million hectares in 2000 to 22.1 million hectares in 2020. This improvement was seen in all biomes, with the Amazon (60%), Cerrado (56.4%), Atlantic Forest (52%) and Pantanal (25.6%) (MAPBIOMAS, 2020) showing the greatest retraction, but there are still large areas with some degree of degradation.

Pasture degradation can be understood as a continuous and degenerative process, with losses in vigor, which cause significant reductions in their productivity, culminating in soil degradation (Figure 1).

Figure 1. Scheme of the continuous process of pasture degradation. Source: Macedo (1999).



According to Macedo et al. (2015), the main causes of pasture degradation are related to improper management in their formation or the absence of management itself, with the main factors being the misuse of soil conservation practices, soil preparation, planting systems and methods, acidity correction and/or fertilization and the inadequacy of the stocking rate in the formation of pasture.

Nitrogen (N) deficiency in pastures is one of the main factors that can lead pasture to a state of degradation, since its availability is essential for the growth of forage plants. According to Werner (1994), N is one of the most important nutrients for forage plants, as it is responsible for the production of green matter in plants, participates in the constitution of proteins, and influences the photosynthetic process of plants due to its participation in the chlorophyll molecule.

Moreira et al. (2009) studying four doses of N applied to *Uroclhoa decumbens* Stapf grass. cv. Basilisk obtained results of 20.2 cm of pasture height for the dose of 150 kg $^{ha-1}$ and 20.4 cm for the dose of 300 kg ha1 of N, demonstrating that grass growth is influenced as a function of the dose of nitrogen fertilization.

Regardless of the nitrogen source, Santos et al. (2018) found an increase in dry matter, positively changing plant height and recovery of tiller density and other structural characteristics.

Nitrogen fertilization is one of the largest costs with fertilization of non-leguminous crops in the country (NUNES et al., 2015). Thus, the growing use of waste as an alternative for organic fertilization and low cost in plant production can be highlighted, which is specifically due to the high content of nutrients, carbon and organic compounds. Several types of residues can be used for crop fertilization, which in addition to reducing costs, can have a slow release and prolonged enrichment action on the soil (ABREU JUNIOR et al., 2005; JUNIOR et al., 2015).

GENERATION AND DESTINATION OF AGRO-INDUSTRIAL WASTE

Agroindustries have great representativeness, being responsible for processing primary products from agriculture, in products or by-products that are identified in the food industry, such as canned goods, slaughterhouses, biofuels, leather industry, textile production and several others (GONDIM, 2017), generating large amounts of waste every year (MAKRIS, 2007).

Waste generally has low levels of nutrients and biomass and high polluting capacity, which when disposed of or disposed of inappropriately in nature, in addition to polluting soils and water bodies, can cause public health problems. The high cost of treatment, disposal and transportation of this waste has a direct influence on the final value of the product or by-product generated by the agroindustry (ROSA et al., 2014).

Waste can be divided into two groups: organic and inorganic. Organic products are those obtained in industrial processing, or that contain organic raw material in one of the processing phases. The main organic waste generated by the agroindustry are animal waste, agricultural crop residues and wastewater sludge. Partially the waste is reused in the agricultural production cycle, but the vast majority is discarded in the environment without proper treatment, making it highly harmful to the environment (SIQUEIRA MELO et al., 2011).

In summary, the objectives of waste treatment between the year 1900 and the 70s were solid waste removal, biodegradable organic treatments and elimination of pathogenic organisms. However, from the 80s onwards, the focus was changed, emphasizing the characterization and elimination of constituents that cause prolonged effects on environmental impacts and public health (METCALF; EDDY, 2016).

The principles of the primary treatment of waste and effluents is the removal of solid particles and organic matter in a way that causes a decrease in the values of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). BOD quantitatively represents the need for oxygen to balance the biodegradable organic matter (OM) present in the water by the activity of microorganisms. The COD quantitatively represents the oxygen required to balance the total OM in the water. High COD and BOD values represent highly polluting waste with complex treatment. In comparison examples, domestic sewage and pig manure have BOD values, respectively, 500 and 90,000 mg of oxygen per liter of waste (BERTONCINI, 2008).

Bertoncini (2008) also points out that primary treatments are flawed in relation to the removal of pathogens, N and phosphorus (P), whose levels must be within the standard for the discharge of waste into water bodies. Therefore, secondary treatments such as post-treatment and effluent disinfection are necessary.

In the mid-2000s, new technologies and knowledge were incorporating new sources of biomass in organic and organomineral fertilizers, such as agro-industrial waste, meeting part of the National Solid Waste Policy (PNRS) where it aimed to change from non-renewable sources to renewable sources. The PNRS also determines the treatment and exact destination of the waste produced during the production chains (CRUZ; PEAR TREE; FIGUEIREDO, 2017).

Normative Instruction No. 25 (MAPA) also refers to where each compound is defined within the organic fertilizer division, through the intrinsic characteristics and raw material of each compound. It defines the criteria for registration with the agency, and how each class can be arranged and restrictions on its use in agriculture (BRASIL, 2009).

In Brazil, the resolution of the National Council of Water Resources (CNRH) No. 54, puts into force the guidelines, modalities and general criteria for the practice of direct reuse of non-potable water throughout the national territory. According to the resolution, direct reuse is that in which water is taken to the point of use without being diluted in water bodies, underground or surface. In the third article, it contemplates the modalities for water reuse, such as reuse for urban, agricultural, environmental, industrial purposes, and in aquaculture (BRASIL, 2005).

Generation of waste in slaughterhouses

Brazil is known worldwide for its performance in agribusiness, being a major producer and exporter of grains and animal products such as meat and its derivatives. It is currently the world's largest producer of soybeans, coffee, sugar, and oranges, and also the largest exporter of beef and poultry in the world (CEPEA, 2024; SANTOS et al., 2023).

According to the Brazilian Association of Meat Exporting Industries (ABIEC), Brazil has the largest commercial cattle herd in the world, with approximately 197.2 million animals, representing about 12% of the global herd, distributed throughout the national territory. The states of the Midwest region, such as Mato Grosso, Mato Grosso do Sul and Goiás, together with Minas Gerais, are the ones that concentrate the largest herds in the country. In the 2023 annual report, ABIEC highlighted that Brazil recorded a total of 10.6 million tons of beef slaughtered (in carcass equivalent) and exported 2.29 million tons in the same period, most of which was composed of fresh beef, which corresponded to 89.93% of exports (ABIEC, 2024).

The slaughter of cattle in slaughterhouses implies the quality and added value of the meat, so humane slaughter is currently used, which is defined as a set of procedures that offer well-being to the animals from shipment to bleeding (GONÇALVES; SOUZA, 2017).

The first stage of cattle slaughter is stunning or stunning, which consists of bringing the animal to a state of unconsciousness so that it does not suffer from the bleeding process (SOBRAL et al., 2015). Bleeding consists of the section or cutting of the anterior aorta and the anterior vena cava, at the beginning of the carotid arteries and the end of the jugular veins located in the ventral region of the neck, so that the blood is drained from the animal's body (SILVA, 2011).

It is estimated that an adult bovine has 6.4 to 8.2 L of blood per 100 kg of live weight, and that an efficient bleeding should eliminate 50% of the total blood from the animal organism (KOLB, 1984). According to Alencar (1983), bovine blood is a physiological fluid composed of water, fat, carbohydrates, minerals and protein (17%).

Like most industries, with the slaughter of cattle, slaughterhouses are responsible for the generation of waste, which become serious environmental problems when they are released without any type of treatment into nature (ROCHA MARIA, 2008). The blood from the beheading of animals is characterized as a waste from the meatpacking industry, but it can be reused after treatment, such as dehydration of the blood to manufacture animal feed or fertilizers (ARAÚJO et al., 2016). For Pichek et al. (2014), the use of blood from slaughterhouses in agriculture can be a good alternative, given its high nutritional content, and stimulates the microbial activity of the soil, in addition to providing small producers with the opportunity to produce their own organic fertilizer.

FORAGE RESPONSES TO THE USE OF RESIDUES

Most industrial waste, when used correctly, can contribute to the physical, chemical and biological development of the soil, providing a favorable environment for plant development (MESQUITA et al., 2012). According to Pires and Mattiazzo (2008), for the use of residues in agriculture to be viable, it is important to know the agronomic efficiency of the residue used, and to observe the development of crops when some industrial residue is used as a source of fertilization.

The reuse of waste generated by the meatpacking industry in pastures can be an alternative for the use of by-products, which contributes to the improvement of economically viable techniques that protect the environment (DIM et al., 2010). Silva Neto et al. (2013) analyzed the application of liquid slaughterhouse residue (LPR) in a Quartzarenic Neosol cultivated with Marandu grass, and found a reduction in acidity and Al3+ contents and an increase in V% in the 0-10 cm layer and in the effective CEC in the 0.10-0.20 m layer.

Alonso and Costa (2017) verified the increase in the dry matter, green matter, height and bromatological characteristics of *Uroclhoa brizantha* cv. Xaraés, after the application of doses of dairy cattle manure, highlighting organic fertilization as a possible substitute for mineral fertilization, producing more sustainably.

Freitas et al. (2016) pointed out that bovine blood sludge (BSB) can be used as a soil corrector, mixed or not with carbonate and calcium oxide, but its use should be limited, due to the fact that its use can cause an exacerbated increase in pH; there was also a change in the contents of Ca, Mg, P and Al.

Dim et al. (2010) in an experiment with four doses of slaughterhouse residues applied to Mombaça grass, obtained an increase between the treatments in dry matter production, number of tillers and plant height with a production of 9.3 kg of DM $^{ha-1}$ per ton of residue applied.

Pereira et al. (2015) found an increase in bean yield with the use of 2,500 kg $^{ha-1}$ of slaughterhouse waste, and the application of the residue before sowing did not affect its yield.

Damaceno et al. (2018), studying bone meal in Brachiaria ruziziensis grass, found a significant increase in soil pH with the treatments in relation to the control (without application of bone meal) and an increase in dry matter production between the treatments studied.

Freitas et al. (2016) in a study with different doses of bovine blood dregs, intercropped with three sources of soil amendments, found a difference between the treatments with and without lime in the elevation of soil pH, thus concluding that blood dregs have the potential to correct the soil.

Carvalho (2018), evaluating the productivity of Marandu grass under biofertigation with slaughterhouse waste, found that up to certain limits, there was a positive correlation between dry matter production and biofertilizer doses, in addition to contributing to the increase of microorganisms in the soil.

Orrico Júnior et al. (2013) cultivated piatã grass under increasing doses of poultry slaughterhouse effluent, and observed that higher values of tillering and forage mass were obtained when high doses of organic fertilizer were supplied.

According to Rodrigues et al. (2024), it is plausible to recommend the use of organic fertilizers as strategic sources of fertilization from the meatpacking industry, since it favored the good morphological development of the tiller and impacted on significant increases in the forage production of Marandu grass.

FINAL CONSIDERATIONS

The use of agro-industrial waste in agriculture is a great alternative to achieve sustainable rural developments, as it comprises the production cycle as a whole, aiming at the sustainable use of all products and by-products.

They can meet resource shortages in seasonality regions and the rationalization of renewable resources, in addition to being great alternatives for increasing profitability in a production chain.

In addition to solving one of the biggest problems in Brazil today, which is the environmental damage of improper disposal of waste in receivers, depleting non-renewable sources of resources. However, one must be aware of current legislation and use agro-industrial waste with extreme rationality, due to the biological and sanitary risk factors presented by them, emphasizing that errors in use projects can lead to greater problems than improper disposal.

Finally, the greater use of agro-industrial waste in agriculture, unfortunately suffers obstacles, due to the lack of financial resources and policies on the part of the public power, however a greater investment in research and an understanding of the business community of how waste can become valuable co-products, can transform waste into a whooping cough of the new times, and achieve sustainable development, from an economic, social and environmental point of view.

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CORN SEED PROCESSING PROCESS AT DUPONT DO BRASIL S.A-PIONEER SEMENTES DIVISION

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ABSTRACT
Corn is one of the most important cash crops originating in the Americas. Although of tropical origin, it is cultivated in practically all parts of the world. It stands out in the Brazilian agribusiness scenario as one of the most important commodities. In the past, seeds from one harvest were produced to be sold only in the following year's harvest. Currently, most of the seeds produced in the harvest are already sold in the "off-season" and those produced in the "off-season" are sold in the harvest. Therefore, the processing of corn seeds plays a fundamental role in the seed production chain, being operationally specialized when compared to other large crops. The corn cob is usually harvested, handled, peeled and dried, to later be threshed, cleaned, classified, treated and bagged. The companies stand out in the international market as leaders in seed production, meeting the most specific needs of the producer when selecting materials, harvest after harvest and Pioneer's business in Brazil is directed more intensely to the hybrid corn, popcorn and soybean seed market.

Keywords: Classification. Treatment. Storage.

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INTRODUCTION

Currently, Brazil has a very relevant position in world agriculture, the result of a transformation that has occurred in the last 40 years, through the process of modernization. It has become the country with the most possibilities to increase its production in response to the increase in local and, especially, international demand. The corn crop stands out in the Brazilian agribusiness scenario as one of the most important commodities.

According to CONAB (2013), the area planted with grains in the 2012/2013 harvest, estimated at 53.23 million hectares, is 4.6%, equivalent to 2.34 million hectares larger than that cultivated in 2011/2012, which totaled 50.89 million hectares. In relation to production, the 2012/13 harvest, estimated at 185.05 million tons, is 11.4% higher than the 2011/12 harvest, when it reached 166.17 million tons.

The reason for the increase in crops was the change in the concept of agriculture. In the past, farmers produced only one crop per year in the area, but with changes in concepts, it was possible to produce two crops per year in the same area. Later, there was also an advance in agriculture in the Brazilian cerrado: the use of two crops per year by farmers, the harvest and the off-season. The area cultivated with corn, first and second crops, totals 15.84 million hectares, as a result of which there was a growth of 4.4%, equivalent to 665.6 thousand hectares (CONAB, 2013).

In the past, seeds from one harvest were produced to be sold only in the following year's harvest. Currently, most of the seeds produced in the harvest are already sold in the "off-season" and those produced in the "off-season" are sold in the harvest.

In Brazil, there are also differences between the various groups of producers with regard to the use of more or less advanced technologies in corn production (GARCIA, 1987). There is a large portion of small producers who do not care about commercial production and high productivity rates, and a small portion of large producers, with high productivity rates, using more land, more capital and more technology in production.

The objective of this work was to report the internship carried out at Dupont do Brasil S.A - Pioneer Seeds Division in the production unit, in which an "Integration" work was carried out, to transmit the standards of safety, ethics, product quality and social responsibility of the company. And obtain knowledge of all production processes, assisting the team of each sector in the activities whenever possible.

THEORETICAL FRAMEWORK

Corn is one of the most important cash crops originating in the Americas. Although of tropical origin, it is cultivated in practically all parts of the world. Its economic importance is characterized by its various forms of use (DUARTE, 2004).

The seed input plays an important role in the development of agriculture, and contributes greatly to increasing productivity. It is necessary that the seed reaches the hands of the farmer with good genetic, physiological, sanitary and physical quality and also in adequate quantities in a timely manner for the rural producer (VON PINHO, 1999).

Processing is an essential part of the various stages of seed production, when the lots need to be handled properly to improve quality. Size and density are differential factors used in the separations carried out during processing (VAUGHAN et al., 1976).

The processing of corn seeds is operationally specialized when compared to that of other large crops. The corn cob is usually harvested, handled, peeled and dried, to later be threshed, cleaned, classified, treated and bagged. Classification is a process of extreme necessity and importance, due to the great variation in size, shape and quality of the seeds on the ear itself. In addition, density separation is essential to finish the improvement of the physiological quality of the seed lot.

Representing the final stage of the production process, processing refers to all the stages of seed preparation for commercialization, carried out after harvest, such as pre-cleaning threshing, drying, cleaning, standardization, treatment and packaging (VON PINHO, 1999).

According to Silveira & Vieira (1982), the final quality of the seed depends on the care taken to maintain the quality obtained in the field during processing and storage, minimizing the injuries that occur during processing, especially mechanical injuries.

For Delouche (1967), any equipment used in handling is a source of mechanical damage and contamination. The conveyors, elevators and other equipment used to move seeds, from harvesting, processing and packaging, can have an influence on the quality of the seed.

The ability of a seed to produce a normal plant can be reduced or nullified by mechanical injuries caused during processing (GREGG et al., 1970).

Amaral et al. (1984) found that the use of air machines and sieves and gravity table eliminated undesirable materials, increasing the physical and sanitary purity of pea seed lots.

Lollato & Silva (1984) and Buitrago et al. (1991) found that bean seeds processed on the gravity table had better physical, physiological and sanitary qualities.

Assmann (1983), working with soybeans, found that the gravity table separated the heavier seeds from the lighter ones, managing to separate the deteriorated, insect-damaged, mechanically damaged and dead seeds, improving the physical and physiological characteristics of the low and medium vigor lots.

Matthews & Boyd (1969) observed that beneficiation, in addition to improving the physical quality of a flock, can increase physiological quality, if any of the physical properties are related to vigor

The companies stand out in the international market as leaders in seed production, meeting the most specific needs of the producer when selecting materials, harvest after harvest.

Pioneer's business in Brazil is directed more intensely to the market of hybrid corn, popcorn and soybean seeds, and the company was a pioneer in Latin America to obtain the ISO 9001 certificate, both for production units and for its seed analysis laboratories, thus fitting into a strict quality standard.

The company also has several research stations throughout Brazil. At its stations, researchers work on the genetic improvement of soybean varieties and corn and sorghum hybrids. With advanced technologies, Pioneer has been focusing its research and development on products for the grain market of high quality and health, being grains with high oil and protein content for use in animal feed, as well as corn hybrids with special characteristics for the production of whole plant silage and wet grain.

With all this, the company stands out in the international market, as a leader in seed production, meeting the most specific needs of the producer when selecting materials, season after season.

COMPANY DESCRIPTION

Pioneer is a multinational company that originated in the United States, more specifically in the city of Johnston in the state of Iowa, where it was created in 1913.

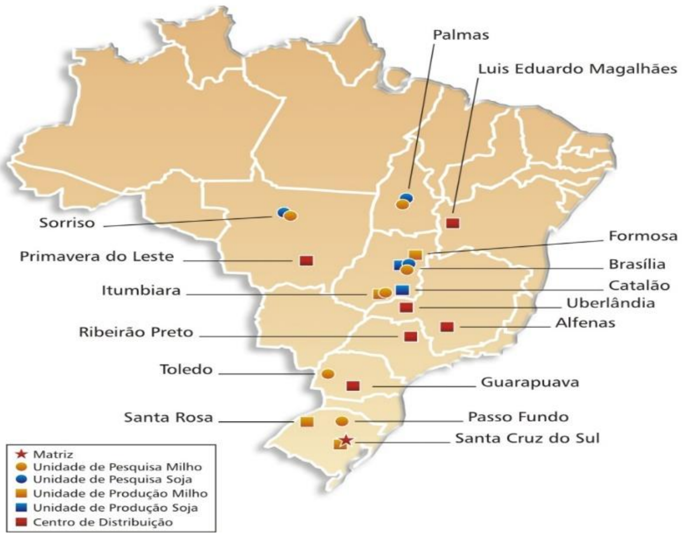
Henry Wallace, its founder, was a researcher who started a corn seed breeding program. The studies of the bloodlines and their crosses were so successful that in 1924, Henry Wallace won a productivity contest. In 1926, Wallace founded Pioneer Hi-Bred, being the first company dedicated to developing, producing and marketing hybrid corn seeds.

In Brazil, Pioneer began its activities in 1970, through a commercial partnership with Proagro – Comércio e Indústria Pró – Pecuária Ltda., of the Gomes Filho Group, from Bagé – RS. In May 1972, the formation of the company Proagro Pioneer S.A. - Agricultura, Indústria e Comércio, headquartered in Porto Alegre, was announced. In January 1976, the company transferred its headquarters to Santa Cruz do Sul – RS, where its headquarters are fixed to the present day.

In June 1982, the shareholding control became fully owned by Pioneer Hi-Bred International, headquartered in Des Moines, Iowa – USA, and thus Proagro Pioneer ceased to exist, establishing Pioneer Sementes Ltda. On March 15, 1999, Pioneer Hi-Bred International was acquired by the traditional multinational company DuPont, headquartered in the city of Wilmington, in the state of Delaware in the USA. In Brazil, Pioneer Sementes was officially incorporated by Dupont do Brasil in November 2005, currently having the following corporate name: Dupont do Brasil S.A. – Pioneer Sementes Division.

Today, Pioneer Sementes has five processing units in Brazil, two in Goiás (Itumbiara and Formosa), one in the Federal District (Brasília), and two others in Rio Grande do Sul (Santa Rosa and Santa Cruz do Sul), but in 2012 Pioneer inaugurated another unit, in the city of Catalão – GO, processing soybean seeds (Figure 1).

Figure 1 – Geographic distribution of the company's operations in Brazil



Source: DuPont Pioneer, 2013

ITUMBIARA UNIT

The Itumbiara unit is multidepartmental, there is not only the production of seed of commercial hybrids, there is the production of matrix seed, production research and seed quality laboratory, in the city of Itumbiara there is still a research station.

The production department is responsible for carrying out the process that begins with the receipt of the seed from the lines that will generate the hybrids until the shipment of the seed bags to producers, branches or resellers.

The mother seed department is responsible for multiplying the strains developed by the research, so that it can meet the demand of the production units. The mother seed processing unit located in Itumbiara is responsible for all the supply of mother seed to all units in Brazil, it also exports lines to some countries.

The production research department is responsible for designing and conducting experimental trials, which allow providing information about the strains to the production department. The information provided is extremely important for you to achieve acceptable yields, since the strain usually has a low productive potential.

The seed quality laboratory is responsible for carrying out the analyses of the corn seeds produced by the mother seed and production, in addition to the analyses necessary for research and production research, throughout Brazil. The analyzes carried out range from physical purity, where the existence of material other than corn seeds is analyzed, there are also physiological quality tests, where the germination and vigor of the seeds are verified, and genetic testing, where possible genetic contamination in the lots is verified.

The research station located in Itumbiara works together with the company's other stations, spread around the world, its focus is to develop corn hybrids for areas of north-central Brazil with low altitude.

MATERIALS AND METHODS

SEED FIELDS

Corn seed fields are usually made in places that have a pivot-type irrigation system, there is the possibility of planting in a non-irrigated area, but this occurs in sporadic situations. The Itumbiara unit establishes its seed fields in some regions that have the necessary characteristics for the production of corn seeds, these regions are called production centers. The production centers need to have some basic characteristics, availability of irrigated area, be at a favorable altitude for corn production, in the range of 600 to 1000 meters and not be far from the UBS, today the most distant fields are 300 kilometers away.

Currently, the Itumbiara unit works with three production centers, the Morrinhos center, the Paraúna center and the Minas Gerais center, each center groups a group of municipalities.

- The Morrinhos nucleus has as main municipalities: Morrinhos, Goiatuba, Pontalina, Vicentinópolis, Vianópolis and Piracanjuba;
- The Paraúna nucleus has as main municipalities: Paraúna, Palmeiras de Goiás, Rio Verde and Acreúna;

The Minas Gerais nucleus has as main municipalities: Uberlândia, Iraí de Minas, Patrocínio, Monte Carmelo and Monte Alegre de Minas.

In the nuclei of Morinhos and Paraúna there is a summer harvest and an off-season off-season harvest, in the nucleus of Minas Gerais it is planted only in the summer harvest. The company's production system is a system of cooperativism, where responsibilities are divided between the producer and the company:

The company is responsible for the supply of seeds, insecticides and fungicides, detasseling operation, core cutting and harvesting.

The cooperative member is responsible for the supply and application of herbicide, fertilizer, in addition to the application of other pesticides supplied by the company, planting and irrigation are carried out by the producer. The cooperative member must necessarily be the owner or tenant of the area and the pivot.

In each nucleus there is a field team, which is made up of agricultural technicians and agronomists, who are responsible for advising the cooperative producers and supervising the operations carried out, monitoring all stages, from planting to harvesting.

BENEFICIATION UNIT

Weighing and Receiving of ears

Upon arrival of the truck at the entrance, the driver must present the note, and the concierge writes down all the necessary data (driver's name, carrier, license plate), soon after the truck is sent to the scale. On the scale, the person responsible for weighing must check the documentation (invoice of the shipment of the harvested material with the breakdown of the type of material, delivery order, truck departure time, delivery number, crop number and breakdown of the producer's name). After weighing, the driver must pick up the scale ticket, where this ticket contains all the necessary data for the quality control of this load in the unit (name of the cooperative, farm, UBS, crop, material, lot, seed category, initial and final moisture of the seeds, impurities/straw, initial weight and final weight of the sample, last load of the crop: Yes or no, approval of the load, quality of the seed, responsible for checking the load, distance from the crop, carrier code, truck plate, line on which the load will be received, gross weight of the trailer, tare weight of the trailer, and net weight of the load). With the scale ticket in hand, the driver goes to the receiving to unload the material on the receiving line.

Receiving at the Pioneer unit in Itumbiara-GO is done in ears, and the average receiving capacity is 20 tons/hour.

The Itumbiara unit has two reception lines, being located next to each other, from this the lines are called side A and side B.

The employee responsible for unloading, based on a receipt control spreadsheet, delivered to him by the sector leader, will define which truck will be unloaded next and which line will be received. When defining the trailer to be unloaded, the employee checks the scale ticket and guides the correct parking position of the trailer. With the truck parked, the employee explains the safety procedures to the driver and asks him to get off the truck and give him the keys to it, then the same employee through a thermometer called "Datalog" checks the temperature of the truck, where it cannot exceed 41°C, due to consequent problems in the physiological quality of the material. The temperature of the truck is checked at four different points, and thus an average is obtained. For trucks that exceed this temperature limit, a notification and decision report (RND) is opened, segregating the material for later analysis of longevity and vigor in the laboratory.

Before unloading the material, other employees in the sector put the chocks on the rear tires of the truck. Soon after, the employees carry out the operational procedure of opening and unloading the truck. At the Pioneer unit in Itumbiara, the unloading of the trailer is done through a tarpaulin that is located below the load, so that when this tarpaulin is pulled, the load is unloaded at the dumper. To pull this load, the tip of the canvas is connected to a hydraulic drive roller, where it is rolled up and consequently pulling the load towards the tipper. When the unloading is finished, the tarpaulin is placed again on the floor of the truck, but this tarpaulin is placed folded, so that it does not break in the unloading of the next load.

In sequence, the ears with straw that were unloaded in the dumper are directed to the hoppers of the spreaders through a belt called "plow off". Each receiving side contains 7 spreaders, with a consequent 7 tables for manual ear selection.

When falling into the spreaders, the ears are spread by spreader rollers, and the straw is directed to the refuse belt where it will be unloaded into a refuse collection truck. The scattered ears will be directed to the selection tables. Each hybrid to be de-spread has a preferential side, and a specific adjustment in the despreader, to avoid excessive losses or delay in unloading the material. Upon arriving at the selection tables, the employees select the bad ears (where they will be directed to the discard belt), the ears not yet stripped (where they will be directed to the return belt) and the ears of atypical characteristics (where they will be directed to the discard belt). The good ears will go to the drying process.

Still in the receiving sector, there are some samples to determine the quality of the material being unloaded.

To determine the initial moisture content of the seeds, 10 ears are sampled as soon as the trailer doors are opened. With the help of the lime Soon after, 35 to 40 grams of seeds are weighed and then crushed. From this material, 3 to 4 grams are taken and placed in the tray of a device called OHAUS. The value obtained is entered in a spreadsheet where the corrected value is determined.

For waste sampling of the spreaders and selection table, a sampling box is pushed on the waste belt and only removed when it is full. Subsequently, this scrap material is glued to a plastic bucket and then placed in the sample separation box. This sample sorting box consists of a wooden box with a sieve at its bottom that will separate the threshed seeds from the straw, the ears crushed by the rollers of the spreader, and the ears discarded by the sorting table. Soon after, the separated materials are weighed and thus the percentage of discards of each type of waste is obtained.

Finally, the last sampling done at the receipt will determine the percentage of straw of the material to be discharged. Sampling is done on the inclined conveyor belt (before reaching the hoppers of the spreaders), and 1 linear meter of the material is collected. Soon after, the sample is weighed with straw, which must weigh between 18 and 22 kg. Soon after, the material is manually peeled and weighed again. From the difference of the two weighings, the weight of the straw and consequently its percentage are obtained.

Drying and threshing of ears

Freshly harvested ears may have an inadequate content for storage, depending on variable factors during harvest. The high moisture content can affect the quality not only during the storage period, but also hinder the efficiency of the machines used in processing.

The most appropriate time to harvest the seeds is as close as possible to physiological maturity. For corn, the physiological maturity of the seeds can vary between 28 and 42% moisture, depending on the hybrid.

Drying on ears is carried out when the seeds have moisture content around 28 to 35%, or at their physiological maturity, thus ensuring high quality. Drying on the cob prevents the embryo from suffering direct action from temperature and also from mechanical damage.

The material that was selected at the receipt will be destined for the dryer, for this the tripper is positioned in the destination drying chamber.

The Pioneer dryer consists of 5 drying buildings totaling 66 fixed-bed drying chambers, with each chamber having an average capacity of 75,000 kg wet and 30 to 35,000 kg of dry cobs.

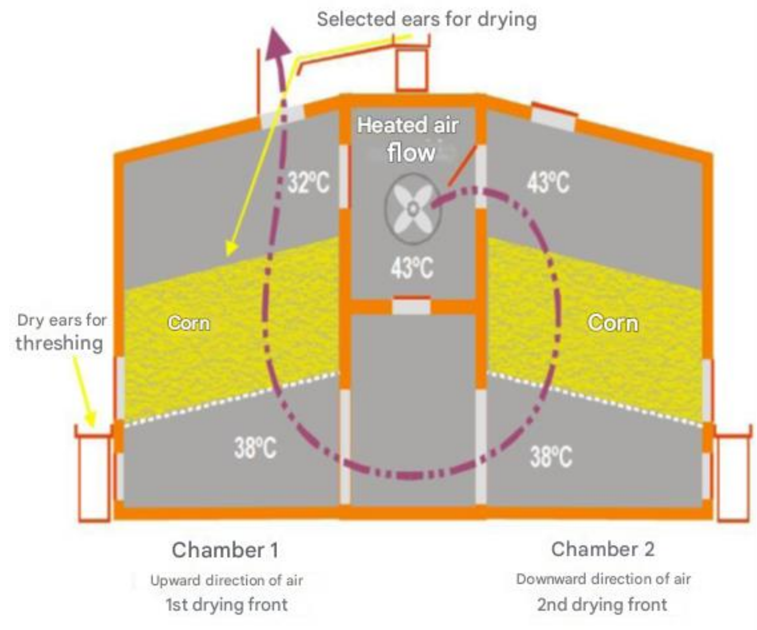
The drying of the ears will work in stationary layers, with upward and later downward air flow, until the material obtains the final desirable moisture of 12%. As a source of heat for drying the seeds, Pioneer uses a furnace system, where the dry cob obtained in the threshing is used, thus saving on energy sources. This cob that would become a disposal problem at Pioneer is seen as a solution, since its burning will generate heat energy for the drying of the wet material that reached the chambers. This cob in the threshing process is separated from the seeds by a sieve and stored in silos, so that when the furnaces need cobs they can automatically supply them.

The drying process is seen as a critical point in interfering with the physiological quality of the seeds, since for each hybrid there is a drying time, a filling height of the chamber and an adequate air flow.

When the seeds arrive at the drying chamber, they receive the upward air flow at a maximum temperature of 38°C and minimum relative humidity of 35%, when the inversion time is given, the inversion test is done to check the moisture of the seeds. After the test, the chamber's airflow is reversed, working with a maximum temperature of 43°C and minimum relative humidity of 20%. The drying period at the rising moment is the most critical in the process, since a temperature above 38°C can cause the pericarp of the seed to crack. Thus, the regulation of this process should be observed, as the rupture of the pericarp will result in less longevity due to the increase in gas exchange between the seed and the medium.

To regulate this process, the psychrometric chart is used, which is based on the ambient temperature and relative humidity, determining the ideal air temperature that the furnace should heat, so that the air sent to the drying chambers by the ventilation of the upper tunnel reaches the drying chambers at around 20% humidity, in the downward direction (Figure 2).

Figure 2. Diagram of operation of a drying chamber.



The downward airflow reaches chamber 2 through the upper tunnel vent. When it reaches chamber 2, the air has a relative humidity of around 20%, but when it passes through chamber 2, this air flow takes with it the moisture extracted from the ears stored in the chamber, reaching the lower tunnel with a higher relative humidity, around 45%, and so the same will happen at the end of its passage through chamber 1, where this flow will present an even higher relative humidity (around 75%).

To ensure the physiological quality of the seeds, preliminary tests of sensitivity to drying carried out in the production research sector give security as to the drying speed, chamber filling height and ideal air flow to be used.

Some tests serve as parameters to determine the exact moment when the seed has adequate moisture (12%) for threshing. The tests used are:

- Hours of drying.
- Temperature difference of inlet and outlet of the air to the chamber.
- Difference in relative humidity of air inlet and outlet to the chamber.
- Humidity test.

The moisture test is the most important and reliable, being carried out with the help of a screw-type sampler, where samples are collected at 3 points in the chamber. After collection, the ears are threshed with the help of a lime The seeds that have been threshed are packed in a small pot, where the moisture test is later done in a device called GAC, to determine if the seeds are really suitable for threshing.

After the moisture test and confirming the moisture content of 12% of the seeds, the ears are directed to the threshing building. The threshing building consists of 40 silos with a capacity of up to 160 thousand kg each.

The thresher has the capacity to thresh 60 tons/hour, working in order to press and rub the ears against each other, which reduces damage to the seeds. Just below the thresher there is a sieve responsible for separating the cob from the seed mass.

The pre-cleaning machine located further down the thresher removes cob residues, small grains and dust from the seed mass. After threshing, the seeds are transported to the silos via elevators and belts.

Before arriving at the silos, still on the conveyor belt, the seeds are treated with insecticides (Actellic and K-Obiol), to protect against stored grain pests (moths, weevils and caterpillars).

For seed unloading, the silos have an impact damping system, to prevent mechanical damage and consequent reduction of the productive potential. In the silos, sensors monitor the temperature of the seeds inside the silos and activate the aeration system depending on the environmental conditions and conservation parameters of the stored seeds. Thus, the aeration system keeps the seeds in ideal temperature conditions to ensure quality during storage.

Classification, Treatment and Bagging Tower

The Pioneer tower in Itumbiara has 5 floors, with an average sorting capacity of 20 thousand kg / hour, depending on the hybrid.

The access of the seeds from the silos to the tower is done via conveyor belts. Upon arriving at the tower, the seeds are directed by the DRM to the buffer silos. These silos house the seeds that will later be classified.

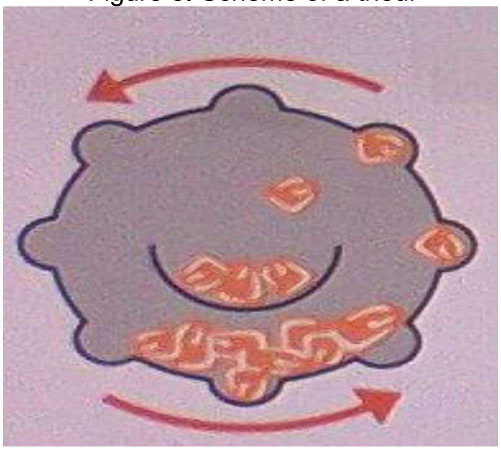
The stage prior to classifying the seeds consists of a pre-cleaning process, where large amounts of dust, broken seeds and pieces of cob are discarded.

When going through pre-cleaning, the seeds are sent to a machine called "CARTER DAY", where it is composed of a set of 6 perforated cylinders that work like a sieve, rotating horizontally, thus classifying the seeds first by width and later by thickness. The seeds enter the cylinder through one end, and the rotation of the cylinder turns the seeds in such a way that each seed, individually, will be positioned in order to present the appropriate dimensions for the perforations, so that the smaller seeds pass through the perforations and are transported to a discharge spout. As the larger seeds do not pass through these perforations, they move along the entire length of the cylinder, being discharged into another discharge spout. With this, the larger and smaller seeds will be destined for another Carter Day, but the larger ones will now separate by thickness, separating flat seeds from round seeds. In this way, several cylinders are mounted in sequence, in order to allow separations in different sizes in a single continuous flow operation.

After separation into width and thickness, the seeds will be sorted by length. The machine used to separate the seeds according to length is a honeycomb cylinder separator called a trieur.

The trieur consists of a cylinder with alveoli of defined size on its internal surface, a chute for seed collection, discharge screws, flow retarder, cylinder tilter and pulley of variable diameter and through its reducers rotates counterclockwise, separating short, medium and long seeds (Figure 3).

Figure 3. Scheme of a trieur



The trieur works in such a way that the short seeds fit into the cells and are discharged over the chute to later fall into a spout and be housed in a silo.

After separation in length, the seeds will be separated by specific weight. For this operation, the gravity table is used.

The gravity table is composed of a perforated cover, allowing the passage of air, in an upward direction. The air is adjusted to lift light seeds, while heavy ones remain on the table surface, separating the seeds into stratified layers. With the elliptical movement of the table and with the inclinations of the table lid, the lighter seeds, present in the upper extract, flow downward and are discharged at the lower discharge edge of the table. The heavy seeds are led upwards, concentrating in the highest part of the table, where they are discharged. Between the outputs of light and heavy seeds, there is an intermediate material formed by medium seeds, which will return to the process and will be gravitated again.

After the entire classification process, the seeds will be taken to treatment, for subsequent bagging of them.

There are 2 types of treaters in the Pioneer tower, the conventional and continuous flow treatment treater, and the additional treatment and batch flow treater, treating 200 Kg of seeds/batch.

The conventional treatment is composed only of the fungicide Maxim (fludioxonil), which is a systemic and contact fungicide. For additional treatment, there are several combinations of insecticides, fungicides and even polymers.

Treated seeds are identified with a dye, thus differentiating from untreated seeds. The treatment is intended to protect the seeds against the attack of fungi and pests in the period of emergence in the field, or even in storage.

The demand for additional treatment is growing in expansion, due to the ease and convenience it offers to the producer. For additional treatment there is a varied mix of products, such as insecticides: Standak, Cruizer, Poncho and fungicide: Maxim, in addition to the use of Polymer.

The polymer is important to ensure the attachment of the products to the seed, thus not allowing soil moisture to disaggregate the products from the seeds.

In Itumbiara, there are 2 bagging lines, one semi-manual and the other fully automated. The bagging works in three shifts, and the average bagging in this winter harvest of 2011 was 6 thousand bags per day. However, the company's record for withdrawals in a working day is 21 thousand bags.

The bagging scale will release the seeds after treatment in variable quantities according to the data passed to the machine operator, such as (lot weight, number of bags, bag size, hybrid identification). Each bag contains 60 thousand seeds, and to guarantee this number Pioneer works with the addition of 5% more seeds per bag.

Printing on the bag is also carried out in this sector, with data such as: batch, hybrid, sieve, disc suggestion and net weight being printed. The sack is standardized with the company's requirements and is made of multiwall paper.

After bagging, the bags are placed on the pallets and sent to a cold chamber (10°C) for greater longevity of the seeds.

At the end of the treatment and also at the end of the classification, the company plants all seed lots. Plantability simulates field sowing, identifying percentages of failures and doubles. Also through plantability and the best discs for each hybrid and sieve are indicated, thus guaranteeing the producer a good final stand in his crop.

Storage and Shipping

When the product is ready, it is accommodated on pallets, facilitating its movement within the warehouse, such as the use of forklifts. Bags of corn seed are stored in cold chambers, at 10ºC and 50% relative humidity. These conditions are necessary to preserve the quality of the seed and extend its shelf life.

The unit's production is shipped in two ways, on pallets or in "beaten load". Shipping on pallets is mainly done when the product will be transferred to a branch or delivered to cooperatives and resellers, there are also large producers who receive it on pallets. Shipment in "hit loads" is when the bags are removed from the pallets and allocated directly to the truck body. It is done this way when the recipient does not have equipment to remove the pallets from the truck. The "beaten load" is mainly used when it comes to direct delivery to the customer.

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PRODUCTIVE REALITY AND POSSIBILITY OF USING CULTIVARS OF THE GENUS *MEGATHYRSUS*

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ABSTRACT

Inadequate pasture management in Brazil has resulted in degradation and reduced livestock productivity. Disordered intensive grazing compromises the response capacity of forages, while the lack of soil correction and fertilization, together with inadequate practices, contribute to low productivity and degradation of the environment. Erosion, especially laminar erosion, is a significant indicator of this problem, causing soil loss and increasing runoff. In addition, poor practices promote the emergence of weeds, aggravating the situation. It is crucial to adopt sustainable management technologies, such as pasture reform and recovery, to maintain their productive capacity. The choice of suitable forages and specific management are essential to ensure the sustainability of the animal production system. Cultivars of the genus Megathyrsus maximus are highlighted for their high dry matter production and nutritional quality. Since the 1980s, several cultivars have been developed in Brazil, starting with the Colonião cultivar, one of the first, and also others such as Tanzania-1, Mombasa, Massai, BRS Zuri, BRS Tamani and BRS Kenya, more current. The productive capacity of the forage canopy is influenced by factors such as temperature, light and nutrients, which must be respected for good production and persistence of pastures. Proper management, with grazing strategies, is necessary to optimize production and efficiency in pasture use.

Keywords: Forage. Pasture management. Intensive systems.

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INTRODUCTION

The use of pastures is essential for livestock in Brazil, as they predominate as the main source of food for cattle raising (MATOS et al., 2021), but inadequate soil and forage management has caused a drop in productivity and degradation.

The degradation of pastures directly affects productivity and raises livestock costs, as it requires greater feed supplementation to maintain the performance of herds. In addition, the loss of soil quality intensifies erosion and increases vulnerability to adverse weather conditions, compromising the profitability and sustainability of the sector (OLIVEIRA; MONTEBELLO, 2014).

Faced with this reality, the development of technologies aimed at pastures has made it possible to change this scenario. However, for this transformation to occur effectively, it is necessary to constantly carry out research that seeks to expand knowledge about the behavior and responses of forages to environmental factors, as well as aspects related to their use and management (FREITAS et al., 2016; ABREU et al., 2017).

As a response to the need for more efficient plants, the launch of new forage cultivars aims to meet the demand of the sector. In this sense, studies that evaluate genotypes can contribute to the improvement of these characteristics, in addition to promoting the diversification of pastures and reducing the impact of monoculture (MAIA et al., 2021).

In addition, the adoption of appropriate management practices emerges as one of the alternatives to mitigate the effects of seasonality in forage production. It is observed that the growth stage at which the plant is harvested directly influences the yield, chemical composition, regrowth capacity, and persistence of the crop (MATOS et al., 2021). In general, less frequent cuts or grazing provide greater forage production, but markedly reduce its nutritional quality (SOUZA et al., 2020). Thus, it is essential to seek a balance between forage production and quality, in order to meet the nutritional needs of the animals and, at the same time, ensure the persistence and productivity of pastures (MAIA et al., 2021).

The analysis of forage plant growth, therefore, offers important subsidies to evaluate the growth potential of cultivars, their responses to environmental variations and grazing management. This analysis also allows inferences about the physiological processes involved in plant responses to various stimuli (ABREU et al., 2017).

Finally, to establish effective strategies for the use of these grasses, it is essential to know the growth pattern, the production of forage plants and their behavior in the face of different managements, enabling a more efficient use and assertive recommendations for the sector.

DEVELOPMENT

PASTURES IN BRAZIL

In Brazil, pastures are the main source of food for cattle, supported by favorable climatic conditions and large areas of arable land. However, soils that are often acidic and have low fertility require specific management and a careful choice of forages to maintain productivity. These strategies not only meet the demand for animal protein, but also strengthen the livestock economy and ensure the sustainability of production systems (SISTE et al., 2023).

Regarding the territory, Brazil has a wide extension and a favorable climate, which allows large areas of pastures, which occupy approximately 50% of the country's rural establishments (CORDEIRO et al., 2015). However, despite this large area destined for pasture, about 130 million hectares are degraded or in the process of degradation, requiring urgent interventions.

In addition, although pastures represent the main and most accessible source of feed for livestock, they are influenced by the weather, especially during drought, which reduces forage production and quality. In the rainy season, pasture degradation is mainly caused by management failures, which is one of the factors that most limit forage production (SANTOS et al., 2021).

Given this situation, it is essential that pastures maintain productivity, which occurs with the continuity of leaf and tiller emission, a fundamental process for the restoration of leaf area after cutting or grazing. This emission ensures the longevity of the forage and its photosynthetic capacity, crucial for the development and growth of the plant (SARAIVA et al., 2019).

However, when the objective is to intensify animal production via intensive grazing, the regeneration capacity of plant tissues is affected by the constant removal of leaf area, compromising light absorption and, consequently, reducing pasture productivity (ANJOS et al., 2020).

Thus, it can be seen that the main problems of pasture productivity lie in the lack of soil correction and maintenance fertilization, added to the inadequate management of forages, such as disrespect for the correct periods of grazing and resting. The adoption of pasture management technologies, including reforms and fertilization, becomes essential to avoid a sharp drop in the carrying capacity, plant production and weight gain of the animals (FACTORI et al., 2017).

CHALLENGES AND OBSTACLES OF PASTURE PRODUCTION FOR LIVESTOCK

One of the main challenges in pasture production in Brazil is the adoption of efficient management practices, which are essential to sustain the growing demand for animal protein. Despite the country standing out as one of the largest meat exporters and having significant projections of increased production in the coming years, pastures still face critical problems. In this context, the high global demand positions Brazil as a potential supplier, benefiting from factors such as the wide availability of land and favorable climatic conditions. However, many pasture areas remain degraded due to inadequate management, resulting in serious socio-environmental and economic impacts. Thus, the low productivity and sustainability of livestock become significant obstacles for the sector (CORDEIRO et al., 2015).

These problems are closely associated with inefficient or neglected management practices, which include weed control, inadequate fertilization, mowing, fallow of animals, unplanned paddocks, excessive volume of animals, as well as plowing and harrowing in sloping areas, among other factors. The influence of regional physiographic conditions cannot be underestimated either (SARAIVA et al., 2019).

In addition, Kill-Silveira et al. (2020) address the complexity of proper pasture management, highlighting that this process is influenced by climatic variations throughout the year, different types of soil with different physical and chemical characteristics, and the grazing categories and habits of animal species. Another critical point is the introduction of grass cultivars, which often occurs without proper studies on the behavior of these species and their practical applications, which can make it difficult for managers to understand. The lack of technical assistance represents another challenge, as this support is crucial to increase production efficiency. Without this guidance, most producers remain in a position of mere exploitation of available resources, unable to implement significant improvements in animal production.

In this scenario, there is a growing pressure and restriction to the clearing of new areas for the establishment of pastures. This reality drives the search for management strategies and technologies that can provide the intensification of the production of cultivated pastures, generating economic gains and ensuring the sustainability of animal production systems (JACK et al., 2017).

This understanding leads to a critical point for increasing productivity: the planning and optimization of the use of production factors, such as water supply, temperature, photosynthetically active radiation, and nutrients. In addition, it is essential to choose the forage correctly and optimize the management factors, establishing appropriate goals for each grazing ecosystem. These actions aim to ensure the quantity and quality necessary for animal performance and productivity, ensuring the economic viability and sustainability of the production system (MATOS et al., 2021; FACTORI et al., 2017).

PASTURE USE SYSTEMS

Different management methods in pastures can be presented in two systems: continuous and rotational, as highlighted in Chart 1. There are a variety of opinions about what would be the best system to use, but these opinions are many and divergent. Studies have shown a significant effect of grazing pressure on animal performance and the performance of plant varieties. A common element in these experiments has been the interaction between stocking rate, grazing system, and the performance of forage varieties (MACHADO et al., 2019).

Table 1: Comparison of Advantages and Disadvantages between Continuous and Rotational Grazing Systems

	Continuous	Rotational
Advantages	Simplicity in management; Possibility of using native pastures; Ease of installation; Lower demand for labor; Lower costs and investment in more advanced technologies; Reduced stress for animals (VIERIA, 1997; JUNIOR; NETO, 2001; COSTA, 2007)	Improvements in weight gain and feed efficiency; Better control of pathogens and parasites, contributing to the health of animals; Higher stocking rate per area; High-quality, nutrient-rich forage; Improvements in pasture quality; Stimulating the growth of a variety of plant species, including grasses and legumes; More nutritionally balanced feed for the ruminant, with a positive impact on meat quality; Maintenance of soil health; Reduction of soil compaction and erosion; Enrichment of the soil in nutrients by the deposition of animal manure; Reduction in the need for chemical fertilization; Reduction of the environmental impact of livestock; Preservation of natural resources and avoidance of water contamination; (SHIBU; DOLLINGER, 2019; FUKUMOTO et al., 2010).

Disadvantages	Low rate of weight gain and feed efficiency; Less control over capacity capacity; Impact on forage growth and regeneration; Greater compaction and wear of the soil; Increased susceptibility to pests and pathogens in pasture (COSTA, 2007; JUNIOR; NETO, 2001; JÚNIOR, 2002; VIEIRA, 1997).	It requires a detailed analysis of costs and investment of more advanced technologies; It requires better management and technical knowledge and continuous supervision; Failures in management can compromise results; Climatic variations and unpredictability of weather, such as prolonged droughts, which can affect the availability of forage; Requirement for food supplementation, increasing production costs; (SATO et al., 2014; ALEMU et al., 2019).

Combined with the genetic improvement of forage plants, the grazing system adopted can be fundamental for the improvement of the production process. The continuous system is the most used, as it requires lower expenses for its installation, requiring only the implementation of fences, water supply and troughs (FLORINDO et al., 2017).

However, even with all the favorable conditions in Brazil, several localities do not take adequate advantage of these conditions, due to the low efficiency of grazing management. The choice of the type of grazing system is based on the simplicity and advantages of the operations performed, especially in maintaining pasture productivity (MATOS et al., 2021).

In the continuous system, the animals remain extensively in the pasture throughout the year, requiring the use of a perennial cycle pasture. The category of animal (cow, calf, etc.) must be adjusted according to the production capacity of the forage; thus, lighter categories should be allocated to areas of lower production or the adjustment of lower capacity should be made for heavier categories (SILVA et al., 2016).

This system requires a smaller volume of labor, since it is not necessary to alternate the area for the crowded animals. However, a problem that prevails in this system is the pressure of animals on the forage, which hinders the revitalization of the plant, delays regrowth, and increases the amount of damaged plants (LIMA et al., 2018).

On the other hand, the rotational grazing system is characterized by the periodic and frequent exchange of animals from one paddock to another, with the objective of offering a rest time for the forages. This system allows for better results, since forage management is carried out intensively, providing greater availability of quality forage (BISI et al., 2019).

After the occupation of each paddock, for a variable period of time of a few days, when its vegetation is totally or partially defoliated, the paddock remains at rest, without the presence of animals, allowing the recovery of its foliage and completing the grazing cycle (MACHADO et al., 2019).

MAIN FORAGES USED

In Brazil, cattle production, for the most part, uses two genera of pastures: *Urochloa* and *Megathyrsus*, tropical grasses with high production potential, both in quantity and quality. However, this potential has not been explored due to inadequate management and the lack of nutrient replacement in the system, especially nitrogen (N), causing a decline in production and ultimately harming animal production (SILVA et al., 2016).

As in other economic activities, the production of pastures undergoes constant evolution. In this sense, the choice of variety or the recovery of pastures becomes a necessary procedure for the establishment or maintenance of high productivity (ABREU et al., 2017).

The species *Megathyrsus maximus* Jacq. is one of the main forages cultivated worldwide in tropical and subtropical regions. In Brazil, it is highly valued for its high dry matter production capacity, forage quality, ease of establishment and acceptability by animals (ABREU et al., 2017).

In the 80s, when the work of genetic improvement of *M.* maximus grass began, the interest of technicians and cattle breeders in this species resurfaced. Allied to the novelty also came a greater awareness of the importance of pasture management and soil fertility for these pastures to be maintained (GARCEZ et al., 2020).

The first cultivar of *M. maximus* used in Brazil was cv. Colonião and since the beginning of the breeding program in *M. maximus* , the cultivars launched by Embrapa Beef Cattle so far have been: Tanzania-1 (in 1990), Mombasa (in 1993), Massai (in 2000), BRS Zuri (in 2014), BRS Tamani (in 2015), as the first hybrid cultivar of *M. maximus* developed by EMBRAPA, and more recently, in 2017, BRS Kenya (JANK et al., 2017a).

Within this context, the Tanzania cultivar, originally from Tanzania, Africa, is a variety of *M. maximus* that was released for commercialization by Embrapa in 1990 due to its high annual production and excellent nutritional value. Its development aimed to replace Colonião grass, standing out for producing up to 80% more leaf mass, 6% more growth in the dry season and 32% more seeds. Its smaller size and abundance of leaves favor a more uniform grazing, minimizing the mosaic effect typical of the Colonião and Mombaça cultivars, as reported by Jank et al. (2017a) and Embrapa (2013).

Tanzania grass is medium-sized, growing around 1.30 m, with a cespitose shape and clumps. Its leaves are decumbent, free of hairiness and waxiness, and flowering is concentrated in April in the southeast and central-west regions. Dry matter data show significant yields of 27.80 t $^{ha-1}$ with irrigation and 24.43 t ha-1 without irrigation, while crude protein reaches 16.2% in leaves and 9.8% in stems. Compared to Mombaça grass, the

Tanzania cultivar has a superior performance, with protein levels of 13.91% compared to 11.55% (LIMA, 2009). Tanzania grass is well adapted for silage due to the high production of forage, but it is not ideal for haying due to the thicker and juicier culms, which make the process difficult (GOMIDE et al., 2016).

Adapted to soils of medium to high fertility, Tanzania has good tolerance to poorly drained soils and resistance to grassland leafhoppers, although it is susceptible to the fungus *Bipolaris maydis*. The presence of stems during flowering can reduce the nutritive value of the pasture and make it difficult for the animal to harvest, but these effects can be minimized with proper management practices. Its use has expanded among producers in integrated crop-livestock systems, replacing elephant grass and *U. decumbens* in degraded areas (SANTOS; COSTA, 2006).

One of the biggest challenges that Tanzania grass has is its susceptibility to leaf spot. This fungal disease causes dark spots on leaves, compromising photosynthesis and reducing pasture productivity. Over time, this problem has led many growers to replace Tanzania with other, more resistant varieties, as controlling the disease can be difficult and costly, especially in regions with high humidity, where the fungus proliferates more easily. Today, Tanzania grass has lost ground precisely because of the difficulty of maintaining healthy and productive pastures in the face of this threat (MARTINEZ et al., 2010; MARCOS et al., 2015).

In addition to susceptibility to leaf spot, another important obstacle in the use of Tanzania grass is the difficulty in obtaining its seeds. The production of seeds of this variety is complex, requiring specific conditions to ensure viability and adequate germination, which often results in low supply in the market and high prices. This further discourages producers, who are looking for more affordable and resistant alternatives. Thus, problems with the disease and the limitation of seeds have made Tanzania an increasingly less viable option in production systems that seek sustainability and efficiency (TOMAZ et al., 2010; GOMES et al., 2008)

The Mombaça cultivar, originally from Tanzania and selected by Embrapa Beef Cattle in collaboration with the Agronomic Institute of Paraná, was commercially launched in 1993. This cultivar stood out for its high productivity and low seasonality index, presenting up to 28% more weight gain per area than the cultivar Tanzania-1. Mombaça grass is valued among cattle breeders for its long leaves, tall size and high acceptance by animals, forming clumps up to 1.65 m in height, purplish stalks and slightly hairy leaves on the upper face. Although it requires soils of medium to high fertility for good establishment, its wide adaptation and nutritional value make it an attractive choice for forage production (JANK, 1995; FONSECA et al., 2010; JANK et al., 2010; LEMPP et al., 2001).

With dry matter yields between 15 and 20 t $^{ha-1}$ and crude protein contents between 10 and 12% throughout the year, Mombasa maintains about 82% of leaves in the composition and is well accepted by cattle, buffaloes, sheep and goats. Its high capacity to use available phosphorus (P) and moderate resistance to grassland leafhoppers make it superior to other cultivars. In addition, the high production of dry biomass in Mombasa has encouraged its potential use for silage, favoring production systems that seek greater food security and versatility in forage management (CERQUEIRA, 2010; EUCLIDES et al., 2008).

Another highlight is the Massai grass, which is a low-sized grass, with clumps up to 60 cm in height and narrow, brittle leaves, with an average width of 9 mm. Very versatile, it can be used both in extensive, intensive and rotational grazing as well as for cutting and haying. Its leaf production reaches 15.6 t ha^{-1} of dry matter, a number comparable to that of colonião grass, but with less seasonality, that is, it maintains production throughout the year in a more uniform way. In nutritional terms, Massai grass offers 12.5% of crude protein in the leaves and 8.5% in the stems, values similar to those of the Tanzania cultivar, making it an attractive option for animal nutrition in different regions of Brazil (LEMPP et al., 2001).

The adaptability of Massai grass was extensively tested by Embrapa Beef Cattle, showing its ability to develop in various soil types (pH 4.9 to 6.8), latitudes between 3° and 23°5', altitudes from 100 to 1,007 meters and annual rainfall between 1,040 and 1,865 mm. In the northeastern semiarid region, the cultivar proved to be productive and versatile, being studied in systems with different N levels, where up to 934 kg of N per hectare per year generated good results without affecting plant morphology. In addition, its good tolerance to shaded areas and adaptation to silvopastoral systems make Massai grass an excellent alternative to enrich areas of the Caatinga, improving forage production and contributing to the feeding of sheep and other ruminants in challenging environments (LOPES, 2012; CARVALHO et al., 2014; ARAÚJO, 2015).

Two decades after the launch of the Tanzania-1 and Mombaça cultivars, Embrapa Beef Cattle, in partnership with Unipasto, launched the BRS Zuri cultivar in 2014. This new forage was developed from populations of *M. maximus* collected in Tanzania, East Africa, and underwent rigorous tests in the different Brazilian biomes. BRS Zuri stands out for its high productivity, regrowth vigor, carrying capacity, and good animal performance. In addition, it is resistant to grasshoppers and leaf spot caused by the fungus *Bipolaris maydis*, a common problem in the Tanzania-1 cultivar. Adapted to well-drained soils of medium to high fertility, this cultivar shows a significant accumulation of forage and leaves, surpassing the Mombasa in some aspects. Its leaves are wide, long and arched, with a dark green color, characterizing a tall cespitosa plant (EMBRAPA, 2014).

In tests carried out by Embrapa, BRS Zuri showed a production of 21.8 t $^{ha-1}$ of leaf dry matter under manual cutting, with approximately 85% of this yield concentrated in the rainy season, which makes management in a rotational stocking system the most indicated. In terms of nutritional value, the cultivar showed a crude protein content between 11% and 15% in the leaves and from 7% to 12% in the stems. In comparative studies on the response to P, BRS Zuri stood out with an average yield of 6,694 kg $^{ha-1}$ of total dry matter, higher than that of BRS Kenya, in addition to presenting a leaf proportion of 65.7%, an index also higher than that of Mombaça and BRS Kenya grasses, with 62.6% and 63.0%, respectively (JANK et al., 2017b).

BRS Tamani is the first hybrid grass cultivar developed by Embrapa Beef Cattle in collaboration with several Embrapa units, such as Embrapa Acre, Cerrados, Dairy Cattle, Southern Livestock and Rondônia. Resulting from the cross between a sexual plant (S12) and an apomictic access (T60 - BRA-007234) (EMBRAPA, 2015).

With a short size and cespitous growth, the Tamani cultivar reaches up to 1.3 meters, with long, thin and arched leaves that reach 1.09 cm in length, in addition to being rich in crude protein and highly digestible. In cutting trials, the dry matter yield reached 15 t $^{ha-1\ year-1}$. In the dry periods, Tamani has a crude protein content of 10% and digestibility of 60%, while in the waters, these values rise to 12.4% of crude protein and 59.6% of digestibility. The cultivar is indicated for the Cerrado and for the Amazon and Atlantic Forest biomes, as long as they are in well-drained soils and of medium to high fertility. Despite its good resistance to pests, Tamani does not tolerate waterlogged soils, preferring areas with good structure and, ideally, previously cultivated soil. In terms of resistance, Tamani has similar tolerance to *M. maximus* cultivars, such as Massai, Mombasa and Tanzania (EMBRAPA, 2015; MACIEL et al., 2018)

Another BRS Kenya cultivar, launched by Embrapa Beef Cattle in 2017 in partnership with Unipasto, is an intermediate-sized hybrid of *M. maximus*, bred to meet the demand for a forage of high productivity and quality, in addition to easy management due to its smaller size and reduced stalk elongation. Its characteristics include soft leaves, tender culms, and high tillering capacity, which facilitates management, especially in rotational systems. In the Cerrado and the Amazon, this cultivar blooms between January and February, with continuous tillering that extends the grazing period until May or June, according to rainfall. Another differential is the resistance to the grasshopper by antibiosis, a factor that contributes to the longevity and quality of the forage (EMBRAPA, 2017; JANK et al., 2017a).

BRS Kenya offers good yields, with an average production of 13.2 t $^{ha-1}$ of dry matter in the waters and 1.41 t $^{ha-1}$ in the dry season, surpassing the Tanzania and Mombasa cultivars. In terms of quality, crude protein reaches 10.6% in drought and 11.8% in water, values higher than those of Tanzania and Mombasa, while neutral detergent fiber (NDF) remains between 72% and 75%, a lower rate than that of the other cultivars. However, it is important to note that BRS Kenya is not suitable for waterlogged soils, as its performance is compromised in areas with drainage problems. For optimal management, Embrapa suggests the entry of the animals into the paddocks when the forage reaches between 70 and 75 cm and the removal around 35 to 40 cm. Although there are no specific guidelines for silage production, the potential for use is promising, given the quality of the biomass of this cultivar (EMBRAPA, 2017; JANK et al., 2017a).

In a general context, grasses of the genus *Megathyrsus* maintain their productivity levels with adequate nutrient replacement, through maintenance fertilization. Adequate soil management, fertilization, and knowledge about the nutritional needs of plants are fundamental factors, as they interfere with pasture productivity and quality (JANK et al., 2017a).

Irrigation enables greater forage mass production in *M. maximus* grass cultivars. Irrigation makes possible a better balance in DM productivity between autumn/winter and spring/summer. By associating adequate temperature and radiation with the necessary water availability and high fertilization rates, especially nitrogen fertilization, the recovery of the pasture occurs faster and it is possible to obtain pastures with excellent nutritional value (CARDOSO et al., 2017).

Regarding pasture management, in situations of reduced defoliation intensity, losses may occur, as a higher senescence index of a material that can be consumed by animals will be observed. The results demonstrate the importance that the structure of the forage canopy has on the accumulation and nutritional value of the forage produced and on the ingestive behavior, intake and performance of grazing animals. Thus, the development of management strategies based on grazing heights becomes a viable option aiming at the efficiency in the productivity of systems in pastures in tropical areas (SBRISSIA et al., 2017).

The monitoring and control of canopy height contribute to the selection of management strategies, and enable the understanding of very significant relationships regarding the responses of the forage plant and the animals. In this way, it becomes possible to understand the effects of canopy structural variations related to production, plant persistence and animal performance. Different forage plants are able to change the composition of the canopy in response to the defoliation regime. It is also noteworthy that the search and seizure of forage by grazing animals are influenced by the spatial and structural arrangement of the canopy (ANJOS et al., 2020).

The growth stage at which the plant is harvested directly affects yield, chemical composition, regrowth capacity and persistence (COSTA et al., 2012). In general, less frequent cuts or grazing provide higher forage production, however, at the same time, there are sharp decreases in its chemical composition (GOMIDE; GOMIDE, 2000; COSTA et al., 2003). Therefore, a balance between forage production and quality should be sought, in order to ensure the nutritional requirements of the animals and simultaneously ensuring the persistence and productivity of pastures (COSTA et al., 2004). Evaluating the effects of plant age on forage yield, regrowth vigor and growth parameters of *M. maximus* cv. Centenário Costa et al. (2013) found that the age of regrowth affects forage yield, growth rates, leaf expansion and leaf area index of the grass.

In a study with four grass cultivars of the genus *Megathyrsus* at two cutting intervals, Santos (2022) found that the cultivars Zuri and Mombaça stood out when managed with an interval between cuts of 21 days, because in this regime they had high production of dry mass, that is, they generated more biomass (Table 1). In addition, they exhibited robust vegetative growth, with taller and wider leaves, indicating good plant development.

Table 1: Accumulated productivity (kg of DM ha^{-1} $year^{-1}$) in the second cycle and average height of grass of four cultivars of *Megathyrsus grass.*

Cultivate	Productivity (kg $^{ha-1}$)		Height (cm)	
	21 days	28 days	21 days	28 days
Tamani	11.022	11.469	49,4	53,4
Kenya	11.157	10.486	64,7	70,4
Zuri	14.645	12.062	75,9	80,7
Mombasa	14.850	12.951	77,8	82,6

Source: Santos (2022)

Also according to the same author, the Tamani cultivar stood out for the production of many tillers, being recommended for those who want a higher density of plants in the field, which can increase soil cover. The Kenya cultivar benefited from a longer cutting interval of 28 days, showing good adaptation to less frequent management and maintaining a satisfactory productivity, which makes it suitable for management systems with more spaced cuts. At 21 days, this cultivar did not reach the entry height suggested by Embrapa, which is 70 and 75 cm (EMBRAPA, 2017).

FINAL CONSIDERATIONS

So the importance of management is noted, because when not carried out correctly, it generates degradation and a drop in livestock productivity, with problems. Therefore, the adoption of sustainable practices, such as choosing suitable forages and soil correction, is essential to reverse this scenario. Cultivars such as those of the genus *M. maximus* stand out for their high production and nutritional quality, being alternatives for the recovery and maintenance of pasture productivity. Proper management is vital to ensure the sustainability and efficiency of the animal production system.

In view of this, the studies indicate that the management of cuts should be adjusted according to each cultivar and the production objectives, considering the different responses in terms of productivity and morphological development of the plant.

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TROPICAL FORAGES IN INTEGRATED SYSTEMS: STRAW FOR NO-TILLAGE

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ABSTRACT
In recent years, crop-livestock integration (ICL) has gained prominence as a promising strategy to increase sustainability in agricultural and livestock production. This system, widely adopted in the Brazilian Cerrado, enables the rational use of inputs and land, favoring both grain production and cattle raising in the same area. The advantages of ICL include the recovery of degraded areas, the maintenance of soil fertility levels, and the reduction of the need for chemical inputs, such as herbicides and pesticides. The adoption of the no-tillage system (NTS) combined with the intercropping of crops, especially forage and grains, allows the formation of a protective layer on the soil that minimizes erosion and improves water retention. In addition, the benefits of crop rotation and succession contribute to nutrient cycling and biological control of pests and diseases, crucial elements for the long-term economic viability of ICL. The implementation of this approach faces challenges, especially regarding regional adaptation and variation of forage species. Even so, studies indicate that the integrated system has substantial advantages in the environmental resilience and productive stability of agricultural properties.

Keywords: Crop-livestock integration. Sustainability. Soil recovery. No-tillage system. Culture consortium.

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INTRODUCTION

In recent years, the intercropping between tropical forages and other crops, known as the crop-livestock integration system, has been increasingly adopted by rural producers in the Cerrado, mainly due to studies demonstrating the feasibility of the intercropping between a given crop and the various forage species in simultaneous sowing.

Such a system consists of the exploration of the same area for the purpose of grain production and livestock exploration for the production of meat, milk, or others, with the potential to increase production and reduce the risks of pasture degradation, thus improving the chemical, physical and biological characteristics of the soil, in addition to the productive potential of grains, forages and silages. Currently, this technique stands out as being part of the sustainable and competitive technologies to leverage Brazilian agribusiness (ALMEIDA et al., 2012).

The use of integrated systems is a way to partially or totally compensate for the lack of forage during the dry season, with the cultivation of forages sown in succession to summer crops (MACHADO; ASSIS, 2010).

The intercropping and/or succession system provides increased forage availability and silage production in the dry season, with sufficient quality for nutritional maintenance of the herds, promoting weight gain and straw production for no-tillage, in addition, its main advantage is the recovery of degraded pastures at a lower cost (BARDUCCI et al., 2009).

In the integrated crop-livestock system (ICL), soybeans also play a fundamental role, because in addition to being an economically relevant crop, they contribute to the sustainability and recovery of the soil. In intercropping with forages, soybeans improve fertility, favor nutrient cycling and reduce pest cycles. This integrated cultivation also helps to form a layer of straw, which protects the soil and maintains moisture, essential for no-tillage. Thus, soybeans strengthen agricultural yields and promote synergy between crops and livestock, consolidating themselves as a key element in sustainable systems (VENGEN et al., 2020).

DEVELOPMENT

CONSERVATION SYSTEM

Agriculture, especially after the 1950s, opted for a technological model that makes intensive use of mechanization, highly effective fertilization and pesticides. This model ended up increasing crop production, but causing numerous environmental problems, with an emphasis on soil degradation by erosion, loss of organic matter and consequent compaction, due to the inappropriate use of agricultural practices (KAMIYAMA et al., 2011).

Studies related to the efficiency of soil management conservation systems in relation to the control of nutrient losses show that the amount of nutrients that are lost is lower when the system is used, compared to conventional ones. This decrease with the use of conservation systems can be attributed to the effects linked to the increase in soil cover with plant residues, and to the decrease in water and soil losses (GUADAGNIN et al., 2005).

The use of conservation management techniques, such as the no-tillage system (NTS), has as a priority to conserve the characteristics of both the soil and the environment, without dispensing with the achievement of high productivity of the crop of economic interest (CARVALHO et al., 2004).

SDP, which is currently the most widely used conservation management in the country, has not been fully executed, but it still has benefits, especially in erosion control in regions with high rainfall (DENARDIN et al., 2008).

No-till system (NTS)

Population growth, especially in underdeveloped countries, coupled with increased demand for food, has led to major changes in agriculture. Such changes can be explained by the use of innovative technologies that sought greater production, leading to an expansion in agricultural frontiers, with the inclusion of new areas for planting, however, simultaneously with this expansion, there was an increase in environmental degradation. To solve this problem, NTS was introduced in several agricultural areas in Brazil, and this system has been consolidated over time among farmers and researchers as a conservationist technique that adapts to different regions and technological levels from large to small producers (TORRES, 2003).

NT is a conservation cultivation technique in which planting is carried out without the stages of conventional tillage and harrowing, keeping the soil always covered by developing plants and plant residues (CRUZ et al., 2008).

The use of NTS was already adopted for a long time in other countries such as the United States and also in Europe, however, the introduction of this system in Brazil occurred at the end of the 1960s, which began in small areas as a form of academic studies on soil conservation management (MOTTER; ALMEIDA, 2015). The pioneer farmer in the adoption of no-tillage was Herbert Bartz, in 1972, in the State of Paraná. In the regions of the Cerrado biome, NTS was consolidated in the 1990s with the arrival of immigrants from the southern region of Brazil with extensive experience, as well as due to the adaptation of soybeans in these areas (VILAS BOAS et al., 2007).

In the search for management systems that reduce soil loss and benefit the use of water, NTS has been qualified for showing, especially in the most superficial layer, greater structural stability, which, associated with the conservation of crop residues in the most superficial layers of the soil, has provided greater protection against the impacts caused by rain. contributing to better infiltration and reduction of water loss through surface runoff (CARVALHO et al., 2004).

One of the basic premises of NTS is the adoption of crop rotation, preferably alternating commercial crops, such as soybeans, corn, rice, beans and sorghum, with green manures such as sunn hemp, velvet bean, pigeon pea and grasses such as millet and brachiarias, providing efficient soil covering, in addition to high nutrient cycling and increased productivity of crops in succession (SILVA et al., 2006).

Crop residues should cover at least 80% of the soil surface, or maintain 6 t $^{ha-1}$ of dry matter for soil cover. This is one of the most important requirements for the success of no-tillage, as it affects practically all the modifications that the system promotes, and the most variable between different regions, since the options for farms and soil cover depend on climatic conditions, as well as the availability of information regarding alternative species and sowing times in each location (CRUZ et al., 2008).

In the Brazilian Cerrado, the climate is characterized by a dry winter, with shortening of the photoperiod, which makes it difficult to establish plants at this time of year. Thus, the establishment of a soil cover with plants sown for this purpose, in March and April, has been the greatest challenge for the system in the region (ALVARENGA et al., 2001).

The use of forage species such as those of the genus *Brachiaria* for the formation of straw has aroused the interest of farmers and researchers (APDC, 2001). These forages have great potential in maintaining straw on the soil due to their high C/N ratio, which delays its decomposition and increases the possibility of use in warmer regions.

Timossi et al. (2007), evaluating forage species for straw formation for the adoption of the no-tillage system, found that the vegetation cover provided by brachiaria (*B. decumbens* and *B. brizantha*) ensured accumulation of dry plant mass, above 11 t $^{ha-1}$, at the time of chemical management.

Crop-Livestock Integration

Agriculture and livestock in Brazil kept their productive activities carried out separately, that is, they did not occur simultaneously, with almost no synchronism. This practice, over the years, contributed to accelerate the degradation process of both pasture and crop areas, as there was no replacement in the soil of the nutrients extracted by pastures used in livestock and crops and the replacement was only partial, with fertilization carried out at sowing (ALMEIDA et al., 2012).

A very efficient alternative, which proposes maintenance of productivity and recovery and/or indirect renewal of pastures is the crop-livestock integration, where the insertion of crops is not occasional, but a constant part of a grain production system and animal production, which will interact and complement each other in aspects related to management, fertility, soil physics and biology, raising the income of producers and introducing social progress to the countryside. The system allows for a more rational use of inputs, soil, machinery and the property's labor, in addition to increasing food production, diversifying the producer's income alternatives (MARCEDO, 2009; MARTHA JR. et al., 2011).

The crop-livestock integration system consists of the implementation of different types of production systems, whether for grain, fibers, meat, milk, among others, in the same place, in a plantation that is intercropped, sequential or rotational (MACEDO, 2009). On a property, the use of the land alternates, in time and space, between crops and livestock. And it is in the high potential for synergism between the components of pasture and crop, that the benefits of ICL are found (VILELA, 2008).

Also according to Macedo (2009), positive points are found in the literature with the use of this system, with biological improvements, such as breaking the cycle of pests and diseases and increasing the biological activity of the soil. Regarding the physical and chemical properties of the soil, it has an improvement in fertility, through nutrient cycling and efficiency in the use of fertilizers, due to the different needs of rotation crops. The modifications in relation to the physical properties have been in the increase of the stability of the aggregates, reduction of the apparent density, compaction and increase of the water infiltration rate.

In a study carried out by Ikeda et al. (2007), at Embrapa Cerrados, they observed significant reductions in weed seed banks in crop-pasture rotation, when compared to the continuous tillage system, especially when no-tillage was adopted. The reduction in the use of agrochemicals, in relation to breaking the cycles of pests, diseases and weeds, is another beneficial factor to the environment of systems such as crop-livestock integration.

Crop-livestock integration is a system that has been increasingly adopted on properties over the years, fully or occasionally, in many countries. As it is a more complex system, it generates impacts on the soil, environment, economic performance and the entire management of the property. These impacts can be both positive and negative, which will depend on the situation, and need to be well understood (MACEDO, 2009; VILELA et al., 2011).

According to Franzluebbers (2007), the most varied systems, such as crop-livestock integration, are fundamental to replace and preserve organic matter (OM) and provide well-structured soils that will favor a higher rate of rainwater infiltration and the penetration of roots into the soil, which will increase the volume of soil explored by the root system of plants and, consequently, the greater efficiency of the use of water and nutrients.

CROPS IN SUCCESSION IN THE OFF-SEASON PERIOD

The entire sustainability of an agrosystem can be measured by the action of several aspects related to the natural phenomena of the region and the management that can occur due to anthropogenic modifications. Several approaches have been used in recent years to reduce the harmful effects of the entire agricultural system on the environment. Techniques such as NTS, use of soil cover and crop succession are fundamental (JUNIOR et al., 2009).

Crop rotation and/or succession proves to be one of its main advantages to improve or maintain soil fertility, thus contributing to the reduction in the appearance of pests and diseases in the crop. Having a greater diversification of crops within a property can lead to a reduction in the risks of failure in agricultural activity, thus contributing to a maintenance and improvement in crop productivity (FIDELIS et al., 2003).

Another benefit of crop succession that is of paramount importance is nutrient cycling, as varied crops require different fertilization, that is, leading to different types of residues that will remain in the soil after cultivation (FRANCHINI et al., 2011).

With the conservation practices and care of the plant residues present in the soil, whether or not the incorporation occurs, these factors are beneficial to the microbial action, reducing the negative effects on agricultural soils, leading to favorable effects on the crop that is implanted (MOREIRA; SIQUEIRA, 2002).

INTERCROPPING BETWEEN SOYBEAN AND FORAGE, OR SOYBEAN IN SUCCESSION

The intercropping between grain crops and forage crops in the crop-livestock integration system is used to anticipate the establishment of pastures, favoring a better soil cover for no-tillage, reflecting positively on their properties, since the high volume of roots in depth and production of organic matter increases nutrient recycling (VILELA et al., 2011; GUEDES et al., 2010; SOUZA et al., 2011).

One of the most used intercropping in integration systems is that of corn with tropical forages, which can be carried out in the most different methods. Sowing can be carried out simultaneously, that is, at the same time as corn sowing, or in a lagged way, at the time of corn cover fertilization. The spacing of corn can be normal, reaching up to 0.90 m between rows, or reduced, with a spacing of 0.45 m. The variation between the mechanism of forage implantation is also great, ranging from the mixture of forage to fertilizer to adapted seeders, with forage seed boxes (BROCH; CECCON, 2007).

On the other hand, the intercropping of grass with soybeans, although it can be carried out, is operationally complicated and, in certain situations, can harm the productivity of grains or the forage itself (VILELA et al., 2011).

Brazil is the largest exporter of soybeans, having exported 66.6 million tons between January and August 2022, which demonstrates the economic importance that the grain has for the country (CONAB, 2022), and losses in productivity impact the Brazilian economy.

In a study carried out in Dourados-MS, with single soybeans intercropped with different forage species, it was found that the cultivation modalities did not differ in terms of grain yield, and it was possible to observe numerical differences, but not significant (MACHADO et al., 2017).

In another study carried out by Machado et al. (2009), with the intercropping of soybean with different forages, no statistically significant difference was observed, but the authors report a decrease of 16% in the yield of soybean intercropped with Massai grass. Due to the high costs in soybean production, even small decreases (8%) can compromise the entire economic sustainability of the producer.

Soybeans sown after pasture have been showing good results. Vilela (2008) in an experiment at Embrapa Cerrados, noted a benefit of pasture on soybean grain yield. Soybean sown after a three-year cycle of U *. brizantha* cultivar Marandu pasture showed a higher yield of 17% than that found in the continuous tillage system. It is worth noting that this higher grain productivity was found in the area that received the lowest amounts of fertilizers, about 45% less, during the 17 years of cultivation.

According to Vilela (2011), the greater efficiency in the use of soil nutrients by grain crops in the ICL system, when compared to single cultivation, leads to greater fertilizer savings and a consequent decrease in production expenses. However, such benefits are not easily achieved in a short time.

Santos (2017), cultivating soybean in straw of single Paiaguás grass and Paiaguás grass with pigeon pea, subjected to N doses, verified a reduction in soybean yield with the increase of the N applied. Both the application of N doses and the vegetation cover composed of pigeon pea left residual N in the soil, provided a harmful environment for nodulation and may possibly be harmful to the main productive indexes.

FINAL CONSIDERATIONS

The crop-livestock integration system is established as a viable and sustainable alternative for producers who seek to maximize the productivity of their agricultural properties, reducing environmental impacts. In addition to providing greater resilience to the agricultural system, ICL contributes to the more efficient use of natural resources, allowing for improved soil and crop management. Although the challenges of regional adaptation and choice of ideal species for intercropping persist, the continuity of research and the dissemination of knowledge on the subject can consolidate this system as a standard practice in Brazil. The adoption of NTS and the use of vegetation covers, combined with crop rotation and succession practices, represent the main foundations of ICL, ensuring not only soil conservation, but also the improvement of property profitability.

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EVALUATION OF NATIONAL MAIZE VARIETIES IN ARAGUAÍNA-TO

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ABSTRACT
The present work was developed with the objective of evaluating maize varieties regarding grain yield in the region of Lavras. A total of forty-two genotypes, including varieties, single, double and triple hybrids were evaluated in a randomized block design, with two replications. The grain yield of the genotypes was evaluated. In order to correct irregularities in the booth, the analysis of covariance was performed, and later the analysis of variance was performed. It was verified that the treatments differed from each other for the evaluated trait, forming two groups of means. The most productive group contains the simple hybrid BRS 1055 and 15 other genotypes.

Keywords: *Zea mays*. Commercial hybrids. Grain yield.

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INTRODUCTION

The corn crop stands out in the Brazilian agrarian scenario as one of the most important. The area destined to agriculture in the country in the year 2011/2012 was approximately 51.68 million hectares, and corn culture represented 30% of it, estimated at 15.45 million hectares (CONAB, 2012). Among the states, Minas Gerais contributes with 1.205 million hectares planted with corn, representing 7.8% of the total cultivated in the country.

The total corn production in Brazil estimated in the 2011/2012 harvest was 65.903 million tons and the national average productivity was 4,265 kg $^{ha-1}$ (CONAB, 2012). In the state of Minas Gerais, the production was 7.5 million tons, with an average productivity of 5,782 kg $^{ha-1}$. It can be observed that the average of this state is 35% higher than the national average. Among the factors that contribute to this higher average, we can highlight the existing edaphoclimatic conditions, the level of technology employed by producers, in addition to the use of cultivars with better performance. Regarding this last factor, it can be seen that the market for corn cultivars is dynamic. Each harvest, new cultivars are made available for commercialization.

For the 2011/2012 harvest, 489 corn cultivars were made available for planting, 316 conventional and 173 transgenic, from various seed producing companies (EMBRAPA, 2012). The dynamics of cultivar renewal was maintained, as seen in previous harvests. Seventy-two new cultivars were added while eighty-one were no longer sold, so there was a reduction in the number when compared to the last harvest (EMBRAPA, 2012). Within this market dynamic, different types of genotypes are available to producers, including single, double and triple hybrids, as well as varieties. Thus, each producer has a range of options for planting, and the choice is influenced by the environmental conditions of cultivation, which are associated with the adaptability of the genotype, the technology used in the conduction of the crop, all of this associated with the financial condition of the same. Therefore, it can be concluded that there is a dynamic of the number and type of cultivars available in the market for planting. This reflects the importance of corn genetic improvement programs, as well as all the research involved until the launch of a cultivar.

Genetic improvement programs aim to obtain cultivars superior to those on the market. In this process of obtaining, several evaluation steps are necessary until commercialization. Among the steps, the evaluation in several places is necessary. With it, important data are obtained, which help breeders from public and private entities in decision-making, as well as technicians and farmers in choosing the cultivars most adapted to their regions.

In view of the above, the present work aimed to evaluate new maize cultivars in the southern region of Minas Gerais.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Farm of the Federal University of Lavras (UFLA) in the 2011/12 summer harvest, in Lavras – MG. The experimental area is located at 21º14' S latitude, longitude of 45º00' W and altitude of 988 m. The climate of the region is Cwa, according to the Köppen classification.

A total of 42 genotypes were evaluated. Among these, we can mention the varieties BRS Gorotuba, AL Avaré, Sol da Manhã, BR 106, BRS 4103, Sintética 1X, BRS Caimbé, the simple hybrid BRS 1055, the double hybrid BRS 2020 and the triple hybrid BRS 3060, which are available for planting.

The experimental design was randomized blocks with two replications, with each plot consisting of two rows of five meters with spacing of 0.60 m between rows and 0.25 m between plants. These dimensions culminated in the stand of approximately 66 thousand plants $^{ha-1}$.

At sowing, 360 kg $^{ha-1}$ of the formula 8 (N): 28 (P2O5): 16 (K2O) were used. Cover fertilization was performed when the plants were at the 4-5 fully expanded leaf stage, and 300 kg $^{ha-1}$ of the formula 30 (N): 00 (P2O5): 20 (K2O) were applied. The other crop treatments were the same as those recommended for the corn crop.

Grain yield was evaluated, which was corrected to 13% of water content, according to Brasil (2009), and expressed in kg $^{ha-1}$.

In order to correct irregularities in the stand, the analysis of covariance was carried out according to Ramalho, Ferreira and Oliveira (2000). The average yields of the plots were adjusted to the ideal stand of 66 thousand plants $^{ha-1}$. After this analysis, the data were submitted to the common analysis of variance. Both analyses were performed using the "GLM" (General Linear Models) procedure of the Sas v 8.0 computer package (SAS INSTITUTE, 2000). The means were grouped using the Scott-Knott test, at 5% probability, using the Sisvar computer package (FERREIRA, 1999).

RESULTS AND DISCUSSION

The result of the analysis of variance for grain yield of the 42 genotypes evaluated is presented in Table 1.

The coefficient of variation (CV) is a measure of experimental accuracy. In this study, the VC value was 10.43% (Table 1), which may indicate precision in the conduct of the test.

Table 1 shows that the source of variation in treatments was significant (P>0.05). This shows that the treatments differ from each other for the grain yield trait. This result was expected, since the genotypes evaluated have different genetic constitutions. As previously mentioned, the treatments evaluated are single, double and triple hybrids, as well as varieties.

By means of the Scott-Knott means test, it was verified that the genotypes were separated into two groups (Table 2). It is observed that the simple hybrid BRS 1055 had higher grain yield, with an average of 13,200.82 kg $^{ha-1}$, although it is in the same group as fifteen other treatments. The triple hybrid BRS 3060 and the variety AL Avaré did not differ for the grain yield trait of the simple hybrid BRS 1055.

It has been observed that single, double and triple hybrids present small differences in grain yield, of approximately 10% (COSTA et al., 2010). Thus, when choosing cultivars for planting, the producer must make a cost-benefit analysis, adopting the most convenient cultivar. It is worth commenting that this analysis is valid since a common question is whether the productive potential of simple hybrids would compensate for the higher cost of their seeds.

The fact that the AL Avaré variety does not differ in grain yield in relation to the simple hybrid BRS 1055 (Table 2), it can bring benefits to small farmers. On properties with low technological level, simple hybrids may not be able to express their grain production potential due to the low amount of inputs used. Thus, the use of varieties could be an alternative. The use of varieties can also be associated with important characteristics such as the possibility of multiplication and reuse of seeds without loss of productive potential (CRUZ et al., 2000) in addition to the low acquisition cost.

Table 1 - Summary of the analysis of variance for grain yield of 42 corn genotypes evaluated in Lavras, MG, in the summer harvest of the 2011/2012 crop year.

FV	GL	QM	Pr > Fc
Repetition	1	5.481.727,10	0.0379
Treatments	41	3.734.352,32	0.0002*
Error	41	1.190.978,37	
Overall average (kg $^{ha-1}$)	10.467,00		
CV(%)	10,43		

* Significant at 5% probability by the F-test

Table 2 - Grain yield results of 42 corn genotypes evaluated in Lavras, MG, in the summer harvest of the 2011/2012 crop year.

Treatments	Productivity (1 kg)	Treatments	Productivity (1 kg)
Sint Super-Precoce 1	7.851,65 a*	Saint 10781	10.277,95 a
BRS Gorutuba	7.867,32 a	Synthetic 1 X	10.329,05 a
MC 20	8.121,00 a	DSS-0402	10.541,60 a
Sint 10783	8.878,97 a	Saint 10723	10.553,82 a
DSS-0404	8.951,55 a	BRS 2020	10.618,87 a
BR 106	8.991,05 a	BRS 3060	10.964,97 b
Sint 10805	9.124,60 a	Synthetic 256 L	10.996,32 b
BRS 4103	9.437,62 a	Sint. Mult. TL	11.091,00 b
Sol da Manhã	9.445,77 a	Saint 10717	11.423,15 b
Sint. Pro Vit A	9.529,95 a	Saint 10699	11.441,17 b
DSS HI 01	9.538,10 a	Saint 10707	11.547,45 b
CMS EAO 2008	9.626,97 a	Saint 10771	11.781,47 b
Bio 4	9.699,55 a	HDS NE 4x3	12.078,82 b
Sint 10731	9.737,32 a	Saint 10795	12.176,95 b
VSL BS 42 C 60	9.754,72 a	AL Alvaré	12.253,60 b
Eldorado	9.757,07 a	2E530	12.334,32 b
DSS HI 02	9.778,55 a	PC 0905	12.344,20 b
Sintético RxS Spod	9.953,32 a	PC 0904	12.393,57 b
BRS Caimbé	9.955,67 a	Saint 10697	12.409,25 b
PC 0402 = IPR 164	10.136,25 a	1I934	12.549,22 b
PC 0903	10.187,35 a	BRS 1055	13.200,82 b

* Averages followed by the same lowercase letter in the column do not differ from each other by Scott Knott's test at the 5% probability level

CONCLUSION

A significant difference was observed between the genotypes evaluated, with the simple hybrid BRS 1055 being the one that presented the highest productivity.

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EVALUATION OF THE VIABILITY AND PROTECTION OF CONVENTIONAL AND BT CORN SEEDS UNDER INSECTICIDE TREATMENT AND STORAGE CONDITIONS

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ABSTRACT
In the process of seed production and marketing, the preservation of quality during storage is fundamental, especially until the time of sowing. A critical factor is protection against pests, such as those of the orders Coleoptera and Lepidoptera, which can cause losses of up to 20% in the stored product and compromise the germination power and vigor of the seeds. Preventive treatment with insecticides on seeds is a recommended practice to prevent pest attacks on the soil and shoots of young plants, reducing the need for later applications. Although effective, the use of insecticides can, in certain cases, cause phytotoxicity, reducing germination and seedling survival, especially when combined with fungicides. In the case of corn, treatment with insecticides is common in processing units, but there is a lack of data on its effects on genetically modified seeds (such as BT corn). The objective of the study is to evaluate the impact of the main insecticides recommended for corn crops, alone or in combination, both on conventional and BT seeds, focusing on seed germination and vigor in varying storage periods.

Keywords: Seed quality. Treatment with insecticides. Storage.

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INTRODUCTION

In the process of seed production and commercialization, one of the main factors that the producer must be aware of is the preservation of seed quality throughout the storage period, and seed quality must be maintained at least until the time of sowing (Carvalho 1992).

During storage, for example, the presence of pests in seeds should be avoided, especially those of the Coleoptera and Lepidoptera orders, which can cause losses of around 20% of the stored product (Carvalho, 1978; Carvalho & Nakagawa, 1988). In addition to quantitative losses, pest attacks on seeds can cause losses in germination power and vigor (Barney et al., 1991).

The preventive use of insecticide in seed treatment has been proposed as an alternative to avoid possible losses resulting from the actions of insects, soil and shoot pests, which can attack seeds and young plants (Silva, 1998). This practice, when properly performed, makes it possible to reduce the number of foliar applications, which often need to be started soon after seedling emergence (Menten, 1991).

Although seed treatment is considered one of the most efficient methods of using insecticides (Gassen, 1996), in some research results it has been evidenced that some products, due to the effect of phytotoxicity, when applied alone or in combination with fungicides, can, in certain situations, cause a reduction in seed germination and seedling survival (Oliveira & Cruz, 1986; Pereira, 1991).

As the treatment of corn seeds with insecticide is routinely carried out in the processing unit and due to the lack of information about its effect on genetically modified seeds, it is of great importance to evaluate the effects of insecticides available on the market, both in seed quality and in the control of pest insects that attack corn seedlings in their early stages.

The objective of this study was to evaluate the effect of the main insecticides recommended for maize crops, or the combination of these, on conventional material and BT (Yieldgard), on seed germination and vigor in different storage periods.

MATERIAL AND METHODS

The research was carried out in the Seed Analysis Laboratories and in the experimental area of the Department of Agriculture of the Federal University of Lavras, Lavras, Minas Gerais.

Seed samples of the simple hybrid DKB390 in its conventional and transgenic versions produced in the 2009/10 harvest were used.

The seed samples of each hybrid were divided into six equal portions, with about 3 kg each, which were treated at the dosages recommended by the manufacturers. The recommended product quantities for 60,000 seeds were Thiamethoxan (Cruiser 350 FS) 0.12L; Fipronil (Standak) 0.4L and Imidacloprid + Thiodicarb (Cropstar) 0.35L, in addition to the combinations of Fipronil + Thiamethoxan, Imidacloprid + thiodicarb + Fipronil (Cropstar + Standak) and Thiamethoxan + Fipronil (Cruiser 350 FS + Standak) and the control (without insecticidal treatment),

Each treatment was carried out with two replications and the seeds were stored in paper bags under controlled conditions, at a temperature of 25°C.

At zero, seven, fourteen, twenty-one and twenty-eight days after treatment with insecticide, germination tests were carried out, (Brasil, 2009); cold test and seedling emergence in bed, according to Barros et al. (1999) and Vieira & Krzyzanowski (1999).

In the cold test, 4 replicates of 50 seeds were evaluated on the fifteenth day after sowing, computing the number of normal seedlings emerged. The seedling emergence test in the bed was carried out with the sowing of 50 seeds per treatment and the use of four replicates for each treatment and each storage season, in substrate, sand and soil in the proportion of 2:1. The moisture was adjusted to 70% of the water retention capacity in the soil. The evaluations were carried out at 7 and 15 days after sowing, accounting only for normal seedlings.

The experimental design was DIC with four replications, in a 2x6x5 factorial scheme. The effect of the factors studied was evaluated through deviance analysis based on generalized linear models. The inferences were adjusted to the superdispersion parameter that was estimated based on Pearson's residuals. The statistical model considered for analysis is represented by

$$y_{ijkl} \sim Binomial(n, \pi_{ijk})$$

$$\ln \frac{\pi_{ijkl}}{1-\pi_{ijkl}} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\lambda_{ijk}$$

where: *yijkl* is the proportion of germinated seeds in *the ijkl-th experimental unit containing* n *seeds,* □ijk is the probability of germination which is a function of μ, a constant inherent in all observations, □i *the fixed effect of* the *i-th* level of the insecticidal factor, □ *j* is the fixed effect *j-th* double combinations. The index *l* represents the repetitions of each combination between levels of the factors (treatments).

The chi-square tests were applied, corresponding to the reduction of sequential deviance for each term of the model, according to the order of the terms of equation 1. After deviance analysis, multiple hypothesis comparison tests were performed on the differences between levels of the factors. The FDR (false dicovery rate) criterion was applied to control the type I error rate caused by the multiple hypothesis comparison procedure. For all tests, a nominal significance level of 5% was considered.

The analyses were carried out with the aid of the R application (R Development Core Team, 2010) and through resources available in the contrast (Kuhn et. al, 2010) and multcomp (Hothorn et. al, 2008) supplementary packages.

RESULTS AND DISCUSSION

Table 1 shows that the seeds treated with the products Imidacloprid + thiodicarb, Thiamethoxam and Fipronil showed similar behavior in the germination and cold tests. For the emergency test, treatment with Fipronil was superior to the others, followed by treatments with Thiamethoxam and Imidacloprid + thiodicarb. For both transgenic and conventional seeds, a reduction in physiological quality was observed when the combination of two commercial insecticides was used. The mixture Imidacloprid + thiodicarb + Fipronil provided lower germination and vigor, so the recommendation of this treatment should be made with caution.

Differences in the performance of insecticides used in seed treatment have been frequently cited in the literature. Dan et al. (2010) evaluated the effect of insecticides on the physiological quality of soybean seeds and found no difference in the results of germination and emergence tests between seeds treated with Thiamethoxam and Fipronil when compared to the control without treatment. The same was not observed for the mixture Imidacloprid + thiodicarb, which provided worse performance than the insecticides mentioned, both in the germination test and in the cold test.

In the present study, the controls showed higher averages of germination, vigor and emergence than the other treatments, in at least one evaluation test (Table 1), indicating interference of the active ingredients used on the physiological quality of the stored seeds. This reduction in seed viability and vigor can be attributed to possible damage to the mitochondrial membrane, which promotes a decrease in aerobic respiration and ATP production and ethanol additions, which are important indicators of respiration intensity and energy availability for the germination process (Reedy and Knapp, 1990; Horri and Shetty, 2007).

Table 1. Predicted proportions for germination (TG), cold test (TF) and emergence test (ET) tests in conventional and transgenic maize seeds. UFLA, Lavras, MG, 2010

Conventional1 Transgenic [1]

Treatments2	**TG**	**F**	**T**	**IN**	**TG**	**TF**	**IN**
Imid+th	97,	2,20a	4	94,04c	75,	36,	54,
l	30a				25c	59bc	30c
Imid+th	92,		4	89,24d	62,	35,	55,
io+ Fp	60b	2,00b			50d	84c	91c
Thiamet	98,		4	96,25bc	90,	35,	83,
Hoxan	40a	6,70a	4	95,57bc	91from	95bc	90b
Thia +	96,				90,	36,	83,
FP	31from	3,05b	4	97,47from	52b	70bc	19b
Fipronil	98,				94,	38,	91,
Test	15a	5,95a	4	98,60a	21from	00b	75a
	97,				94,	41,	89,
One	69a	5,55a			47a	45a	64a

[1Averages] followed by the same lowercase letter in the column do not differ from each other, at a 5% probability.
[2Imid] (Imidacloprid), Thio (thiodicarb), Fp (Fipronil), Thia (Thiamethoxan).

It should be emphasized that despite the differences observed in the viability and vigor of seeds treated with insecticides, in most treatments seed germination values higher than 85% were observed and, therefore, are within the accepted standards for the commercialization of certified maize seeds (IN 25, 2005).

When performing the germination, cold and emergence tests on seeds stored for five different periods, only the cold and germination tests detected significant differences (Table 2). For these two tests, the controls showed equal or superior performance to the treatments in which insecticides were used. The performance of seeds treated with Fipronil was superior to those treated with the other insecticides, in all storage periods. In the seeds where the mixtures Imidacloprid + thiodicarb + Fipronil and Imid + thio were used, lower average vigor and germination were observed, both initially and during storage, again reinforcing that the use of these mixtures should be avoided.

Table 2. Predicted proportions for cold and germination tests performed on conventional and transgenic maize seeds at different storage times. UFLA, Lavras, MG, 2010.

Treatments2	Cold test1				
	0d	7d	14d	21d	28d
Imid+thio	42,41a	41,62b	40,82b	40,04c	39,25c
Imid+thio	b	c	c	d	d
+ Fp Thiameth	39,97b	39.42d	38,87d	38,33e	37,79d
oxan Thia +					
	40,00b	40,61c	41,22b	41,83a	42,45a
		d	c	b	b
	40,58b	40,21c	39,83c	39,46d	39,08c
Fipronil		d	d	and	d
Fipronil	43,23a	42,58a	41,92b	41,27b	40,62b
		b		c	c
Testimmun	43,57a	43,53a	43,49a	43,45a	43,41a
Has					
Treatments	**Germination Test1**				
	0d	**7d**	**14d**	**21d**	**28d**
Imid+thio	70,26b	76,18c	81,24c	85,43c	88,82b
Imid+thio	70,89b	73,76c	76,44d	78.92D	81,21c
+ Fp					
Thiameth oxan	92,73a	92,39b	92,04b	91,67b	91,29b
Thia +	93,53a	92,44b	91,18b	89,73b	88,08b
Fipronil	93,39a	94,48a b	95,39a	96,16a	96,81a
Fipronil					
Witness	95,04a	95,61a	96,11a	96,56a	96,9a

1Averages followed by the same lowercase letter in the column do not differ from each other, at a 5% probability. 2Imid (Imidacloprid), Thio (thiodicarb), Fp (Fipronil), Thia (Thiamethoxan).

CONCLUSIONS

The effect of storage of treated seeds on germination and vigor depends on the insecticide product used. The product Fipronil was the least toxic during the entire storage period.

Regardless of the type of seed, transgenic or conventional, or the period in which they are stored, there is a reduction in their physiological quality when using the combination of commercial insecticides Imidacloprid + Thiodicarb, Fipronil and Thiamethoxan.

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OPTIMIZATION OF COTTON SEED DEVELOPMENT WITH COMMERCIAL INOCULANT

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ABSTRACT

Cotton is a crop of great economic importance. Improving germination and initial vigor of seedlings can result in higher productivity and quality of the cotton produced. To achieve high productivity in most crops, mineral fertilizers are used, thus increasing production costs and environmental impacts. The use of Azospirillum brasilense can potentially increase resource use efficiency, leading to more robust and healthier crops. The objective of this study was to evaluate the ideal dose of the bacterium Azospirillum brasilense in the germination of cotton seeds of the cultivar TMG22 GLTP. The experiment was carried out in a completely randomized design (DIC), and the cotton cultivar used will be TMG22 GLTP. Sowing took place in Styrofoam trays with 2 seeds per cell. The substrate used consisted of coarse sand and Topstrato in a 1:1 ratio. The evaluations took place up to 7 days after the emergency. The variables analyzed were: seedling length and germination percentage.

Keywords: *Gossypium hirsutum*. Production. Emergency. Germination.

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INTRODUCTION

Cotton (*Gossypium hirsutum*) is one of the main crops in Brazil, being cultivated in more than fifteen states. This crop is of great importance due to its complexity in the production and industrialization process, in addition to demanding a high amount of labor (FACUAL, 2005).

In recent years, cotton production in Brazil has increased significantly, while domestic consumption has not kept up with this growth. As a consequence, domestic surpluses increased, allowing for strong export growth. This increase was facilitated by the high quality of Brazilian cotton, which expanded its presence in the international market. (BRAZIL, 2020).

Cotton is a highly demanding crop in terms of soil quality, so areas that are markedly acidic or nutritionally poor, excessively humid or subject to waterlogging, and shallow or compacted soils do not favor the cultivation of this crop (CARVALHO, 1996).

To achieve high productivity in most crops, mineral fertilizers are used, thus increasing the production costs and environmental impacts (HUNGARY *et al*., 2005). After the discovery of the biological nitrogen fixation process (BNF), some crops in Brazil started to use less mineral fertilization (DÖBEREINER, 1997). This process can supply the plant's entire nitrogen need, dispensing with mineral fertilization (TAIZ *et al*., 2013). In this way, new ways to improve the efficiency of nitrogen use by crops are sought.

The constant search for alternatives that allow the maximization of production in a sustainable way is one of the topics most addressed by researchers around the world. When it comes to production, numerous researches are underway for the development of products that stimulate and enhance plant growth, providing favorable conditions for them to fully express their potential (TEJO et al., 2019).

The rhizosphere is an ecosystem composed of a variety of microorganisms that evolved in tandem with plants in the terrestrial environment. They establish relationships in various ways and, in doing so, mutually benefit each other to face the adversities found in different habitats.

Among these beneficial microorganisms, plant growth-promoting bacteria are widely researched and promising groups to be used as biological inputs in sustainable agricultural practices.

The definition of plant growth-promoting bacteria covers a variety of microorganisms that can be free-living or epiphytic and have the ability to establish symbiotic relationships, associative or not, with plants (GLICK, 2012).

The root system of plants must present good development in volume and good architecture to optimize the use of available resources (TAIZ et sl., 2004). Nitrogen-fixing bacteria are essential to help plant root establishment and development (BENEDUZI et al., 2012).

JUSTIFICATION

Improved Agricultural Productivity:

Cotton is a crop of great economic importance. Improving germination and initial vigor of seedlings can result in higher productivity and quality of the cotton produced.

The use of Azospirillum brasilense can potentially increase resource use efficiency, leading to more robust and healthier crops.

Reduction of the use of Chemical Fertilizers:

It is known for its ability to fix nitrogen, which can reduce the need for synthetic nitrogen fertilizers.

Decreasing dependence on these fertilizers can reduce production costs and minimize the environmental impacts associated with the overuse of these inputs.

Sustainability and Eco-Friendly Farming Practices:

The use of beneficial microorganisms such as Azospirillum brasilense is in line with more sustainable and environmentally friendly agricultural practices.

Promoting the use of bioinoculants can contribute to sustainable agriculture by improving soil health and microbial biodiversity.

Contribution to Scientific Knowledge:

Although the benefits of Azospirillum brasilense are known, the ideal dose for germination of cotton seeds of the TMG22 GLTP cultivar may not be well established.

This study may provide new data and insights into the dose-response relationship between Azospirillum brasilense and cotton seed germination, contributing to the existing body of knowledge.

Support for Small and Medium Producers:

Identifying the optimal dose can help small and medium-sized producers optimize their yields with reduced costs, increasing their competitiveness in the market.

Providing recommendations based on scientific evidence can facilitate the adoption of advanced agricultural technologies by these producers.

Economic Efficiency:

The determination of the ideal dose can avoid the excessive or insufficient use of Azospirillum brasilense, ensuring a more efficient and economical use of the bioinoculant.

This can result in a better return on investment for farmers by encouraging the adoption of biotech practices.

OBJECTIVES

General Objective

The objective of this study was to evaluate the ideal dose of the bacterium Azospirillum brasilense in the germination of cotton seeds of the cultivar TMG22 GLTP.

THEORETICAL FRAMEWORK

The world's leading cotton producers are India, China, the United States, Brazil, and Pakistan, which together account for about 74% of global fiber production (COÊLHO, 2021). In Brazil, the largest producers are the states of Mato Grosso, Bahia, Minas Gerais, Goiás, and Mato Grosso do Sul, with Mato Grosso maintaining the leadership since 2020 (IBGE, 2021).

Brazil, on the other hand, is the world's fourth largest producer of cotton. Despite the pandemic, Brazilian cotton lint production reached a record of 3 million tons in the 2019/2020 harvest (COÊLHO, 2021). In the foreign market, Brazil is the world's second largest exporter of cotton, maintaining high stocks since the 2018/2019 harvest (USDA, 2021).

Cotton production requires a large amount of agricultural inputs and fertilizers. In this context, several studies have shown that the use of plant growth-promoting microorganisms can be an effective alternative to improve the efficiency of nutrient uptake by plants (OLIVEIRA et al., 2022), as well as to mitigate abiotic stresses (PORTO, 2022) and biotic stresses, such as resistance to phytopathogens (THULER et al., 2006). The use of microorganisms in cultivation has a great impact, as it reduces production costs and environmental impacts resulting from the indiscriminate use of fertilizers in agriculture

Biological fixation is the process by which atmospheric nitrogen (N2) is converted into forms that can be used by plants. This conversion is carried out by the enzyme Nitrogenase, present in all fixing bacteria. In agriculture, the symbiosis between nitrogen-fixing bacteria and the seed is particularly important (EMBRAPA, 2020). For this biological fixation to occur, it is necessary to carry out Inoculation, which is the process through which nitrogen-fixing bacteria are added to plant seeds before sowing (EMBRAPA, 2020).

Studies by MORETTI et al. (2018) highlighted the importance of biological nitrogen fixation for development and productivity. In this context, the adoption of new technologies that aim to increase biological nitrogen fixation, with an impact on development and yield, becomes essential for competitive and sustainable agriculture. Therefore, practices that reduce and/or optimize the use of inputs should be implemented in agricultural systems, according to previous studies (GALINDO et al., 2016).

In recent years, there has been a significant increase in the study of interactions between plants and microorganisms, aiming to understand the various factors that play a role in the selection of effective bacterial strains to stimulate the growth of large-scale crops (FERREIRA et al., 2014).

Among some microorganisms, the bacteria that stimulate plant growth stand out as highly promising biological inputs to promote sustainability in agricultural systems. They offer a range of benefits ranging from stimulating the growth of plant shoots and roots to enhancing enzyme protection against biotic and abiotic stress conditions (MAMÉDIO et al., 2020). They act through mechanisms that foster plant growth, including biological nitrogen fixation, synthesis of amino acids and phytohormones, and enhancement of the availability of nutrients, such as phosphorus, through phosphate solubilization processes (FRACASSO et al., 2020).

According to Santoyo et al. (2021), in recent years, plant growth-promoting bacteria have been investigated through the use of biological inputs. These microorganisms, initially found in the soil, when associated with plants, have the potential to contribute, both directly and indirectly, to the enhancement of crop growth.

MATERIALS AND METHODS

The experiment was carried out in a greenhouse located on the campus of the UNITPAC university, in the municipality of Araguaína - TO, with an altitude of 277m, Latitude: 7° 11' 31'' South, Longitude: 48° 12' 28'' West and average temperature of 26.4 °C.

Table 1. Seedling length (CP) evaluated at different doses of the bacterium Azospirillum brasilense in cotton seeds of the cultivar TMG22 GLTP.

Treatment	Average
T0	13.1897a
T2	12.9295a
T8	12.4372a
T5	12.4372a
T3	10.5013b
T1	6.6744b
T10	5.7378c

*Averages followed by the same letter in the column do not differ from each other by 5% of the probability by the Scott Knott test. T0 = Witness; T1 = 1 ml; T2 = 2 ml; T3 = 3 ml; T5 = 5 ml; T8 = 8ml; T10 = 10ml bacterium Azospirillum brasilense.

For the seedling length variable, there were significant differences. For seed germination (SG) there were no significant differences.

The treatments T0, T2, T8 and T5 had the highest averages but did not differ between them. T10 presented the worst average for seedling length. The use of nitrogen-fixing bacteria is more widespread in legumes, and the main example is soybeans. Bacteria have been used in soybeans since the 80s, today 100% of soybean crops in Brazil use the inoculation of these bacteria to help make N available to the plants. This symbiosis is so efficient that savings of approximately 7 billion dollars are observed per year (EMBRAPA, 2024).

When inoculating Azospirillum is used, significant improvements are found in relation to the agronomic characteristics of some plants (DARTORA, 2013).

The use of Azospirillum has been bringing many benefits to the producer. This association between the bacterium and the crop is very advantageous, in view of the fixation of nitrogen and also the production of phytohormones that stimulate plant growth (HUNGARY, 2011).

Because it is a cheap method in relation to mineral fertilization and brings benefits to the growth of the crop, in addition to the fixation of N to the soil, the use of Azospirillum has been increasingly increased in crops throughout Brazil. (EMBRAPA, 2015).

As shown by Rocha et al. (2020), the inoculation of the bacterium A. brasilense together with mineral fertilization brought increases in corn crop productivity. This shows that the association of mineral fertilization with the inoculation of the bacterium brings positive benefits to crop performance.

Among these bacteria, Azospirillum brasilense stands out for its ability to promote plant growth and development. In addition to biologically fixing atmospheric nitrogen, this bacterium also produces several plant hormones that stimulate root growth. As a result, there is a greater absorption of water and nutrients, contributing to a more robust development of the crop (Baldani & Baldani, 2005).

For Taiz and Zeiger (2010), small concentrations of growth-promoting substances can alter the hormonal balance providing morphological responses in plants. This can be explained by the fact that T2 (2 ml) presented a high root growth value. However, very high doses of T10 (10ml) are already harmful to the morphological development of some parts of the plants and probably to the germination of seeds. The control T0 (0ml) did not show different behavior compared to root growth, this may have happened due to the cultivar used.

CONCLUSION

Increasing the dose of Azospirillum brasilense bacteria can positively affect seedling growth. But the 10 ml dose does not favor this development.

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STRUCTURAL CHARACTERISTICS OF UROCHLOA *BRIZANTHA* CV DUNAMIS DURING ITS ESTABLISHMENT SUBJECTED TO DIFFERENT DOSES OF NITROGEN

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ABSTRACT
Dunamis Grass is a hybrid cultivar formed by the junction of two other brachiarias, Marandu (*Urochloa brizantha*) and Decumbens (*Decumbens cv. Basilisk*), known for having rustic characteristics and resistance to biotic and abiotic factors. The objective of this study was to evaluate the agronomic characteristics of Dunamis grass under a greenhouse cutting regime with three doses of nitrogen fertilization (50, 100 and 150mg/dm³ of N) plus control (without fertilization) in a completely randomized design with six replications. Structural characteristics (average leaf length, number of tiller leaves, final leaf length, total number of leaves in senescence, number of dead leaves, maximum plant height, number of tiller per plant, number of tiller per pot) will be evaluated. The experiment will be conducted at the Centro Universitário Tocantinense Presidente Antônio Carlos – (UNITPAC), located in the north of Tocantins.

Keywords: Hybrid. Junction. Agronomic.

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INTRODUCTION

In Brazil, pastures occupy a prominent position in the agricultural scenario, however, soils have serious fertility limitations. Thus, fertilizing represents an improvement in productivity rates per hectare and in the persistence of forages, even for species adapted to low soil fertility (LOPES et al., 2013).

According to estimates from the last Brazilian Agricultural Census of 2017, planted pastures throughout the national territory increased from 102.4 million hectares in 2006 to 111.7 million hectares in 2017 (IBGE, 2017). In general, pastures are conducted without proper nutrient replacement, a factor that makes their maintenance unfeasible (IEIRI et al., 2010).

The Dunamis (*Brachiaria Híbrida cv.)* is a hybrid resulting from the crossing of the brachiarias Marandu *(Urochloa brizantha)* and Decumbens *(Decumbens cv. Basilisk.)*, which united characteristics of agronomic interest of both varieties in a single plant. Their rooted stolons, absent in Marandu, have the potential to improve soil cover, reduce degradation, and extend the lifespan of pastures. This, in turn, promises to increase the productivity, sustainability, and profitability of Brazilian livestock farming (Milagro Agro Brasil, 2021).

Knowing that this species was produced through two species of the genus Urochloa, the best characteristics were selected in terms of resistance to biotic and abiotic factors, taking into account that in the original species it was not possible to obtain a good use of nitrogen in the form of topdressing.

The dynamics of N (nitrogen) in the soil is very complex and differentiated in relation to other nutrients. This nutrient has great mobility in the soil, undergoes numerous transformations mediated by microorganisms, has high movement at depth, transforms into gaseous forms and is lost by volatilization and has a low residual effect (Aguiar & Silva, 2005). As a result, part of the N applied to the pasture is often lost from the system, which reduces the efficiency of use, mainly because nitrogen fertilizers are usually applied in topdressing, without incorporation into the soil.

JUSTIFICATION

According to Embrapa (2014), by 2030, the global demand for pastures should increase by 33%, which would be possible due to the increased use of fertilizers, intercropping of grasses and legumes, and better management (EMBRAPA, 2023). Fertilization and soil correction, as well as proper pasture management, are determinants for nutritional quality, which promote substantial growth of the aerial part of the plant and intensify forage productivity (LOPES et al., 2013; CASTRO et al., 2016). Alexandrino et al. (2010) point out that in relation to grasses of the genus Urochloa, nitrogen fertilization is important from its establishment aiming at good pasture management, contributing significantly to the number of tillers until the development and length of leaves.

Brachiarias are forage plants widely used in pastures for cattle. They are generally known for their rusticity and ease of handling.

It is important to emphasize that this work has the characteristics of evaluating the possible changes or not resulting from the application of nitrogen in Dunamis grass, providing specific data on doses and demonstrating any changes in the tillering exposed by the plant. Having some points of answers about grass: nitrogen is an essential nutrient for the plant and its absence can cause chlorosis (yellowing of the leaves), stunted growth and lower biomass production (Martha Junior, G.B.; Vilela, L.; Kichel, A.N).

At optimal levels, brachiarias grow vigorously and produce more forage, promote a more robust root system, which improves water and nutrient absorption. Nitrogen directly affects the photosynthetic rate of the plant, which is nothing more than the ability to absorb light and nutrients, capturing and reserving energy to carry out the processes of plant development, it is also a component of chlorophyll (Primavesi, O.).

Dunamis grass (*Dunamis, Brachiarias Hibrida cv.*) and characterized as the third generation of brachiarias, that is, the evolution of the species and the resolution of problems previously suffered by Brazilian cattle raising.

GENERAL OBJECTIVE

To evaluate whether there will be changes in the structure of Dunamis grass under different doses of nitrogen.

THEORETICAL FRAMEWORK

PASTURE SEEDS

Within pasture management, the choice of seeds is a very important step for the beginning of every production cycle, success in pasture formation depends on a good seed, and its use is totally justifiable, since seed represents only about 10% of the total cost of pasture formation (MACEDO et al., 2005).

There are many factors that affect seed quality, especially genetic, physiological and environmental factors. As genetic, differences in vigor, longevity and advantages measured by heterosis stand out.

Physiological diseases have their action determined by the environment during production, harvesting, processing and storage. Sanitary factors are characterized by the deleterious effects of microorganisms and insects associated with seeds. In the same way that problems of yield reduction are observed at the field level, quality reduction may also occur for marketing and sowing purposes, due to the incidence of pathogens (LUCCA, 1985).

As highlighted at the beginning, the cost of seed within the formation of a pasture represents only 10% of the total cost of formation (MACEDO et al., 2005), based on losses caused by malformation, introduction of undesirable pathogens within the property, soil degradation, the expense with the seed becomes almost derisory.

MORPHOLOGIES OF BRACHIARIAS

The grasses of the genus Brachiarias, about 90 species, commonly called brachiaria, have a markedly tropical distribution, with Equatorial Africa as their center of origin (Ghisi, 1991).

Morphological characteristics such as plant height, stalk/leaf ratio, growth rates, tillering dynamics, removal of apical meristems, leaf expansion, among others, have a direct relationship with forage productivity and quality, in addition to subsidizing the adoption of more appropriate management practices (COSTA et al., 2003).

(BRIJANTA CV IN UROCH. MARANDU)

The name Marandu, given to cultivar, means "novelty" in the Guarani language, and was the one that best translated the prominence given to this new alternative forage for the cerrado (Embrapa, 1984).

Belonging to the genus brachiarias, classified as brachiarias brizantha (Hochst ex A. RICH.) STAPF. cv. marandu, this grass originates from a volcanic region of Africa, where soils generally have good fertility levels, with annual rainfall of around 700 mm and about 8 months of drought in winter (Rayman, 1983).

It is a very robust cespitous plant, 1.5 to 2.5 m high, initial stems prostrate, but producing predominantly erect tillers. It has very short and curved rhizomes, erect flowering stems, often with tillering at the upper nodes, which leads to the proliferation of inflorescences, especially under cutting or grazing regime. It has hairy sheaths and eyelashes at the margins, generally longer than those between us, hiding the knots, which gives the impression of dense hairiness in the vegetative stalks. Its leaf blades are linear-lanceolate, sparsely hairy on the ventral surface and glabrous on the dorsal surface. The inflorescences are up to 40 cm long, usually with 4 to 6 racemes, quite equidistant along the axis, measuring 7 to 10 cm in length, but can reach 20 cm in very vigorous plants. It has unil spikelets serialized along the rachis, oblong to elliptical-oblong, 5 to 5.5 mm long by 2 to 2.5 mm wide, sparsely hairy at the apex (Valls and Sen Dulsky, 1984).

UROCHOLA (DECUMBENS CV. BASILISK.)

It is a perennial species, which occurs natively in tropical East Africa at altitudes above 800 m, under a moderately humid climate, in open pastures, or in areas with sporadic shrubs and in fertile soils (BOGDAN, 1977).

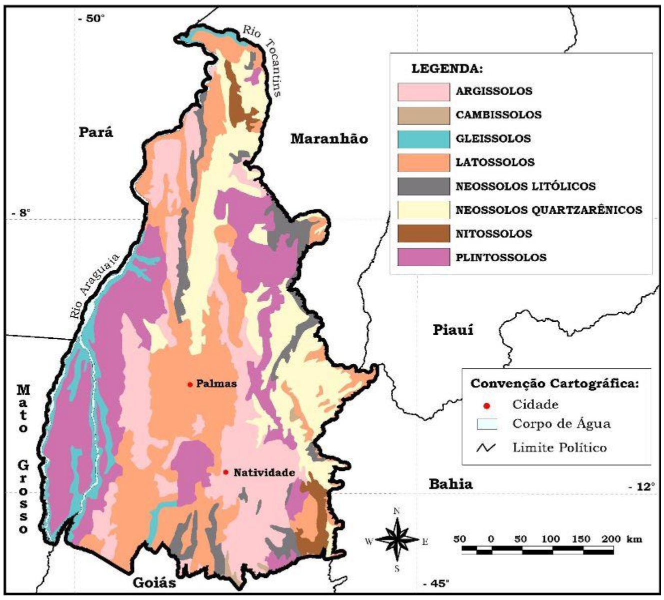
Brachiaria decumbens cv. Basilisk is probably one of the most well-known and cultivated grasses in the entire tropical region.

Originally from the Great Lakes plateau in Uganda, it was taken to Australia in 1930 and reproduced by seedlings, at first, until the dormancy of its seeds broke (AERO, 2020).

Brachiaria decumbens has a prostrate growth habit, with an average height of 50 cm to 100 cm. It emits a large number of stolons, well rooted and with protected growth points. *Brachiaria decumbens* has lower yield potential when compared to cultivars of the brizantha species and lower response to fertilization (AERO, 2020).

SOILS OF THE NORTHERN REGION

To characterize the soils of the State of Tocantins, soil maps of the Araguaia Basin – Tocantins were used, at a scale of 1:1,000,000, prepared by PRODIAT (Brasil, 1982), according to the Brazilian Soil Classification System (Embrapa, 1999), and the surfaces of soil occurrence were surveyed by means of a planimeter (Figure 1)



(Source, IMPAR, 2005, Figure 1)

The Red-Yellow Latosols, the Quartz Sands (Quartzarenic Neosols) and the Litholic Soils (Litholic Neosols) predominate in the State, which together make up 63.8% of the state's surface. The Red-Yellow Latosols represent about 32.9% (91,310 km²) of the state's surface. They are presented with inclusions and in associations with concretionary Pétric Plintosols (Concretionary Soils), Quartz Sands (Quartzarenic Neosols), Red-Yellow Podzolics (Red-Yellow Ultisols) and Litholic Soils (Litholic Neosols).

They occur in all micro-regions of the state, especially in Rio Formoso, Gurupi, Dianópolis and Porto Nacional. The Quartz Sands (Quartzarenic Neosols), with about 18% (49,881 km²) of the state surface, have in the micro-regions of Jalapão, Bico do Papagaio and Araguaína their main occurrence. They are associated with and include Red-Yellow Latosols, Yellow Latosols, litholitholytic Plintosols (Hydromorphic Laterite), Concretionary Perisols (Concretionary Soils) and Podzolic Plintosols (Ultisols).

Litholic Soils (Litholic Neosols), like Red-Yellow Latosols, also occur in all micro-regions, appearing in third place in terms of surface of occurrence in the State. They represent about 12.9% (35,847km²). They are associated with and include Red-Yellow Podzolics (Red-Yellow Ultisols), Concretionary Soils (Concretionary Pétric Plinthosols), Red-Yellow Latosols (Red-Yellow Ultisols) and Rocky Outcrops.

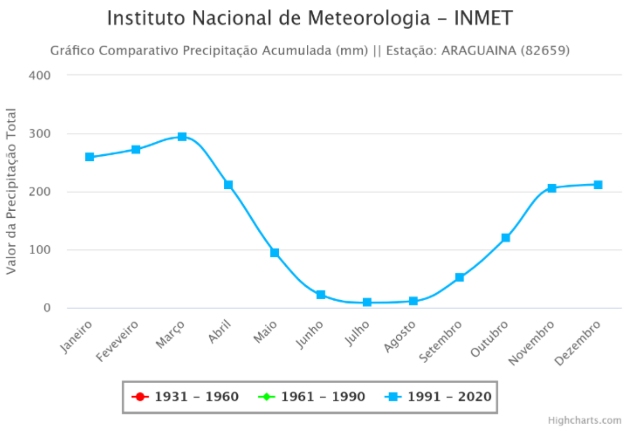
In the micro-region of Dianópolis, the presence of this soil is predominant, representing 28.5% of the soils occurring there. Red-Yellow Podosols (Red-Yellow Ultisols) appear associated with Red-Yellow Latosols, Yellow Latosols, Litholic Soils (Litholic Neosols), Concretionary Soils (Concretionary Pétric Plintosols) and Cambisols. They represent about 9.5% of the state soils and have the micro-region of Miracema do Tocantins as their main area of occurrence, reaching about 50.3% of the total of the micro-region.

Of the Concretionary Soils (Concretionary Pétric Plintosols), about 7.9% are associated with and with inclusions of Red-Yellow Latosols (Red-Yellow Ultisols), Red-Yellow Podzolics, Hydromorphic Laterite (Litholympintic Petrosols) and Quartz Sands (Quartzarenic Neosols), mainly in the micro-region of Jalapão. The Glysated Soils (Gleisols) and the Hydromorphic Laterites (Litholithic Pétric Plinthosols) occur with greater intensity in the Rio Formoso micro-region and represent, respectively, 6% and 6.5% of the soils of the State. They are associated with and include Alluvial Soils (Fulvic Neosols) and Hydromorphic Soils (Gleisols).

There are areas with Purple Latosols in Bico do Papagaio, with Yellow Latosols in Rio Formoso, with Terra Roxa (Red Nitosols) in Dianópolis and with Reddish Brunizem (Chernosols) in Bico do Papagaio and Araguaína. Regarding agricultural suitability, about 55.4% (153,752 km²) of the soils in the state are classified as suitable for tropical fruit trees and crops, 14.1% (36,006 km²) suitable for planted pastures, 17.6% (48,717 km²) for silviculture and natural pasture and 12.9% (35,322 km²) without agricultural suitability (EMBRAPA, December/2000).

WEATHER

The data presented in figure 2 represent the behavior of rain and temperature throughout the year in the state. Climatological averages are values calculated from a series of data from 30 years observed. It is possible to identify the rainiest/driest and hot/coldest seasons in a region.



(SOURCE: INMET, figure 2)

In summary, climate data obtained through monitoring organizations has a great function within the production chain, guiding the producer's decision-making within their cultural treatments, the temperature oscillation in the state of Tocantins and one of the challenges that cultivars have in their adaptation and expression of their maximum productive potential.

The state of Tocantins is under the domination of the semi-humid tropical climate, predominant in the central region of Brazil, being characterized by the occurrence of a dry seasonal period and a rainy period. It usually has a season with drought of about 4 to 5 months, and the occurrence of rainfall concentrated in the summer (EMBRAPA). The region of Araguaína-TO has a humid tropical climate, with a maximum temperature ranging between 30 and 34 ºC and a minimum between 19 and 21 ºC. The vegetation that predominates in the region is the cerrado, but part of the municipality's territory consists of transition forest between the cerrado and the Amazon forest (IBGE, 2018).

NITROGEN FERTILIZATION

Nitrogen fertilization with urea in Dunamis grass pastures is an essential practice to improve forage productivity and quality. Nitrogen is one of the most important nutrients for grass growth, and urea is one of the most widely used nitrogen sources in livestock and agriculture due to its nitrogen content (about 46%).

The application of urea can significantly increase dry matter production, providing greater forage availability for livestock. It promotes a higher concentration of proteins in the grass leaves, improving the nutritional value of the pasture. Nitrogen stimulates tillering (emission of new shoots) of the grass, increasing the density of the pasture.

MATERIAL AND METHODS

EXPERIMENTAL DESIGN

The experiment will be carried out at the Presidente Antônio Carlos University Center – UNITPAC, located in the municipality of Araguaína, state of Tocantins, northern region of the country, whose climate is defined as humid tropical (AW, according to the Koppen-Geiger classification), with average annual precipitation around 1,800 mm to 2,000 mm, and annual temperature ranging between 24°C and 27°C. The rainy season occurs between the months of November and April and the dry season extends from May to October. The predominant soil type in the area is Neosol and the part that will be used in pots will be corrected with a proportion of 1.5 t per ha, equivalent to 150g per dm^2. The doses of nitrogen used will be 0, 50, 100 and 150g per dm^2.

TREATMENTS

The treatments will consist of different levels of nitrogen application:

1. T1: 0 kg/ha de N (testemunha)
2. T2: 50 kg/ha de N
3. T3: 100 kg/ha de N
4. T4: 150 kg/ha de N

SOIL PREPARATION AND PLANTING

For soil preparation: it will be used as a substrate for planting seeds base fertilization (nitrogen extract).

The Dunamis grass seeds will be planted in pots.

APPLICATION OF TREATMENTS

Nitrogen application will be carried out in topdressing, divided into three applications during the growing phase (initial, intermediate and before harvest).

DATA COLLECTION AND STATISTICS

For data collection, a metric ruler and scissors will be used. The visual analysis will be carried out in order to ascertain the number of tillers in senescence.

A completely randomized design will be used, with 4 treatments and 6 replications, totaling 24 experimental units. Will the data be submitted to analysis of variance by the test?

DISCUSSION OF THE RESULTS

The results will be interpreted based on the effects of different nitrogen levels on growth, nitrogen use efficiency and physical characteristics of Dunamis grass.

The practical implications for pasture management and environmental sustainability will also be discussed.

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HYDRAULICS IRRIGATION AND DRAINAGE

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ABSTRACT

The study and understanding of fluids is relevant to the extent that we understand that they are present in almost all situations in our day-to-day lives and understand and have a real notion of the characteristics of fluids, such as density, which is the ratio of the proportion of the mass of a fluid in relation to its volume, We also seek to understand how a fluid can influence bodies through buoyancy, which is characterized as a vertical force that acts on the object immersed in a fluid, known as Archimedes' Principle, can allow us to use them in the best possible way in our favor and in our daily activities.

Keywords: Fluids. Density. Buoyancy.

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INTRODUCTION

Fluids are substances or products that have the ability to deform and take on the shape of their respective containers or when subjected to shear stresses, even if such stress does not reach proportions of great magnitudes,

The study of the behavior of fluids acquires its maximum relevance when we start from the principle that by knowing its characteristics, such as specific mass, knowing its viscosity, we can come to understand how a fluid starts to behave in situations where it is exposed to an energy coefficient, whether in free conduits or penstocks (GIANINI 2015).

In agriculture, knowing the properties and behaviors of fluids can be the difference between using water rationally, making the best use of it, using it in the right place and time as a way to maximize results within agricultural production

Understanding how we can make the best use of the knowledge that we can assimilate in the face of study to understand the behavior of fluids in the most varied situations and applications, can be a watershed, which leads us to success and total failure in the development of an activity, in this case, understanding how a fluid behaves within our field of action, which is agronomy, allows us to understand how to act in order to greatly enhance the best use of water, as well as we can also understand how to use other types of fluids in a positive way.

GENERAL OBJECTIVE

The objective of this experiment was to understand how different types of fluids behave when subjected to different situations, in this case water and vegetable oil, ascertaining the reactions and changes in them when subjected to heating and what is the reaction in a situation of immersion of different bodies, analyzing items such as density of the bodies and buoyancy suffered by them when immersed.

Objective 01

The objective of experiment 01 was to verify changes in density in an oil column when subjected to a temperature of 90 degrees, observing how much temperature changes influence the characteristics and properties of the fluids.

Objective 02

The objective of experiment 03 was to ascertain the influence that the density of different bodies exerts when such bodies are exposed to the same fluid and the degree of buoyancy that acts after these bodies in a given fluid

THEORETICAL FRAMEWORK

DENSITY

The interaction of the density and/or density/viscosity ratio of a fluid is very relevant to determine how each fluid behaves in free conduits or penstocks, (GEANINI. 2015)

Also for Geanini (2015), "the specific mass (ρ) of a fluid is defined as its mass per unit of its volume. Specific mass is a quantity dimensioned in (ML-3), usually expressed in kg.m-3 in SI or g.cm-3 in CGS".

The representation of the specific mass equation of water can be represented by the following equation

$$\text{Example: } =1000\frac{(t-4)^2}{150}$$

This formula allows us to measure the density of a substance when it is subjected to a certain temperature

Where ρ is the mass, density of the water in (kg/m , $^{-3}$ and t is the temperature in (°C).

It can also be calculated by the formula below in situations where the temperature variable is not involved.

$\rho = \frac{M}{V}$, where we can calculate the ratio of the proportion of the mass by the volume occupied by it.

Each and every pure substance is characterized by its density, that is, what differentiates it from another or from other pure substances, is the ratio of the mass proportion of each substance in relation to its volume, (PAOLI, et al. 2018);

Also for PAOLI (2018), "density is an important physical property and can be used to distinguish a pure material from an impure one (or alloys of this metal), as the density of materials that are not pure (mixtures) is a function of their composition"

Ramalho, (2007) states, "in determining the density, it is necessary to take into account all the factors that can influence the result, such as atmospheric pressure and ambient temperature"

THRUST

Buoyancy is a vertical force that acts on every object immersed in a fluid. This force is known as Archimedes' Principle, (YOUNG and FREEDMAN. 2015)

When an object is totally or partially immersed in any fluid, a force called buoyancy will arise on the object, which is exerted by the fluid and has a vertical direction and upward direction, (SILVA, 2016)

Buoyancy corresponds to the weight of the volume of liquid displaced by the body immersed in a fluid. Knowing that weight is the result of the product of the mass by gravity and calling the mass of displaced liquid mDES, we have:

$E = mDES \cdot g$

MATERIALS AND METHODS

EXPERIMENT 1

Density

Objective: To determine the heated oil density.

Materials:

Figure 01 - U-shaped tube

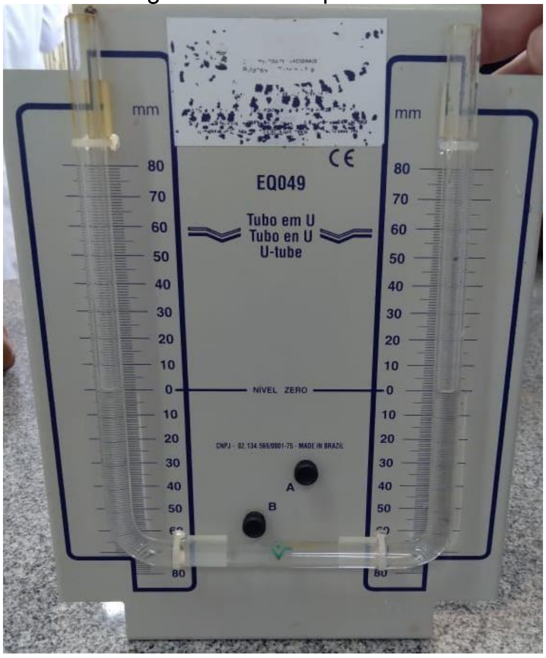

Figure 02 - Heating plate

Figure 03 - Beaker with oil

Figure 04 – Pipeta

Figure 05 - Mercury thermometer

Procedure

1° Heating the oil to 90°C 2° Cooling the oil to 60°C

3° Put the oil on one side of the U-tube

EXPERIMENT 2

Thrust

Objective: To measure the value of buoyancy in bodies

Materials

Figure 06 - Metal cylinder

Figure 07 - Polymer cylinder

Figure 08 - Beaker with water

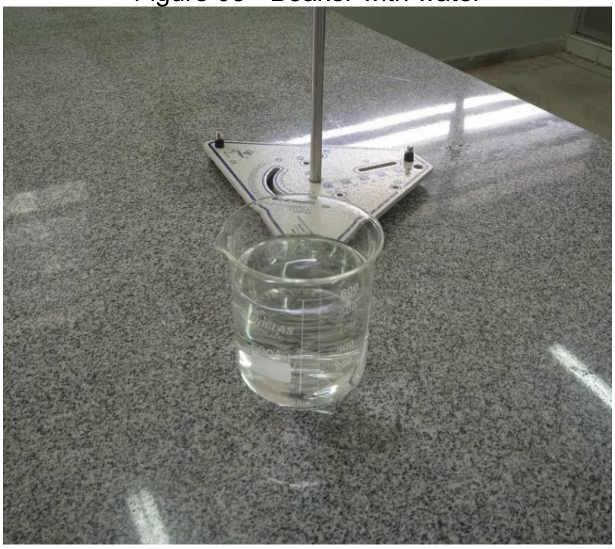

Figure 08 – Haste

Procedure

1° Placing the dynamometer

2° Measure the weight of the cylinders before water 3° Measure the weight of the cylinders after water

RESULTS AND DISCUSSION

DENSITY FORMULAS, AND THE RESULTS OBTAINED IN THE U-TUBE EXPERIMENT

$$P1=P2P1=P2$$

P_0 →pressure*Atmospheric* =(1.05x10^5)

P_0+ ρ.g.h1 = P_0+ ρ.g.h1 =

P_0+ρ.g.h2 P_0+ρ.g.h2

The height of the water was 0.096 meters and the height of the oil was 0.1 meters, so:

P=(1.05x10^5)+1000∗9.81∗0.096=(1.05x105)+1000∗ 9.81∗0.1

P=1000∗9.81∗0.096=1000∗9.81∗0.1P=1000∗9.81∗0

,096=1000∗9.81∗0.1

P=941.76=981P=941.76=981

P=981941.76=>1.041 kg/m³P=981941.76=>1.041 kg/m³

The value found in the U-shaped tube was 1 (one) point 0 (zero) 4 (four) 1 (one) kg/m³, where the values were made by measurement with a measurement meter (in centimeters and millimeters), and each measurement was noted, being replaced in the formula for problem solving.

THRUST FORMULAS, AND CALCULATIONS OF POLYMER CYLINDER RESULTS, AND METAL CYLINDER

P. apparent=P.real=EP.apparent=P. real=E

↓

E=−P.apparent+P.real=−P.apparent+P.real

- Polymer.

The actual weight of the polymer was 0.1 N and the apparent weight was equal to 0 N, so we have:

$E=0-0.1=N \rightarrow E=-0+0.1=0.1$ N$E=0-0.1=N \rightarrow E=-0+0.1=0.1$ N

As the polymer is less dense than water, the polymer will float, and its weight is light, so the force that the polymer will present is very small.

- Metal Cylinder.

The actual weight of the metal cylinder was 0.81 N and the apparent weight was 0.71 N, so we have:

$E=0.71-0.81=N \rightarrow E=-0.71+0.81=0.10$ N$E=0.71-0.81=N \rightarrow E=-0.71+0.81=0.10$ N

The metal is denser than water, so it will be submerged making a force of **0.10 N.**

The experiments that were carried out with both objects presented different results, the objects were similar but of different properties, which resulted in different data.

CONCLUSIONS

Each material has a different density, as the property of these materials is very specific, even though they have very similar characteristics, they will present different results. There is a simple question asked by some people, which is heavier 1 kg of lead or 1 kg of cotton? Many answer that it is lead, for the simple fact that lead is heavier, the answer is that the two have the same weight, plus the volume of cotton will be much larger to reach 1 kg, because its density is lower than that of lead.

Buoyancy is a force that every object experiences when plunged, this force is directed vertically (upwards), the object tends to become lighter.

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GREEN HYDROGEN AND ITS RELEVANCE IN THE DECARBONIZATION OF THE BRAZILIAN PORT SECTOR

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ABSTRACT
This article investigates the role of green hydrogen (H_2V) in the decarbonization of Brazilian ports, with emphasis on initiatives such as the projects implemented in the ports of Pecém and Suape. Green hydrogen is highlighted as a fuel alternative, produced through the electrolysis of water using renewable energy, aligning with the climate goals set by the International Maritime Organization (IMO). The research analyzes the benefits associated with this transition, including the reduction of polluting gas emissions, the creation of jobs and the strengthening of the sector's competitiveness, in addition to addressing the challenges related to production costs and the necessary infrastructure. The study also presents international examples, such as the ports of Rotterdam and Yokohama, which already incorporate sustainable technologies into their operations. It is concluded that green hydrogen represents a viable solution for the energy transition in Brazil, with the potential to position the country as a leader in the global clean energy market.

Keywords: Green Hydrogen. Decarbonisation. Brazilian Ports. Sustainability.

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INTRODUCTION

The growing search for clean and renewable energy sources in recent decades is closely related to the growing awareness of the adverse impacts of greenhouse gas (GHG) emissions and the urgent need to decarbonize essential sectors of the global economy. The maritime sector, historically dependent on fossil fuels, stands out as one of the main targets of these initiatives, due to its substantial and continuous emissions. According to data from the International Maritime Organization (IMO), maritime transport is responsible for about 2.89% of global carbon dioxide (CO2) emissions, which makes its decarbonization a strategic priority on the international stage (IMO, 2020).

In response to this demand, in 2023, the IMO revised its Greenhouse Gas Strategy, setting ambitious targets, such as a 40% reduction in CO2 emissions by 2030 and 70% by 2050, with the aim of achieving net-zero emissions by the middle of the 21st century. This strategy includes adopting alternative fuels, such as green hydrogen (H2V) and other low-carbon sources, as well as imposing additional pressure on member countries to adapt their policies and regulations to these global targets (IMO, 2023).

In this context, ports, which are fundamental for global trade and logistics, emerge as strategic locations for the implementation of sustainable energy solutions. Green hydrogen (H2V), produced from renewable sources through water electrolysis, emerges as a promising alternative to decarbonize port operations and contribute to the sector's energy transition. In Brazil, the strategy of alignment with IMO goals is evident in initiatives such as the National Hydrogen Program (PNH2), which encourages the use of H2V in the maritime sector. The ports of Pecém and Suape stand out for leading pilot projects aimed at the production and use of H_2V, reinforcing the country's commitment to reducing emissions in maritime transport and port activities.

This article aims to discuss the importance of decarbonizing the maritime sector, emphasizing the need for clean and renewable energy alternatives in response to concerns about greenhouse gas emissions. In addition, it highlights the significant contribution of maritime transport to global CO2 emissions and the urgency of implementing strategies to mitigate these emissions, in line with the targets set by the International Maritime Organization (IMO).

Thus, in section two of the article, a brief review of seaports and the main equipment necessary for their operations will be presented. Decarbonization will be addressed in section four, while in section five the challenges and opportunities related to energy production will be discussed. The understanding on green hydrogen will be presented in section six, leading to the discussion of its relationship with ports in section seven. Finally, a comparative analysis of costs and environmental impacts will be carried out for a specific piece of equipment, aiming to prove how decarbonization contributes to the reduction of emissions and positions green hydrogen as a clean source of energy. The study will conclude with a reflection on the importance of decarbonization in the search for a more sustainable future.

METHOD OF STUDY

This study used a qualitative and exploratory approach, focusing on the analysis of initiatives, policies and technologies related to the integration of green hydrogen in Brazilian port operations. The methodology was based on a literature review and document analysis, covering technical reports, academic articles and case studies relevant to the theme.

The data was collected from secondary sources, including reports from the National Waterway Transport Agency (ANTAQ) and the Energy Research Company (EPE), which highlight Brazil's potential for the production and use of green hydrogen in port operations. In addition, academic articles such as those by Carlson and Trencher (2024) and Chen et al. (2024) were used to support the analysis of electrification technologies and alternative fuels in the global port context.

The analysis of initiatives and case studies was carried out to identify decarbonization practices and the use of green hydrogen. The Port of Pecém was one of the main examples in Brazil, being recognized as an emerging green hydrogen hub with electrification and infrastructure projects for the production and export of H_2V. Internationally, the Port of Rotterdam was considered a reference, standing out for its integration of fuel cells and Onshore Power Supply (OPS) systems (EPE, 2022); (PORT OF ROTTERDAM AUTHORITY, 2022).

The environmental, social, and economic benefits of the technologies were evaluated based on indicators reported in the literature, such as the reduction of greenhouse gas (GHG) emissions and the potential for job creation. At the same time, technical and economic challenges, such as high production costs and regulatory barriers, were discussed in the light of experiences reported in other port contexts (CHEN *et al.*, 2024); (HOWARTH *et al.*, 2021).

To enrich the analysis, a comparison of environmental impact and cost with the cost of an electric truck with a diesel-powered truck was presented. This comparison used metrics such as emissions reduction and operational efficiency, in line with the global decarbonization guidelines established by the International Maritime Organization (IMO) (IMO, 2020).

SEAS PORTS

Seaports are complex infrastructures that play a vital role in international trade. They are defined as sheltered areas that allow the berthing of vessels and the movement of cargo and passengers, according to Mamigonian (2017) and CTC Infra (2023).

A seaport is a facility designed to facilitate the loading and unloading of goods and passengers. The main elements that guarantee its functionality according to CTC Infra [(1)] (2023), Intermodal Digital (2023), National Port System (2023), CTC Infra [(2).] (2023), PUC-Rio. (2017) include:

- Mooring Area: Space where ships anchor to load or unload goods. This area should be of adequate depth to accommodate different types of vessels.
- Navigation Channels: Water paths that allow for the safe entry and exit of ships. The depth and width of these channels are critical to avoid strandings and ensure the fluidity of maritime traffic.
- Quay or Dock: Structures that allow ships access to land, facilitating the loading and unloading of cargo. The wharves are equipped with cranes and other equipment for cargo handling.
- Storage Areas: Spaces designated to store goods temporarily before or after transportation. These areas can include covered warehouses and outdoor patios.
- Land Infrastructure: Road and rail networks connect ports to the interior of the country, allowing for the efficient flow of cargo. Integration with other modes of transport is vital for modern logistics.

Ports are also home to a variety of industrial facilities and services that support their operations:

- Specific Terminals: Areas within the port dedicated to handling specific types of cargo, such as container terminals, bulk terminals (for bulk products), and liquid terminals (for fuels and chemicals).
- Port Services: These include tugboats, cranes, stevedores, and administrative services that ensure the efficient operation of the port. These services are crucial to optimize the docking time of ships.
- Security and Control Facilities: Integrated systems that ensure the safety of port operations, including environmental monitoring, maritime traffic control, and sanitary inspections.

Ships play a central role in port operations. They range in size and type, from small fishing boats to large freighters. The main types include:

- Cargo Ships: Designed to transport goods on a large scale, they can be specialized in containers, solid or liquid bulk.
- Oil tankers: Specific vessels for the transport of oil and oil products.
- Bulk Carriers: Used to transport agricultural or mineral products in bulk.
- Passenger Ships: These include cruises and *ferries* that transport people between tourist destinations or coastal regions.

EQUIPMENT

Ports use a variety of equipment to ensure efficient cargo handling. This equipment can be classified into two main categories: vertical movement and horizontal movement.

a. Vertical Movement

Cranes: Used to lift cargo from the ship to the dock or vice versa. Gantry cranes are common in container terminals.

Portêineres: Large machines responsible for loading and unloading containers onto ships. They can operate with high efficiency, handling up to 45 containers per hour.

b. Horizontal Movement

Forklifts: Used to move cargo between different areas of the port. There are variations such as electric, gas, and *Reach Stackers*, which are specially designed for container handling.

Conveyor Belts: Equipment used to transport materials between warehouses and cargo areas.

Mechanical Loaders: Specialized equipment for loading bulk solid materials onto ships.

ENERGY SOURCES USED

The operation of port equipment requires several sources of energy, which can include:

Fossil Fuels: Many cranes and forklifts still run on diesel or gasoline, although there is growing pressure to reduce the emissions associated with these fuels.

Electric Power: Electric equipment, such as electric forklifts and electric cranes, are increasingly common due to their energy efficiency and lower emissions.

Renewable Energy: Installing solar panels and wind turbines in ports is becoming a common practice to reduce reliance on fossil fuels and minimize the environmental impact of port operations.

The efficiency of port operations depends on the synchronization between ships' activities and land operations. The continuous modernization of port infrastructures is essential to meet the growing demands of global trade, while seeking to minimize environmental impacts to improve logistics operations and promote sustainable practices in the sector. The decarbonization of port activities must be a priority to ensure a more sustainable future in international trade.

UNDERSTANDING DECARBONIZATION

Decarbonization is the process of reducing greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), to mitigate the impacts of climate change. This concept involves transitioning from fossil fuel-based energy, economic, and industrial systems to low-carbon or zero-carbon alternatives, such as renewables, energy efficiency, and carbon capture and storage (CCS) technologies (UNFCCC, 2015).

Decarbonization is one of the central pillars of the Paris Agreement, which set the goal of limiting global temperature rise to 1.5°C above pre-industrial levels, requiring coordinated efforts by countries to significantly reduce their emissions by mid-century (UNFCCC, 2015).

General decarbonization strategies vary between countries, but have as a common axis the reduction of dependence on fossil fuels and the promotion of renewable energy sources. In the European Union, the European Green Deal seeks to make the continent the first to achieve climate neutrality by 2050. The strategy includes investments in renewable energy, electrification of transport and restructuring of heavy industries, such as steel and cement production, to reduce emissions (EUROPEAN COMMISSION, 2019).

China, the largest emitter of CO_2 in absolute terms (EUROPEAN COMMISSION, 2024), has committed to peaking its emissions before 2030 and achieving carbon neutrality by 2060. Its strategy includes the massive development of solar and wind energy, as well as investments in carbon capture and storage technologies (CHINA STATE COUNCIL, 2021). Japan and South Korea are also focusing on transitioning to hydrogen as an alternative fuel and increasing the energy efficiency of their industries (IEA, 2021).

In the United States, the second largest global emitter, the *Inflation Reduction Act* of 2022 presents guidelines for large investments in energy and climate security in the country. The law provides significant financial incentives for low-carbon technologies such as electric vehicles, green hydrogen, and solar energy. It is estimated that these measures could reduce US GHG emissions by up to 40% by 2030, compared to 2005 levels (US GOVERNMENT, 2022).

In Brazil, the commitment to decarbonization is strengthened by its predominantly renewable energy matrix. About 84% of electricity in the country is generated by renewable sources, such as hydroelectric, wind, and solar. The National Energy Plan 2050 provides for the expansion of these sources and the integration of green hydrogen technologies, advanced biofuels, and transport electrification systems (MME, 2020).

DECARBONIZATION OF PORTS

In the context of decarbonization, ports play a strategic role in the global context, as they require energy-intensive operations such as cargo handling, berthing operations, port equipment, and logistics activities, emit large amounts of GHG (IMO, 2020).

The energy transition in ports begins with the electrification of essential equipment such as cranes, forklifts, and cargo handling vehicles. This equipment, which traditionally uses fossil fuels, is being replaced by electric or hydrogen-powered versions (CARLSON *et al.*, 2024). Renewable energy sources can be integrated into port operations to power equipment and infrastructure, reducing reliance on electricity generated by fossil fuels.

Sustainable ports are investing in modern technologies and sustainable practices to reduce emissions and increase operational efficiency. Table 1 presents detailed examples of decarbonization initiatives adopted in ports on different continents.

Table 1: Examples of decarbonization initiatives on different continents

Continent	Harbor	Initiatives	Reference
Asia	Port of Shanghai	Automation, renewable energy	(ALAMOUSH *et al.*, 2023)
Europe	Port of Rotterdam	Electric cranes, LNG and hydrogen infrastructure	(ALAMOUSH *et al.*, 2023)
Americas	Port of Santos	Studies for hydrogen infrastructure	(WEI et al., 2023)
Oceania	Port of Auckland	Investments in renewable energy	(AGARWALA *et al.*, 2021)
Africa	Porto de Durban	Crane modernization and clean energy	(ALAMOUSH *et al.*, 2023)

In addition to the transition to renewable energy, operational efficiency plays an important role. The use of digital technologies, such as *digital twins*, virtual representations that allow simulating the behavior of real systems, real-time monitoring systems and artificial intelligence, allows optimizing the logistics flow and reducing energy waste (EOM *et al.*, 2023). Studies indicate that the application of these technologies can reduce port emissions by up to 50% (CHEN *et al.*, 2024).

The decarbonization of ports is an important part of the attempt to achieve global climate goals and ensure the sustainability of the maritime logistics chain. In addition to reducing greenhouse gas emissions, it promotes economic and social benefits, such as attracting new investments, generating jobs, and strengthening global competitiveness. To maximize this potential, it is essential to implement robust public policies, encourage public-private partnerships, and invest in research and development, transforming ports into sustainable hubs and protagonists in the global energy transition (IMO, 2020).

In shipping, decarbonization is also a strategic measure to mitigate climate change and meet global sustainability goals. The International Maritime Organization (IMO) points out that the sector is responsible for 2.89% of global CO_2 emissions, highlighting the need for coordinated action to reduce its environmental footprint and comply with the Paris Agreement, as well as the targets of its 2023 GHG Emissions Reduction strategy (IMO, 2020).

Among the most recent IMO goals, the goal of net zero emissions by mid-century, with a 40% reduction in carbon intensity by 2030, stands out. Another important point is the expansion of the use of low-emission alternative fuels, such as green hydrogen and ammonia, which should make up at least 10% of the energy consumed by the maritime sector by the same year (IMO, 2023). Despite the great potential for reducing emissions, high production costs and lack of infrastructure are still significant challenges for the implementation of these fuels, especially in developing countries (MALLOUPPAS *et al.*, 2021).

Initiatives such as the Poseidon Principles, which promote sustainable financing for low-carbon vessels, are key to accelerating the energy transition (IMO, 2020). In Brazil, the National Hydrogen Program (PNH2) has boosted decarbonization projects in maritime transport. The country, with a robust renewable energy mix that includes hydroelectric, solar, and wind power, has great potential to lead the use of green hydrogen in maritime operations (EPE, 2022).

The transition to more sustainable maritime practices requires global cooperation, technological innovation, and financial support. Alternative fuels, digital technologies, and sound regulatory policies represent the most promising path to achieving climate goals and reducing the sector's carbon footprint. Brazil, with its renewable potential and emerging initiatives, can play a central role in this global transformation.

ENERGY PRODUCTION: CHALLENGES AND OPPORTUNITIES

Energy production is a central issue for sustainable development and climate change mitigation. With the growing need for decarbonization, new energy sources such as green hydrogen are gaining prominence. Energy production in Brazil and in the world, focusing on new energies, especially hydrogen, and discusses the challenges and opportunities associated with these sources.

Brazil is one of the world leaders in renewable energy generation, with an energy matrix that stands out for its sustainability. Approximately 84% of the country's installed capacity comes from renewable sources, the main ones being:

- Hydroelectric plants: They represent about 68% of electricity generation, taking advantage of the country's vast water availability.
- Wind Energy: With accelerated growth, wind energy already accounts for approximately 15% of the electricity matrix.
- Solar Energy: Solar energy has shown a significant increase in installed capacity, contributing about 7% of total generation.

In addition to these traditional sources, Brazil is positioning itself to become a leader in green hydrogen production. Green hydrogen is produced through the electrolysis of water using electricity generated by renewable sources. This process emits no greenhouse gases, making it a promising alternative for decarbonization in hard-to-electrify sectors.

Globally, the energy matrix is still dominated by fossil fuels, which account for about 78% of electricity generation. However, renewables are growing rapidly:

Growth of Renewable Energy In 2022, solar and wind energy were responsible for meeting about 77% of the increase in global electricity demand. The transition to these sources is driven by the urgent need to reduce carbon emissions.

Green hydrogen is emerging as a viable solution for decarbonization in sectors such as transportation, industry, and heating. Produced through electrolysis with renewable electricity, green hydrogen does not generate emissions during its production or use.

Challenges also exist according to Barroso *et al.* (2023), PUCRS. (2023), Ministry of Mines and Energy (2023) and CAF (2024) to be tackled as:

- Cost of Production: The production of green hydrogen is still more expensive than fossil fuel-based alternatives (gray and brown hydrogen). The need for significant investments in technology and infrastructure is a key challenge for its large-scale adoption.
- Storage Technology: The storage and transportation of hydrogen is complex. While hydrogen is an efficient way to store energy, current technologies still need to be improved to ensure safety and efficiency.
- Integration into the Energy Mix: Integrating hydrogen as a significant source within the energy mix requires a reconfiguration of existing infrastructures and public policies that encourage its adoption.

- Legislation and Public Policies: The lack of consistent policies can hinder the advancement of renewable energy.
- Social Acceptance: Local resistance to renewable energy projects can delay their implementation.

Opportunities on the other hand arise in the production of H2Verde according to Barroso et al (2023), PUCRS. (2023), Ministry of Mines and Energy (2023), CIBiogás. (2023), GNPW Group (2023), New Energy. (2023), Ember Climate. (2022) and IEE/USP (2023) as:

- Job Creation: The growth of the renewable energy sector is generating new job opportunities in a variety of areas, from manufacturing to installation and maintenance.
- Technological Innovation: The sector is fertile for innovations that can improve efficiency in energy generation and storage. Emerging technologies such as artificial intelligence can optimize processes.
- Global Leadership: Countries that lead in the energy transition can set global standards and gain significant economic advantages by positioning themselves as leaders in clean technologies.
- Supporting Sustainability: The transition to renewable energy not only reduces greenhouse gas emissions but also promotes a more sustainable use of natural resources.

It is verified that energy production is undergoing a significant transformation both in Brazil and globally. Green hydrogen emerges as a promising solution for decarbonization, offering substantial economic opportunities while addressing technical and financial challenges. The effective integration of hydrogen into the energy mix can not only help mitigate climate change but also position Brazil as a global leader in renewable energy.

UNDERSTANDING ABOUT H2VERDE

In this section, we will briefly address the green hydrogen production process and its different derivatives.

PRODUCTION PROCESS

Green hydrogen is obtained through water electrolysis, a procedure that uses electricity generated by renewable sources, such as solar, wind, and hydroelectric, to split water into hydrogen and oxygen. This method is considered environmentally sustainable, as it does not release greenhouse gases during its production, unlike gray and blue hydrogen, which are generated from fossil fuels and are associated with significant CO_2 emissions (IRENA, 2020). Projections indicate that the production of green hydrogen could reach 16 million tons per year by 2030, if there are favorable investment conditions and adequate public policies (IEA, 2021).

Green hydrogen presents itself as an alternative to other types, as it uses energy from renewable sources and separates water molecules through the electrolysis process. This production technique does not generate greenhouse gases during its execution, making it a viable option for reducing carbon emissions (SEDAI *et al.*, 2023; SCHMIDT *et al.*, 2020).

Electrolysis is an electrochemical process that applies electricity to break down chemicals. In the context of green hydrogen production, water electrolysis is used, where water (H2O) is fragmented into hydrogen (H2) and oxygen (O2) by the passage of electric current. The process takes place in an electrolytic cell composed of three main components: two electrodes (anode and cathode) and an electrolyte.

Chemical reactions are represented by the equations:

Anode: $2\ H2O_{(l)} \rightarrow O2(g) + 4\ H+_{(aq)} + 4e^-$ Eq.01

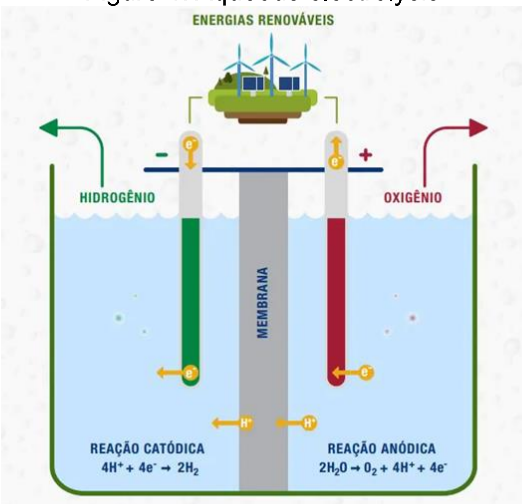
Cathode: $4\ H+_{(aq)} + 4e^- \rightarrow 2\ H2(g)$

Eq.02

The hydrogen produced can be stored and used as an energy source in various applications. Figure 1 illustrates this process.

The device used in the process of aqueous electrolysis is the electrolyzer. It plays the role of providing the platform where electrochemical reactions take place to break down water into hydrogen and oxygen. Its function is to optimize the energy efficiency of the process, minimize losses and ensure operational safety.

Figure 1: Aqueous electrolysis



Source: U.S. Department of Energy (2022)

There are three main types of electrolysis processes currently used according to Albretch *et al*., 2020; Karayel *et al*. 2022; Jansons *et al*. 2023; Lahnaoui *et al*., 2021: (i) alkaline, (ii) polymeric membrane, and (iii) solid oxide electrolysis cells (still in the implementation phase).

Electrolysis units are widely used to generate high purity in hydrogen by breaking water, with alkaline electrolysis being one of the oldest techniques for hydrogen production (KARAYEL *et al*., 2022) and the efficiency of existing electrolysis processes varies between 60 and 81% (IEA, 2021).

For the effective production of green hydrogen, it is essential to consider the availability of renewable energy sources, the efficiency of electrolyzers, the infrastructure for storage and transportation, and the costs involved. In Brazil, the abundance of water resources and the growing capacity to generate wind and solar energy put the country in an advantageous position to become a global leader in green hydrogen production (ANEEL, 2021). Water electrolysis requires approximately 50 kWh of electricity to produce 1 kg of hydrogen, making energy efficiency and the cost of electricity critical factors (IRENA, 2020).

DERIVATIVE PRODUCTS

Green hydrogen can be used in various industrial and energy applications. Among the derived products, *Sustainable Aviation Fuel* (SAF), hydrotreated vegetable oil (HVO), ammonia, methanol and green steel stand out.

a- SAF and HVO

Green hydrogen is crucial in the production of sustainable aviation fuels (SAF) and green diesel, also known as hydrotreated vegetable oil (HVO), both of which are essential for the decarbonization of the transport sector. SAF can reduce CO_2 emissions by up to

80% compared to traditional fossil fuels (ICAO, 2019). HVO, in turn, is a direct replacement for fossil diesel, offering a significant reduction in pollutant emissions (IEA, 2021). SAF is produced from biomass and other waste, while HVO is produced through the hydrogenation of vegetable oils and animal fats, using green hydrogen in the process (IEA, 2021). Global demand for SAF is estimated to reach 100 million tons by 2050, driven by aviation decarbonization goals (ICAO, 2019). The demand for HVO is also expected to grow significantly, with Europe leading the market for advanced biofuels (IEA, 2021).

b. Ammonia

Widely used in the production of fertilizers, green ammonia, produced from green hydrogen, offers a low-carbon alternative compared to conventional ammonia, which uses natural gas as a feedstock. Global ammonia production is responsible for about 1.8% of CO_2 emissions, which can be drastically reduced with the transition to green ammonia (FAO, 2020). In Brazil, the production of green ammonia-based fertilizers can reduce dependence on imports and promote more sustainable agriculture (MME, 2020). In addition to fertilizers, green ammonia can be used as a fuel in marine engines, providing a clean alternative for shipping (IRENA, 2020).

c. Methanol

Green methanol can be used as a fuel and chemical feedstock, replacing traditional methanol produced from fossil fuels. The production of green methanol can reduce CO_2 emissions by up to 90% (IRENA, 2021). Methanol is an essential input in the production of chemicals such as formaldehyde, acetic acid, and plastics, as well as being used as a fuel in fuel cells and internal combustion engines. Global demand for methanol is expected to grow from 100 million tonnes in 2020 to 500 million tonnes in 2050 as we transition to a low-carbon economy (IRENA, 2021).

d. Green Steel

Green steel production uses green hydrogen instead of coal, resulting in a significant reduction in CO_2 emissions. European demand for green steel presents a substantial opportunity for Brazil, which is a major exporter of steel. Europe plans to buy only green steel from 2030, which could boost the demand for green hydrogen in Brazil (EUROPEAN COMMISSION, 2020). Green steel is produced through the direct reduction of iron ore using hydrogen instead of coal, resulting in up to a 90% reduction in CO_2 emissions compared to traditional methods (IEA, 2021).

Green hydrogen-derived products have significant advantages in terms of sustainability and reduced carbon emissions compared to their fossil counterparts. For example, SAF and HVO produced from green hydrogen have a significantly lower carbon footprint than traditional fossil fuels (ICAO, 2019). Similarly, green ammonia and methanol offer cleaner and more sustainable production, in line with global decarbonization goals (IRENA, 2020). However, green hydrogen production still faces challenges such as the high cost of production and the need for adequate infrastructure, compared to more established and cheaper traditional methods (IEA, 2021).

The cost of green hydrogen currently ranges between $4 to $6 per kg, while gray hydrogen costs approximately $1 to $2 per kg (IEA, 2021). However, with the reduction in the costs of renewable energy and technological advancements, the cost of green hydrogen is expected to fall to around USD 2 per kg by 2030 (IRENA, 2020).

GLOBAL CONTEXT OF GREEN HYDROGEN IN DECARBONIZATION

To deepen the analysis of the role of green hydrogen (H_2V) in the decarbonization of Brazilian ports, it is crucial to contextualize this technology in a global scenario. H_2V has established itself as a central solution in the decarbonization of industrial and mobility sectors in several regions of the world, especially in Europe and Asia.

Countries such as Italy have adopted the creation of hydrogen hubs in their ports as a crucial strategy for the energy transition. These hubs not only provide hydrogen for port operations, but also supply nearby industries, contributing significantly to the reduction of CO_2 emissions. This experience can be an important reference for Brazil, where the implementation of H_2V hubs can transform ports into strategic centers for decarbonization and technological innovation (PIVETTA *et al.,* 2022).

In Asia, China, Japan and South Korea are at the forefront of hydrogen development. China, with the "Hydrogen Industry Development Plan 2021-2035", is investing in both blue and green hydrogen production, as well as expanding its refueling infrastructure, aiming to become one of the largest producers and consumers of hydrogen by 2035 (CHINA HYDROGEN ALLIANCE, 2021).

Japan, with its 2017 "*Basic Hydrogen Strategy*", aims to become a hydrogen-based society by 2050, with a focus on importing H_2V from regions with high renewable energy availability, such as Australia. South Korea, through the "*Hydrogen Economy Roadmap*", launched in 2020, has set goals to be among the five largest hydrogen economies by 2040. Both countries are investing heavily in infrastructure and public policies for hydrogen development, with an emphasis on the port and mobility sector (SASAKI *et al*., 2020; CHUNG *et al*., 2021).

In addition to China, Japan and South Korea, India also stands out as a potential leader in the hydrogen economy, with its *2021 "National Hydrogen Mission*", seeks to consolidate itself as one of the largest producers and exporters of H_2V, taking advantage of its abundant solar and wind resources to reduce dependence on fossil fuels and achieve its decarbonization goals by 2050 (GOVERNMENT OF INDIA, 2021).

These global examples demonstrate that robust public policies, combined with substantial investments in infrastructure, are critical to the successful implementation of H_2V. Brazil, with its vast potential in renewable energies such as solar and wind, has the opportunity to follow these examples and apply similar strategies. The creation of H_2V hubs in Brazilian ports would not only contribute to the decarbonization of port operations, but also attract international investments, consolidating the country as a global leader in the energy transition.

ENVIRONMENTAL IMPACTS ON H2V PRODUCTION

Although green hydrogen stands out as a clean energy source in terms of greenhouse gas (GHG) emissions, its production is not without environmental impacts. One of the main challenges is related to the intensive use of water resources, since the electrolysis process requires large volumes of water. This factor can represent a considerable obstacle, especially in regions with water scarcity. In addition, the production of H_2V can generate by-products that need proper management to prevent environmental contamination. In order for the environmental benefits of green hydrogen to be maximized and its negative impacts minimized, it is essential that sustainable practices and strict environmental regulations are adopted (ULLMAN *et al.*, 2022).

Compared to other forms of hydrogen, such as gray and blue hydrogen, green hydrogen has a significant advantage due to its very low GHG emissions. Gray hydrogen, produced from fossil fuels, emits between 9 and 12 kg of CO_2 per kg of hydrogen generated, which directly contributes to the increase in global emissions (EPE, 2022). Blue hydrogen, which uses carbon capture and storage (CCS) technologies, can reduce these emissions to approximately 2 to 3 kg of CO_2 per kg of hydrogen, depending on the efficiency of the capture process. However, blue hydrogen faces significant obstacles, such as the variable efficiency of CCS and the risks of CO_2 leakage during storage, which can compromise the environmental gains of this technology (HOWARTH *et al.*, 2021).

On the other hand, green hydrogen is produced from renewable sources, such as solar and wind energy, through the electrolysis of water, which results in virtually zero CO_2 emissions. However, high water consumption remains a significant environmental concern: it is estimated that around 9 liters of water are needed to produce 1 kg of hydrogen by electrolysis (SENAI, 2023). To mitigate this impact, Brazil has invested in the development of desalination technologies and in the reuse of reused water, especially in regions such as the Northeast, which has an abundance of renewable resources and proximity to coastal areas, which favors the implementation of these solutions (BRASIL, 2021).

Green hydrogen is consolidating itself as the most sustainable alternative in the long term, especially in the Brazilian context, where there is a vast potential for renewable energies. The National Hydrogen Plan (PNH_2), launched by the Brazilian government, aims to foster the development of H_2V, taking advantage of the abundant solar and wind resources, especially in the Northeast region. In this region, the environmental impact of green hydrogen production can be significantly mitigated through the implementation of advanced technologies, such as desalination and water reuse (BRASIL, 2021; EPE, 2022). In this way, green hydrogen not only contributes to meeting climate goals, but also presents itself as a viable and sustainable solution for Brazil's energy future.

LOW-CARBON POWER GENERATION

Another promising application of green hydrogen (H_2V) in Brazilian ports is the generation of energy through fuel cells. Currently, many ports rely on the conventional electricity grid to sustain their operations, which can present problems in terms of both cost and energy security, especially in regions where power supply is limited or unstable. Electricity generation using hydrogen fuel cells can provide a local, clean and reliable source of energy that can power port operations continuously and with less environmental impact.

The implementation of power generation systems from H_2V offers the opportunity to reduce the dependence of ports on the traditional electricity grid, providing greater energy resilience. This aspect becomes particularly relevant in a context of growing demand for electricity and possible restrictions on energy supply due to extreme weather events or failures in electrical infrastructure. In addition, the use of H_2V as an energy source contributes to the reduction of greenhouse gas (GHG) emissions associated with electricity generation, especially in regions whose energy matrix still relies heavily on fossil sources (Serratt et al., 2024).

International experiences demonstrate the successful use of hydrogen fuel cells in port operations. At the Port of Yokohama in Japan, a pilot project implemented the use of fuel cells to power cranes and provide electricity to part of the port facilities. Developed in partnership with Japanese technology companies, the project aims to reduce CO_2 emissions and increase the port's energy efficiency. This initiative is part of Japan's strategy to become a hydrogen-based society by 2050, applying this technology in critical sectors such as transport and port logistics (METI, 2021).

Another important example is the Port of Rotterdam in the Netherlands, which is investing in the integration of hydrogen fuel cells into its operations. The port has been using hydrogen to power mobile generators and forklifts, reducing its reliance on diesel generators. The use of fuel cells at the Port of Rotterdam is part of a broader plan to transform it into a green hydrogen hub in Europe, with significant investments in infrastructure aimed at the production, storage and distribution of H_2V. The goal is to create a sustainable port model that can be replicated in other regions of the world (PORT OF ROTTERDAM AUTHORITY, 2022).

In Brazil, local researchers and projects are also advancing in the application of this technology. Studies carried out within the scope of the SENAI Institute for Innovation in Renewable Energies highlight the potential of hydrogen fuel cells for use in ports, especially in the Northeast, where there is an abundance of renewable energy sources, such as solar and wind. Brazilian researchers have been analyzing the feasibility of implementing fuel cell systems at the Port of Pecém, which is already positioned as one of the main green hydrogen hubs in the country (SENAI, 2023). These projects seek to integrate the production of hydrogen with its direct use in port operations, promoting the reduction of emissions and energy independence.

These examples, both international and national, highlight the great potential of hydrogen fuel cells to transform port operations into true sustainable energy hubs. In Brazil, the integration of fuel cells in the port sector, as is already being studied at the Port of Pecém, would not only reduce GHG emissions, but also increase the energy resilience and global competitiveness of Brazilian ports.

In addition to the Port of Pecém, other Brazilian ports are starting initiatives aimed at decarbonization. The Port of Suape, in Pernambuco, has an ongoing project for the installation of a pilot plant for the production of green hydrogen, using solar and wind energy. Similarly, the Port of Santos, the largest in Latin America, is also exploring the implementation of H_2V technologies to reduce its emissions and position itself as a clean energy hub. Table 2 exemplifies some ongoing initiatives for the production and development of H2V in Brazil

Table 2 Ongoing initiatives for H2V production in Brazil

Harbor	Location	Ongoing initiatives	Partners
Port of Pecém	Ceará	Green Hydrogen Hub; H2V production, storage and export	Port of Rotterdam, Government of Ceará, private companies
Port of Suape	Pernambuco	Feasibility studies for the production and use of H2V; Development of pilot projects	Government of Pernambuco, private companies
Port of Açu	Rio de Janeiro	H2V production from offshore wind energy; Truck and ship supply	Government of Rio de Janeiro, private companies
Other ports	Diverse regions	Feasibility studies; Development of pilot projects	State governments, private companies

Note: The table presents some of the main green hydrogen initiatives in Brazilian ports. It is important to note that new projects and partnerships are constantly developing, driving the expansion of the H2V market in Brazil.

GREEN HYDROGEN AND THE BRAZILIAN PORT SECTOR

Brazil has a vast port network, consisting of 37 public ports and more than 120 terminals for private use, according to data from the National Waterway Transportation Agency (ANTAQ). These ports play a crucial role in the country's economy, being responsible for a large part of national exports and imports. In this context, the adoption of technologies aimed at decarbonization, such as green hydrogen (H_2V), becomes an essential measure to reduce greenhouse gas (GHG) emissions associated with port operations and maritime transport.

The introduction of H_2V in Brazilian ports is a key strategy for the decarbonization of port activities, configuring itself as a decisive step in Brazil's energy transition. This process involves the gradual replacement of fossil fuels with green hydrogen in various operations, which not only generates significant environmental benefits, but also drives technological innovation and promotes a significant increase in operational efficiency.

PORT EQUIPMENT

Port equipment, such as forklifts, cranes, tugboats, and other vehicles used in daily operations, are largely responsible for the emission of local pollutants, such as nitrogen oxides (NOx) and fine particulate matter (PM). The adaptation or replacement of this equipment with models powered by hydrogen fuel cells offers a significant opportunity for the reduction of emissions, in addition to contributing to the reduction of the noise level in port areas. Studies indicate that electrification of port equipment through the use of hydrogen fuel cells can reduce NOx emissions by up to 80% and virtually eliminate fine particulate matter, positively impacting air quality and public health in communities around ports (CHEN *et al.,* 2024).

The use of H_2V in port equipment also provides important operational advantages, such as longer range and significantly shorter recharge times compared to conventional electric batteries. For example, a hydrogen-powered forklift can be refueled within minutes, while a battery-electric forklift can take several hours to complete its charge. This results in greater operational efficiency, with reduced equipment downtimes and an increase in the overall productivity of port operations (CARLSON *et al.*, 2024).

Several pilot projects around the world are already exploring the use of hydrogen-powered equipment in ports. A prominent example is the Port of Los Angeles, in the United States, which is conducting tests with trucks powered by hydrogen fuel cells. This project is part of a broader port transport decarbonization initiative, with the ambitious goal of reducing carbon emissions by 100% by 2035. The Port of Los Angeles collaborates with companies such as Toyota and Kenworth to develop and test these H_2-powered trucks, which are already being used in daily operations of transporting goods in and out of the port (CALIFORNIA AIR RESOURCES BOARD, 2022).

In Brazil, the Port of Pecém, in Ceará, is also standing out as a center for innovation in green hydrogen, focusing not only on the export of H_2V, but also on the use of hydrogen-powered port equipment. The project includes the use of cranes and other heavy-duty vehicles powered by fuel cells, making it one of the first ports in Latin America to adopt this technology. This pilot project is being developed in collaboration with private companies and research institutions, in line with the objectives of the National Hydrogen Program (PNH_2) (EPE, 2022).

These examples illustrate that the use of green hydrogen in port equipment is already an expanding reality, with great potential to be expanded globally. The implementation of H_2V in ports such as Los Angeles and Pecém not only demonstrates the feasibility of this sustainable solution, but also highlights its potential to significantly increase operational efficiency.

Another important initiative, fundamental for the decarbonization of the operation of ships within ports, is the application of the OPS (*Onshore Power Supply*) System, also known as "*cold ironing*" or "*shore-to-ship power*", a technology that allows docked ships to turn off their diesel-powered auxiliary engines and connect to a local power grid and use the electricity. which significantly reduces CO_2, NOx and SOx emissions.

The OPS has currently been the best option for decarbonizing the operation of docked ships, also contributing to a reduction in noise levels. Its implementation in Brazilian ports is close to a reality, given that some strategic ports already consider this technology as initiatives that make up their ESG Agendas.

In Europe, the ports of Germany, Sweden and Norway are at the forefront of applying this solution to serve large commercial and cruise ships. Table 3 presents some benefits and environmental impacts related to the decarbonization of port equipment.

Table 3. Environmental impacts and benefits related to the decarbonization of port equipment

Benefit	Environmental impact
1. Reducing carbon emissions	Eliminating the use of diesel engines significantly reduces greenhouse gas emissions and pollutants.
2. Improvement in air quality	With the reduction of air pollutants, the air quality in port regions is considerably improved, benefiting public health.
3. Compliance with environmental regulations:	European countries have adopted strict regulations that encourage or mandate the use of OPS, contributing to sustainability objectives.
4. Noise reduction:	The shutdown of auxiliary engines also reduces noise levels, positively impacting the urban environment near ports.

Table 4 presents examples of ports around the world that have already implemented the Onshore Power Supply (OPS) system and other technologies aimed at decarbonization:

Table 4 - Some ports that already use the OPS

Harbor	Location	Technology implemented	Year of implementation	Environmental impact
Porto de Los Angeles	USA	Onshore Power Supply	2013	30% reduction in NOx emissions during operations.
Port of Rotterdam	Netherlands	Onshore Power Supply	2015	Significant decrease in CO_2 emissions during berths.
Port of Hamburg	Germany	Bunkering with LNG and OPS	2018	50% reduction in GHG emissions in port operations.
Port of Singapore	Singapore	Onshore Power Supply	2020	Improved air quality and reduced local emissions.
Port of Shanghai	China	Infrastructure for hydrogen	2022	Beginning of the transition to alternative fuels.
Port of Pecém	Brazil	Onshore Power Supply	2024 (expected)	Potential to significantly reduce local emissions.

These examples demonstrate how the implementation of technologies such as *Onshore Power Supply* and other innovations can contribute to the decarbonization of seaports, promoting a more sustainable environment and reducing emissions associated with port operations.

Figure 1 presents some of the most important equipment used in the operation of ports where the most used fuels are diesel and we also present the possible low-carbon energy routes, where electricity and hydrogen appear.

Figure 1 - Port Equipment with their respective fuels used and possible routes to be used

Source: by the author himself.

Figures 2 and 3 show the equipment currently used in the vast majority of ports with their respective alternative route for decarbonized energy and some of the equipment already on the market, from fossil to decarbonized energies.

Figure 3 – Equipment available on the market

Source: US Department of Energy

EXAMPLE OF ENVIRONMENTAL IMPACT

A study by XCMG do Brasil as shown in Figure 4 presents a cost comparison of an electric truck with a diesel truck (VW Constellation 30.320 8x2 diesel-E6) and the E7-29R XCMG electric truck.

Initiatives to decarbonize cargo transport and cargo handling equipment have prospered significantly in the world. Currently in Brazil, there are already companies that promote the decarbonization of these transport and cargo handling equipment through the development of *powertrain*[4] solutions compatible with the reality of each territory.

As an example of one of these *powertrain* solutions on the market and accessible to logistics, transport and port operation companies, *XUZHOU CONSTRUCTION MACHINERY GROUP – XCMG*, A Chinese multinational, invested 0.5 billion dollars in the implementation of an equipment factory in Pouso Alegre - MG with a production capacity of 10,000 pieces of equipment per year, with configurations of thermal engines (Biofuels), hybrids (thermal and electric), electric (BEV) and engines powered by electricity generated from hydrogen cells.

[4] From the moment you start and the spark plug starts the engine until the force generated by it is transferred to the drive wheels, it goes through a system. The set: clutch, gearbox, drive shafts, differential and drive wheels is called Powertrain or powertrain.

Global initiatives such as the one promoted by XCMG are responsible for putting the decarbonization of logistics and transport operations on a higher scale level, considering that the predominance of cargo that is transported from the point of origin to the ports, and which are later moved internally in the port yards and terminals, use equipment with engines predominantly powered by diesel combustion.

The table below compares the costs of the two cargo vehicle solutions, the XCMG E7-29R Electric Truck and the VW 28,480 Meteor (E6 Diesel):

Figure 4 – Comparison of the cost carried out by XCM-Brazil Company of a diesel and electric truck

E7-29R Caminhão Elétrico XCMG

Comparativo de Custo: Caminhão Diesel (VW Constellation 30.320 8x2 (diesel - E6) x Caminhão			
Km diaria	150		
Dias por semana	6		
Km Mês	3.600		
Km ano	43.200		
Km para Amortizar o Investimento	**187.172**		
Tempo para Amortizar o Investimento	**4,33**		
	VW Constellation 30.320 8x2	**Custo Energia fora de Pico ou Mercado Livre E7-29R**	**Economia**
Valor de Aquisição FIPE	741.500	1.000.000	-258.500
Consumo Médio Km/L - Km/Kwh	3,00	0,67	
Preço/Litro Diesel - Kwh	5,71	0,43	
Custo de Abastecimento	356.251	122.083	234.168
Custo Abastecimento /Km rodado	1,90	0,65	1,25
Consumo Arla (Km/l)	50	-	
Preço/Litro Arla	4,00	-	
Custo de Arla	14.974	-	14.974
	0,08		
Custo Abastecimento + Arla	371.225	122.083	249.141
Valor Acumulado de Manutenção	56.152	46.793	9.359
Manutenção/Km rodado	0,30	0,25	0,05
Custo Operacional Total	427.377	168.877	258.500
Custo Operacional / Km Rodado	2,28	0,90	1,38

According to XCMG (2024) there were:

- 65% reduction in cost per km, from R$1.90 to R$0.65 per km on the electric car;
- in 4 years a reduction of CO_2 in the atmosphere of around 47,000t/year for each truck;
- a consumption of more than 15 thousand liters of diesel oil per truck was avoided;
- The carbon credit with the carbon value = 1,000 tons at $76.46/tons, so 47,000t x $76.46=$3,593.62

The transition to electric vehicles in the transportation sector, especially trucks, is an important strategy to reduce greenhouse gas emissions and promote sustainability. This study analyzes the economic and environmental impact of adopting electric trucks compared to diesel trucks, considering several factors such as acquisition cost, consumption, energy price, supply cost, Arla cost, maintenance per kilometer driven and total operating cost.

COST ANALYSIS

The initial investment in acquiring an electric truck is usually higher than that of a diesel truck. However, the difference of R$258,500.00, which is amortized in 4 years and then presents a positive result during its useful life, justifying this choice. This value considers not only the purchase price, but also the savings generated in consumption and maintenance.

Electric trucks have significantly higher energy efficiency. While a diesel truck consumes about 15 thousand liters of fuel per year, an electric truck uses electricity which, in financial terms, results in a reduced operating cost. With the average price of electricity being lower than that of diesel, the savings become evident. The cost per kilometer driven for the electric truck is reduced by up to 65% compared to the diesel truck.

Diesel trucks require the use of Arla (Liquid NOx Reducing Agent), which represents a significant additional cost. In contrast, electric trucks do not have this need, eliminating costs associated with purchasing and storing this additive.

Maintenance costs for electric vehicles are considerably lower due to the lower number of moving parts and the absence of components such as oil filters and exhaust systems. This results in a significant reduction in total operating costs.

ENVIRONMENTAL ANALYSIS

The adoption of electric trucks not only generates substantial financial savings, but also contributes significantly to the reduction of carbon emissions. This study estimates that the transition to electric trucks can avoid the emission of approximately 47 thousand tons of CO_2 per year over four years. This reduction is achieved by eliminating the consumption of more than 15 thousand liters of diesel that would be used by a conventional truck. In addition, this change generates an estimated carbon credit of US$3,593.62 annually, contributing to the financial sustainability of logistics operations and promoting more responsible business practices.

The comparison between diesel and electric trucks reveals that the transition to electric vehicles not only offers significant economic advantages through reduced total operating costs, but also plays a crucial role in mitigating climate change. With an estimated saving of R$258,500.00 that is amortized in 4 years and then presents a positive result during its useful life, justifying this choice, in addition to a substantial reduction in CO_2 emissions, electric trucks are positioned as a viable and sustainable solution for the future of transportation.

CONCLUSION

The development of green hydrogen in Brazil represents a significant opportunity to diversify the country's energy matrix, strategically aligning with global sustainability and decarbonization goals. The incorporation of green hydrogen in Brazilian port operations, exemplified by the Port of Pecém, highlights the national commitment to reducing greenhouse gas emissions and positions Brazil as an emerging player in the global hydrogen economy.

For Brazil to stand out in this context, it is essential to expand the infrastructure necessary for the production, storage, and distribution of green hydrogen. This evolution will require substantial investments in technology and innovation, as well as strategic partnerships with various actors, both national and international, that can drive the development of green hydrogen hubs with international relevance.

Strengthening the regulatory framework will be an essential element to ensure the competitiveness of Brazilian green hydrogen in the global market. Public policies that promote its adoption, along with certification mechanisms and sustainability standards, are crucial to ensure that hydrogen produced in Brazil is recognized as reliable and sustainable in international markets.

The transition to green hydrogen will have profound socio-economic impacts, including job creation, local economic development, and improved quality of life in communities adjacent to ports. However, for this transition to be fair, it is essential to provide support and training to workers currently dependent on the fossil fuel industries, ensuring their inclusion in the new opportunities offered by the hydrogen economy.

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"SER MATA ATLÂNTICA" PROGRAM: CHALLENGES AND POSSIBILITIES FOR THE DEVELOPMENT OF ENVIRONMENTAL PRACTICES IN THE MUNICIPALITY OF VARGEM ALTA, STATE OF ESPÍRITO SANTO, BRAZIL

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ABSTRACT
The "Ser Mata Atlântica" Program, implemented in Vargem Alta, is an environmental education project focused on valuing the local ecosystem and training educators. The main objective of the program is to promote environmental awareness among students and teachers, encouraging sustainable practices and the understanding of ecological and cultural interdependencies. Based on *Ecological Literacy* concepts by David Orr (1992) and on a *place-based learnin approach.*The program aims to create a sense of belonging and responsibility towards the environment among participants. To structure the methodology, the analysis was constructed from the perspective of Content Analysis, as proposed by Bardin (1977) and in the use of thematic categorization according to Franco (2008). As a result, the program has strengthened local environmental education, with teachers and students demonstrating a high level of engagement and awareness. The introduction of practical activities, such as outdoor classes and the use of natural resources as an object of study, promoted meaningful and contextualized learning. The participants' responses highlighted their enthusiasm and involvement with the content, showing that the program met their objectives of developing a critical and reflective ecological awareness. The "Being Atlantic Forest" Program represents a successful experience in environmental education. Its approach, centered on the community and the local environment, proved to be a replicable methodology for other localities that aim to promote sustainability and care for the local environment in their daily educational practices.

Keywords: Environmental Education. Vargem-Altenses ecosystems. Teacher Training.

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INTRODUCTION

This article aims to report the successful experience of the municipality of Vargem Alta, state of Espírito Santo, Brazil, with the "Ser Mata Atlântica" Program, which is an environmental education initiative focused on promoting knowledge and preservation of ecosystems, considering their geography, history and local culture. Based on an interdisciplinary and community proposal, the program was based on the continuing education of educators, the creation of a discipline focused on the study of local ecosystems and practical actions in schools and communities.

Teacher training, in general, must incorporate a perspective of Environmental Education that is continuous and connected to the history and reality of the territories, enabling educators to promote critical and meaningful learning with students. This approach allows teachers to reflect on how these spaces have been occupied and degraded, developing pedagogical strategies that encourage the understanding, defense and preservation of the local environment. Thus, they will be better prepared to contribute to the Sustainable Development Goals (SDGs), especially with regard to Quality Education (SDG 4), Sustainable Cities and Communities (SDG 11), Climate Action (SDG 13) and Life on Land (SDG 15), fostering educational practices aimed at active and environmentally conscious citizenship.

The need to carry out an educational work focused on Environmental Education, in a continuous way and connected with local history, reflecting on the way this territory was occupied, divided and degraded. This can contribute significantly to the construction of meanings in the context of students' learning in order to think about this territory from an environmental perspective, in a process that aims to learn-defend-preserve.

Based on these premises, understanding that Environmental Education can provide opportunities for the construction of knowledge, skills, social values, care for life, society and nature, in order to enhance integral human development, promoting socio-environmental justice and equity, this article aims to present a project developed in the municipality of Vargem Alta, which started from the creation of a continuous program , which was based on the following pillars:

1. Continuing education of environmental educators;
2. Creation of a discipline focused on the study of regional and local ecosystems in municipal public education schools;
3. Actions and projects in municipal schools and communities in the municipality of Vargem Alta.

THEORETICAL FRAMEWORK

A MEETING, A CHALLENGE AND A TRANSFORMATIVE ACTION: THE SER "MATA ATLÂNTICA" PROGRAM IS BORN

The embryo of the Ser Mata Atlântica Program was born from a meeting between the Municipality of Vargem Alta, in which the Municipal Mayor, as well as his secretaries of Education and Environment, were present, and the Águia Branca Environmental Reserve, which is a Private Natural Heritage Reserve that has more than 2,200 hectares of preserved Atlantic Forest and that it is also home to rare, endemic and endangered species, such as the stabbed tanager (*Nemosia toureio*), the uruçu-capixaba bee (*Melipona capixaba*), the juçara palm (*Euterpe edulis*) and the phylum within Espírito Santo (*Philodendron spiritus sancti*) among others, through its environmental managers.

At the time, among other agendas, the managers of the Environmental Reserve brought the need for an environmental education program for the municipality that involved the Environmental Reserve itself, schools and surrounding communities, making themselves available to contribute to this intonation. Much was also said about the need to know the territory and all the natural riches of the municipality, thus allowing full access to its preserved areas for this educational management. In addition, the need to build a correct understanding of the current environmental problem was stressed.

At this time, it was seen that an environmental education program could be articulated between the institutions so that the proposed objective could be achieved. However, between dialogues, reflections and ideas, an important challenge was launched by the mayor to all those present at the meeting: "*What if, in addition to actions in school institutions and communities, we created a discipline in municipal schools so that students get to know Vargem Alta?*". Thus, the provocation of the municipal manager gave rise to the idea that came to be known as the "Ser Mata Atlântica Program".

Starting from a global view , Morin (2000) argues that knowledge should be treated in an integral and critical way, recognizing the interdependence between natural and social systems. This vision proposes an education that transcends the fragmentation of knowledge, aiming to prepare citizens who are more aware of ecological interactions and capable of facing environmental challenges with a systemic and ethical perspective.

With this, a discipline was thought of that could form citizens who knew the history, geography, culture and biodiversity of the Atlantic Forest that occurs in the municipality, thus generating a sense of belonging and appreciation of this territory, recognized as the "City of Green and Water".

From there, a Working Group (WG) was created and added to it was the inclusion of the Stabbed Tanager Conservation Program (PCSA) carried out by the Marcos Daniel Institute (IMD). The PCSA has its actions based on the National Action Plan for Birds of the Atlantic Forest of ICMBio; establishes its actions based on the National Action Plan for Birds of the Atlantic Forest of ICMBio, promoting the conservation of several endangered species and, primarily, the species *Nemosia rourei*, a bird endemic to mountainous regions of Espírito Santo and currently considered critically endangered. In addition to field research activities, the PCSA also includes awareness-raising actions, environmental education and community engagement in conservation practices.

The WG began to think and elaborate the construction of a proposal for a syllabus for the challenge of creating a discipline and, from it, a proposal for Continuing Education of Environmental Educators, with a view to providing opportunities for continuing education focused on the theme that generated the discipline, which were constituted by the Vargem-Altenses ecosystems, culture, history and local geography. With this, the "Ser Mata Atlântica" Program was born,[5] implemented in the municipal school network of Vargem Alta.

THE THEORIZATION OF A PROGRAM FOR THE CONSERVATION OF LOCAL ECOSYSTEMS

Orr (1992) in his work *Ecological Literacy: Education and the Transition to a Postmodern World*, understands education as a process of raising awareness about sustainability, community engagement and building a deep ecological understanding. For the author, education is not neutral in relation to the environment, so that the pedagogical choices we make — what we teach and what we fail to teach — are capable of shaping students' perception of their relationship with nature, promoting or neglecting ecological awareness.

With this theoretical inspiration, the WG advanced in its studies and meetings, resulting in the launch of the program, held on August 2, 2022. On the occasion, the inaugural class of the first class of Training of Environmental Educators of Vargem Alta was also given, marking the beginning of this initiative dedicated to strengthening local environmental education.

Orr (1992) understands that "all education is environmental education" since it has the ability to shape the relationship of students with the environment, whether the nature of

[5] Being Atlantic Forest comes from the concept that we are all connected, we are one with the nature that surrounds us, with the Atlantic Forest, one of the most threatened biomes in the world and also our home. We live in the Atlantic Forest, we are Atlantic Forest. And we are at the right time to rescue our essence, to learn to be, to do and to dream together.

the classes is included or excluded. The author also defends *Ecological Literacy*, that is, ecological literacy that happens through experiences and practices, such as classes in direct contact with the local ecosystem, exactly what the "Ser Mata Atlântica" Program proposed, considering the potential to encourage participatory learning that provides students with the opportunity to develop a practical understanding of the environment, which, By itself, it is very enriching.

The "Ser Mata Atlântica" Program was structured based on the following objectives:

1. To foster the appreciation of the natural, geographical and historical-cultural heritage of Vargem-Altense;
2. Strengthen the socio-environmental theme in the school context;
3. Work on the interdisciplinarity and transdisciplinarity of environmental education;
4. To stimulate the protagonism of the school community regarding local environmental challenges.

Orr (1992) points out that the study of ecology and local history represent essential tools for an environmental education in which it will be possible to prepare students for the ecological and social challenges of the world. For him, understanding and valuing the specific context of a place – its ecosystems, history, and culture – is essential for students to develop an authentic relationship with the environment and a commitment to its preservation.

In this sense, the author argues that environmental education should encourage students to see nature and the history of the place in which they live, not as distant objects, but as intrinsic parts of their lives. As students explore their local ecosystems, they acquire a critical and informed view of society-nature interactions. Thus, in this process it is possible for them to see the impact of human actions, the importance of conservation.

The author argues that the study of local ecology and history generates a sense of belonging that goes beyond academic learning, it is a sense of belonging that inspires care for the environment, developing an ethic of responsibility and respect for nature, as well as for the history of their community. By knowing that, for example, certain historical practices have contributed to the degradation or preservation of their ecosystem, students can reflect on their own role in the continuity of this history. Therefore, instead of distant and abstract teachings, it becomes possible to promote teachings rooted in the students' reality.

THE *PLACE-BASED LEARNING APPROACH* AND THE ECOLOGICAL *LITERACY PERSPECTIVE*

The "Being Atlantic Forest" Program has the format of the *place-based learning* approach - place-centered learning - presented by Orr (1992). For the author, the playful activities carried out in the environment constitute an engaging and concrete practice that not only instructs, but also emotionally connects students to their surroundings and enables the strengthening of the sense of local belonging and encourages environmental responsibility. Thus, this approach creates opportunities for students to be actively involved and develop a genuine interest in preserving and understanding the natural environment.

Place-based learning is an educational approach that seeks to connect academic learning with the geographical, cultural, and ecological context of students, using the local environment as a "classroom". This method values the active involvement of students with their surroundings, promoting a deeper understanding of the contents and encouraging a bond with the community and the local environment (ORR, 1992). Through this practice, it is possible to promote what Orr (1992) calls *Ecological Literacy*, which is a sense of belonging and responsibility in relation to the local environment.

Ecological Literacy, in turn, emphasizes the importance of training environmental educators by advocating for an education that develops an understanding of ecological systems and the interdependence between humans and nature. For the author, environmental education needs to transmit information; It must cultivate an ecological sensitivity that enables educators to understand and relate to the natural world in a deep and responsible way.

ARTICULATION OF THE "SER MATA ATLÂNTICA" PROGRAM WITH THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

The "Being Atlantic Forest" Program stands out as a successful experience in environmental education for several factors. Firstly, because its community approach is directed towards local ecosystems, it fosters a meaningful connection between participants and the environment in which they live, awakening a sense of belonging and responsibility.

This type of educational action, based on knowledge of the territory and the appreciation of local biodiversity, facilitates practical learning and direct understanding of the impacts of human actions on the ecosystem, aligning with the Sustainable Development Goals (SDGs), such as Quality Education (SDG 4), Sustainable Cities and Communities (SDG 11) and Life on Land (SDG 15).

METHODOLOGY

This article was initially designed to present a successful experience of the municipality of Vargem Alta in relation to the "Being Atlantic Forest" Program. Thus, to structure the methodology of the work, the thematic categorization of Franco (2008) and content analysis proposed by Bardin (1977) were taken as a reference. From it, it was possible to organize and interpret the answers of the participants, as well as qualitative data collected during the years of implementation of the program, which allowed a better understanding of the central aspects of the perceptions and experiences of the participants involved.

The data used for this report were extracted from the participants' answers, descriptions of activities and institutional documents related to the "Ser Mata Atlântica" Program. The participants' responses were collected from *Google Forms questionnaires applied between 2022 and 2024 and also from works produced by the participants in this period, in which they describe their perceptions and learning from the experience of participating in the training program.*

Following the approach of Franco (2008), a thematic categorization was applied to deepen the analysis of the data, dividing the answers into specific subthemes that could reflect the particularities of the program. Through this thematic categorization, it was possible to carry out a more detailed analysis of the contents, facilitating the interpretation of the perceptions of the students about the application of environmental practices in their choices and the connection with the local ecosystem.

The content analysis carried out through the approaches of Bardin (1977), allowed the identification and categorization of the recurring themes in the answers of the students, as well as in the analysis of the work carried out, as in the case of the construction of didactic sequences as proposals of practice to be carried out by the students in the schools in which they work. From the initial reading of the contents, central categories were identified that reflect the main dimensions of the students' experience, such as: "practical and playful learning", "integration with the local environment" and "environmental engagement and awareness". Thus, it was possible to organize the information in a systematic and coherent way, creating a framework for the analysis of experience.

ANALYSIS OF THE RESULTS

THE METHODOLOGICAL STRUCTURE OF THE "SER MATA ATLÂNTICA" PROGRAM IN CONTRAST TO THE LACK OF HUMAN AND FINANCIAL RESOURCES

In order to carry out the actions planned by the "Ser Mata Atlântica" Program, it was necessary to organize an action plan method, considering the importance and dimension of the project, the WG organized moments to be overcome as the objectives proposed for each phase were achieved, as follows:

Table 1 – Organization of the Actions of the "Ser Mata Atlântica" Program

Planning of the actions carried out by the WG	
1st moment:	planning meetings and construction of a syllabus proposal for the discipline entitled "Vargem-altenses Ecosystems";
2nd moment:	planning of a continuing education of educators based on the topics of the syllabus;
3rd moment:	carrying out the continuing education of educators;
4th moment:	Insertion of the discipline in the diversified part of the school curriculum of the first full-time school in the municipality of Vargem Alta;
5th moment:	Encouragement in carrying out interdisciplinary and transdisciplinary projects in regular schools with the theme of local ecosystems.

Source: Authors' collection, 2024.

The actions to integrate the premises of the "Ser Mata Atlântica" Program are articulated with Orr's theory (1992), as they emphasized an educational approach that values place-based learning – as we will see later, and the central role of the educator in environmental awareness, as well as in the formation of an ecologically responsible community. In the author's view, environmental education should be contextualized and practical, aiming to connect students to the local ecosystem to promote meaningful and lasting learning.

In this way, by building a menu for the discipline "Vargem-altenses Ecosystems", the initiative promoted this direct connection of students with biodiversity and local ecological history, encouraging a sense of belonging and environmental responsibility, as defended by the author. Knowledge of the local environment is essential for students to develop an ethic of care and appreciation of the environment, something essential for conservation.

In the same sense, the continuing education of environmental educators added to the creation of a specific discipline with themes of local ecosystems helped to equip teachers with the tools and knowledge necessary for the development of interdisciplinary projects. Projects that may be able to promote learning in an integrated and relational way, a practice also highlighted by the author as essential to understand environmental impacts and develop a holistic view of the interactions between human beings and nature.

The target audience of the program was constituted, in the first year of training, for teachers of history, geography, science and pedagogues of the municipal school network of Vargem Alta, designed to teach and monitor the implementation of the discipline in schools, and also some professionals from the technical team of the municipal department of Education. In addition, the technical team of the municipal department of the Environment was incorporated into the scope of the program, considering the participation of its manager in the program's WG, in order to reinforce the need to train its technical staff to improve municipal environmental management, as well as to promote articulated actions between the departments of education and the environment.

The "Ser Mata Atlântica" Program, despite the absence of a specific financial budget, had its beginning made possible by the effort and commitment of the partner institutions, which dedicated their own resources and efforts to the development of the planned activities. Each institution contributed according to its capacities, taking on tasks and demands of the program without depending on external funding. This collaboration between the City Hall, the Águia Branca Environmental Reserve and the PCSA was essential to make the first phases of the program viable. Collective action and the creative use of internal resources allowed the launch and continuity of the project, demonstrating the positive impact of cooperation and community mobilization in the promotion of local environmental education.

FORMATIVE PERSPECTIVES AND PRACTICAL POSSIBILITIES OF THE STUDENTS OF THE "SER MATA ATLÂNTICA PROGRAM"

During the development of the program, when the second class was trained, the students were given the opportunity to participate in a practical activity in the area that comprised the Águia Branca Environmental Reserve, within the municipality of Vargem Alta. After the activity, the participants were invited to answer a provocative question from the trainers: *As educators, we know that playful and practical activities enhance the learning of our students. Based on this premise, we need to know how your experience was in today's activity. Tell us?* The answers presented in Table 2 indicate the perception of each student in relation to the experience lived.

Table 2 – Responses of the second group of students when participating in playful and practical activities in the area of the Águia Branca Environmental Reserve

Student 1	A wonderful experience. The activity provided practical, fun and collective learning, enabling several different practices to be worked with the students.
Student 2	The activity was excellent and a lot of fun!!! It aroused curiosity and interest in the subject and also provided interactivity among the students. I loved it!!
Course 3	Today we had an incredible experience, an outdoor class with dynamics integrated with nature, where we simulated in practice, how to insert Environmental Education in schools. We saw instruments that can be used in class, such as introducing and making students interested in the subject, showing it in practice and teaching in a practical and harmonious way, making there be interest and that everyone gets together and interacts to carry out activities in groups. We know the red lichen and also the old man's beard. These fungi, necessarily red or pink lichens, are indicators of clean air.
Course 4	It was wonderful. Experiencing theory and practice in such a dynamic and fun way highlights new possibilities for approaching the contents. Everything that is tangible creates memories more effectively and provides the possibility of association with the student's everyday situations. This class made it clear that it is necessary to stop and observe what is around us.
Course 5	The experience was great! The field class allowed to expand knowledge and information about the Atlantic Forest forest, located in the Águia Branca reserve. Through group dynamics, it was possible to learn how to use a step marker, a compass, a map and various other information about and during the route. In the class, it was possible to experience very important reflective practices to teach classes with children, which is to hear, see and feel in practice the nature around us!
Course 6	We have participated in wonderful moments in this training. Our third class of the SER Mata Atlântica Environmental Education Training, in the Águia Branca Reserve, "Basic Concepts of Ecology and Environment", was no different. It exceeded my expectations from the welcome, the dynamics, to the passing on of the contents of the meeting. I recognize the great capacity of our trainers. But they have presented us with the contents with lightness and simplicity, allowing each participant to feel free to ask, answering questions, facilitating the dynamics of training and the significant construction of new knowledge. This teaching strategy makes us return to our classrooms even more enthusiastic to pass on all our learning, because we experience in these meetings curiosities that enhance our pedagogical practice, awakening us to reflect on the need to better explore the diversity of resources that nature itself offers us. Another situation experienced in this training that has been of great relevance is the interaction between the participants. We socialize knowledge that promotes the growth of the whole group, which makes our meetings productive and, above all, a very pleasant environment.
Course 7	The Ser Mata Atlântica course brings pedagogical practices of total recognition. On course days, we have activities focused on the theme and without studying papers as usually happens with other courses. We have the opportunity to get to know our biome even more and build new knowledge.

Source: Authors' collection, 2024.

The answers of the students were analyzed and several similarities were found that highlighted fundamental aspects of the learning experience lived in the formation of the program, such as:

1. **Practical and dynamic learning**: Many students emphasized the value of practical learning and how it enabled new forms of teaching for application with their students. Student 1, for example, mentions "practical, fun and collective learning", while Student 4 comments on the importance of experiencing theory and practice in a dynamic way, which "creates memories more effectively".

2. **Interactivity and integration with nature**: Integration with nature and the local environment is an aspect highlighted by several students. Student 3 describes an "outdoor class with dynamics integrated with nature" and emphasizes the discovery of local species as indicators of environmental quality. Student 5, on the other hand, values the "field class" for allowing direct contact with the biodiversity of the Atlantic Forest, favoring reflective learning.
3. **Enthusiasm and engagement**: The answers also reflect the enthusiasm and engagement of the participants. Student 2 describes the experience as "excellent and a lot of fun", and Student 6 comments on the return to the classroom with "enthusiasm" to share what was learned.
4. **Socialization and collective construction of knowledge**: The importance of the exchange of knowledge among participants is highlighted by Student 6, who talks about the "interaction between participants" and the "growth of the whole group". Student 7 also values the opportunity to "build new knowledge" in a practical and contextualized way.

It is noted that the answers of the students reveal an educational experience that was indeed transformative, in which direct contact with the environment, practical teaching and collaborative work strengthened the training of educators and increased awareness about the importance of environmental preservation. These aspects are aligned with the proposals of an ecological education based on place, promoting meaningful teaching that is applicable to the real context.

In the answers, it can be seen that the students valued direct contact with nature and outdoor activities, mentioning the value of learning "on the spot", as in the case of Course 3, which describes the study of lichens and other species as indicators of fresh air. This hands-on learning has the potential to strengthen educators' "ecological literacy" by enabling them not only to understand the ecosystems in which they are embedded, but also to recognize the importance of protecting them.

It is possible to identify that the Sustainable Development Goals (SDGs) are also present in the answers presented by the participants. The testimonies that highlight **practical learning and interactivity** are aligned with SDG 4, which promotes, in turn, inclusive and quality education. The participants emphasized the positive impact of practical and outdoor activities, as described by Student 4, who mentioned the lasting effect of experiencing theory in a concrete way. These educational practices reflect with absolute certainty a contextualized and engaging teaching, promoting an education that goes beyond the traditional classroom.

The connection between educators and the local ecosystem was mentioned by several students, such as Student 5, who valued the "field class" and direct contact with local biodiversity. This experience not only promoted knowledge of the natural environment but also strengthened the community's commitment to sustainability. This is in line with SDG 11, which encourages the creation of more sustainable and resilient communities, with citizens who understand and value their territory.

Also, the testimonies that mentioned the importance of environmental awareness, such as that of Course 3, who mentioned the planting and preservation of trees, dialogue directly with SDG 13. This objective seeks to strengthen education and awareness of climate change, and the program's activities encouraged practices that reduce environmental impact and promote a more harmonious relationship with nature.

Finally, the appreciation of local biodiversity and awareness of the importance of native species, such as lichen and "old man's beard" mentioned by Student 3, are aligned with SDG 15. These SDGs are centered on the conservation and sustainable use of terrestrial ecosystems. The reports of the students reflected the learning about the importance of protecting local biodiversity and used ecosystems as a pedagogical resource, promoting an ethic of care for nature.

One of the activities carried out by the students of the class of 2023 intended to put into practice the knowledge acquired in the course of training. Thus, they organized themselves into groups to elaborate a series of didactic sequences and, when questioned about the objectives, presented the statements highlighted in Table 3:

Table 3 – Objectives of the Didactic sequences produced by the students of the "Ser Mata Atlântica" Program

Student 1	During the II Training Course for Environmental Educators, the project was idealized in actions that were implemented in the rural schools mentioned in the SD, resulting in the DS presented as the final activity of the training.
Student 2	Remembering that the materials used to make the nests must be organic so as not to interfere with the reproduction cycle of the species.
Course 3	The Project was developed in order to raise children's awareness about the continuity of the work related to planting trees and their preservation, the observance and benefits of the production of healthy fruits, as well as the increase of pollinating agents.
Course 4	During the II training course for environmental educators, the project was idealized in actions that were implemented in the rural schools mentioned, resulting in the one that was improved to be presented as the final activity of the training.
Course 5	During classes, they will have rehearsals for the presentation of the song. This sequence is just the introduction on the theme of water and that from this work, many other activities will be proposed raising awareness and further sharpening interest in the theme and the importance of water for living beings.

Source: Authors' collection, 2024.

Some similarities can be identified in the answers presented by the students, which reflect an alignment between the objectives of the students in relation to environmental preservation and the practice of environmental education through concrete and sensitizing activities, which is in accordance with the guidelines of the training received.

Students 1 and 4 present similar excerpts when they mention that, during the training course, the project was conceived and implemented in actions in rural schools, resulting in the creation and improvement of a final product presented in the training. The phrases "during the II Training Course for Environmental Educators, the project was conceived in actions that were implemented in rural schools" appear almost identical in the answers of both, indicating a convergence in the description of the practical implementation of the knowledge acquired.

Student 3 and Student 5 touch on the idea that the activities developed should lead to environmental awareness. Student 3 mentions the importance of "obtaining children's awareness about the continuity of the work related to planting trees and their preservation," while Student 5 mentions introductory activities on the theme of water, sensitizing students about its importance for living beings. Both answers emphasize the role of environmental education in making students aware of attitudes of preservation and ecological awareness.

The answer of Student 2 highlights that the materials used to make nests must be organic, so as not to interfere with the natural cycle of the species. Although this point is specific, it can also be linked to the idea of sustainable practices implicitly mentioned in the awareness actions of other students.

The didactic sequences developed were organized according to different educational levels and contexts, aiming to meet the specificities of each audience and facilitate the implementation of the contents in each area:

- Rural Education: Two specific sequences were produced for the context of Rural Education, valuing the rural environment and sustainable practices related to the place where students live and study. These activities are oriented to the agricultural reality and environmental conservation that permeates the lives of rural students.
- Early Childhood Education: Two other sequences were created for Early Childhood Education, focusing on playful and sensory activities that introduced the children's universe to the ideas of preservation and recognition of the surrounding natural elements. At this stage, the contents should be adapted to be more concrete, arousing curiosity and connection with nature.

- Elementary School – Early Grades: A sequence was prepared for the initial grades of Elementary School, integrating practical activities that introduce environmental issues in an accessible way, promoting awareness from an early age about the importance of caring for the environment.
- Elementary School – Final Grades: Finally, a sequence was developed for the final grades of Elementary School, where students are encouraged to explore more complex topics and to critically reflect on human actions in the environment. The activities in this sequence include greater theoretical depth and promote student engagement in projects and discussions about sustainability.

The analysis of the participants' answers revealed a convergence around fundamental principles of environmental education, aligned with the training promoted by the "Ser Mata Atlântica" Program for environmental educators. The similarities in the descriptions of implementation and awareness show that the students internalized the importance of concrete and practical activities to promote environmental preservation among the students. In addition, the didactic sequences were developed with a focus on the specificities of each educational context, ranging from Early Childhood Education to Elementary School, initial and final grades, and Rural Education. This diversity of approaches allowed each school level to explore the environment in a meaningful and contextualized way, respecting the stage of development and the reality of the students. As a result, the program stimulated not only learning, but also the formation of a critical and ecological awareness, involving students in environmental preservation practices appropriate to their realities.

CONSIDERATIONS

The experience of the "Being Atlantic Forest" Program in Vargem Alta demonstrates the strength and transformative possibility that environmental education can generate in local communities. This project not only fostered a greater connection between educators and local ecosystems, but also cultivated in the participants — students and teachers — a sense of belonging and responsibility towards the natural environment. The success of the program shows that, with commitment and strategic partnerships, it is possible to overcome financial limitations and mobilize local resources to create meaningful and practical environmental education.

The continued training of educators, the creation of a specific discipline on local ecosystems and the implementation of interdisciplinary activities have increased ecological awareness in the school community and fostered a culture of preservation. The program's approach, centered on the community and the specificities of the local environment, proved to be highly replicable and can serve as a model for other localities that wish to promote sustainability and care for the environment in their daily educational practices.

The "Being Atlantic Forest" Program leaves a legacy that goes beyond theoretical learning, as it inspires conservation practices that contribute to the well-being of the community and the appreciation of natural resources. The environmental education promoted by the program offered a perspective of lasting change, forming citizens who are aware and prepared for ecological challenges, who understand the importance of biodiversity and the responsibility to protect the planet.

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THERMAL DECOMPOSITION AND CHARACTERIZATION OF CHARCOAL FROM THREE SPECIES OF THE CERRADO BIOME FOR PRODUCTION FOR ENERGY PURPOSES AND FOR ACTIVATED CHARCOAL

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ABSTRACT
Charcoal is used mostly in the production of pig iron and steel, and also in the production of activated charcoal. The exploitation of wood for energy purposes has fostered the reduction of native vegetation and also had consequences for fauna, flora and soil. Charcoal is produced from planted forests, highlighting Brazil as the only country to use a renewable source in the steel sector. Thus, the objective was to analyze the quality of charcoal produced from the species of the Cerrado biome (Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis) for energy purposes and for the production of activated charcoal, aiming to contribute to sustainable practices in the use of renewable sources. For the analysis of the physical properties of the coal, the density, porosity and moisture content were determined, for the chemical properties the chemical composition (percentage of carbon, hydrogen, oxygen, nitrogen and sulfur), calorific value, volatile and ash content, hydrogen potential (pH) and fixed carbon content and, as for the biological aspects, decomposition, microorganisms and ecological impact. Among the charcoals of the species analyzed, the species Myracrodruon urundeuva stands out, which showed the highest values of plant yield and energy density, followed by the species Amburana cearensis and, finally, the species Tachigali vulgaris. The stimulus to the use of charcoal reflects economic, environmental and social benefits for the country, and the environmental aspect is relevant, reducing the consumption of non-renewable sources and greenhouse gas emissions.

Keywords: Carbonization. Physical Properties. Density.

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INTRODUCTION

The growing demand for renewable energy sources has led to the exploration of sustainable alternatives, among which the use of charcoal stands out. This biofuel, produced from the carbonization of biomass, such as that from trees and native vegetation, emerges as a viable solution to meet energy needs in a more environmentally friendly way.

The Cerrado biome, with its rich biodiversity, is home to a variety of plant species that can be used in the production of charcoal, among them Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis. This study aims to investigate the thermal decomposition and characterization of charcoal of these species, in order to understand their potential for energy generation.

Carbonization is a procedure of thermal deterioration that wood faces, at high temperatures (300 to 500 ºC), with the lack or presence of regulated amounts of oxygen, producing a solid residue, called charcoal. (Wenzl, 1970).

Thermal decomposition consists of a chemical reaction that occurs when biomass is subjected to high temperatures, resulting in the decomposition of its elements, the result of which is the production of charcoal and gases, that is:

Carbonization is an incomplete or indirect combustion reaction of wood. The liquids are volatilized and produced into gaseous compounds, leaving only a solid composed almost exclusively of pure carbon.

The carbonization of the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis allows the determination of several physical, chemical and biological aspects essential for the evaluation of its viability as an energy source, as well as the obtaining of vegetable activated charcoal. It is crucial to carry out integrated studies that consider not only the characteristics of charcoal, but also the environmental and social impact of the exploitation of these species in the Cerrado biome.

Activated Charcoal (CVA) is a biomaterial that can be produced from various plant species, including Amburana cearensis, Tachigali vulgaris, and Myracrodruon urundeuva. It is a porous material produced from the carbonization of wood, followed by an activation process, which can be done through physical methods (such as steam or gases at high temperatures) or chemical (using acids or bases).

The activation process involves two main steps:

a) Carbonization: The wood is heated in a monitored environment (300 to 500 ºC), with the lack or presence of regulated amounts of oxygen, producing a solid residue, called charcoal.

b) Activation: Charcoal is treated with chemical agents or exposed to high temperatures to increase its porosity and surface area.

The production of activated carbon from Amburana cearensis, Tachigali vulgaris and Myracrodruon urundeuva involves these carbonization and activation processes, allowing these natural materials to be transformed into products with applications in various sectors, such as: Water Treatment; Effluent Treatment; Detoxification; Food Industry; Air Filters; Cosmetics; Pharmaceutical industry; Food Preservation.

In this way, activated charcoal is an excellent example of a material that can be used in sustainable and beneficial ways, highlighting its value as both a functional biomaterial and a bioproduct.

As for carbonization, a thermal process involving the heating of organic materials in the absence of oxygen, resulting in the production of charcoal, the evaluation of the various physical, chemical and biological aspects of wood, including the species under study: Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, which are typical of the Cerrado biome, are of great importance, namely:

Physical Aspects:

1. Density: The density of the coal obtained can influence its energy capacity.
2. Porosity: The structure of coal, including its porosity, affects the burning rate and energy efficiency.
3. Humidity: The amount of moisture in the charcoal before and after carbonization is critical, as it interferes with the calorific value and effectiveness of combustion.

Chemical aspects:

1. Chemical Composition: The analysis of chemical constituents, i.e., the amount of carbon, hydrogen, oxygen, nitrogen, and sulfur, is essential to determine the calorific value of coal. Carbon is primarily responsible for the energy released in burning.
2. Calorific Value: This is one of the main parameters to be measured. Both the upper calorific value (PCS) and the lower calorific value (PCI) are fundamental for the examination of the efficiency of coal.
3. Ash Analysis: The percentage of ash produced in the combustion of coal is an important factor in the purity of the material. Ash content impairs the quality of combustion and the dispersion of pollutants.

Biological Aspects:

1. Decomposition: The carbonization process can impact the ability of plant material to decompose in the soil, influencing soil quality and the production of organic carbon in the soil.
2. Microorganisms: The presence of certain microorganisms can influence the carbonization efficiency and quality of the coal. The biological aspect of charcoal can also impair its interrelationship with the soil and fertility.
3. Ecological Impact: Assessing the effects of the removal of species from the Cerrado biome for charcoal production purposes on local biodiversity and ecosystem services is important.

Thus, the general objective of the research is to analyze the quality of charcoal produced from three species of the Cerrado biome (Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis) for energy purposes and for the production of activated charcoal, aiming to contribute to sustainable practices in the use of renewable sources in the steel sector.

To achieve the proposed general objective, the following specific objectives were established in order to direct the research:

(1) Physically/Chemically and Biologically Characterize Charcoal; (2) analyze the Energy Properties; (3) study thermal decomposition; (4) Characterize Activated Charcoal; (5) Analyze Sustainability; (6) Compare the species; (7) Study Compatibility with Industrial Processes; (8) Propose Sustainable Forest Management.

Throughout the research, the yields and energy properties of the charcoal generated from the three species will be compared, in order to identify which one has the most favorable characteristics for use as an energy source, as well as for obtaining activated charcoal.

In addition, an analysis of the environmental impact and sustainability of charcoal production will be carried out, considering aspects such as forest management and the preservation of local biodiversity.

The Cerrado biome, one of the richest vegetation zones in biodiversity in Brazil, is characterized by its xerophilous vegetation and a great diversity of tree and shrub species. Among these, Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis are native trees that have the potential to be used in the production of charcoal.

However, the energy efficiency of this charcoal depends on several factors, including its physicochemical properties, which can be influenced by variables such as the species of origin, the carbonization method, and environmental conditions.

Through the evaluation of thermal decomposition and characterization of the charcoal produced, this research aims to provide essential information that helps in the selection of best practices for charcoal production in the biome in question, providing a more efficient and sustainable use of this renewable energy source.

In summary, understanding the properties of charcoal from species of the Cerrado biome is fundamental, not only for the advancement of academic knowledge in the area, but mainly aiming at the application of public policies that encourage the sustainable use of resources available in forests and the conservation of biodiversity.

Charcoal is acquired from the carbonization of wood, being used as fuel in various sectors, such as: fireplaces, barbecues, wood stoves and heaters. In addition, it is also used in some industrial sectors, such as steel mills. It is a renewable and low-polluting source of energy, but its rudimentary production in brick kilns can emit polluting gases.

With a vast production chain in the areas related to the production of pig iron, metallurgy, machining and production of parts, the metallurgy and steel sectors are of great importance in the Brazilian economic panorama, being the support of other activities, such as the automobile industry, civil construction, for example.

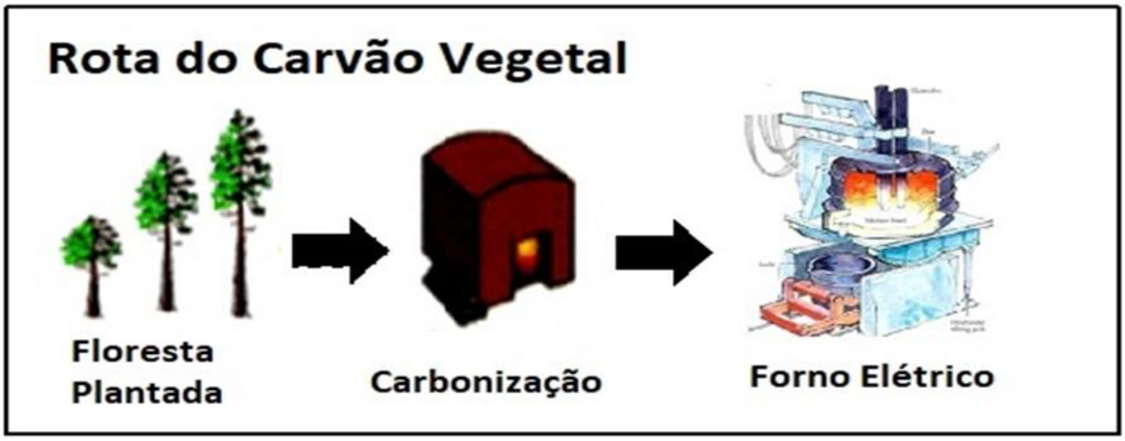
The main inputs used as reducing terms can come from non-renewable or renewable sources, such as mineral coal and charcoal, respectively.

In Brazil, the mineral coal consumed is 100% imported, due to the characteristics of the coal deposits in the country not having the good quality necessary for this purpose.

Charcoal, on the other hand, is produced from planted forests, where Brazil stands out as the only country to use a renewable source in the steel sector (Figure 1).

The charcoal used by companies in the steel and metallurgy sector comes from planted forests, corresponding to 91% of production (IBÁ, 2019). Charcoal has a carbon, ash and calorific value content ranging on average between 75 and 80%, 1% and from 7,500 to 8,000 kcal.kg-1, respectively (PROTASIO et al., 2014).

Figure 1 - Schematic representation of the charcoal route in the ferroalloys sector



Source: Brazilian Tree Industry (IBA, 2019).

The incentive to use charcoal represents dividends in the economic, environmental and social spheres for the nation. In this way, environmental profit is significantly converted, curbing the consumption of non-renewable sources and greenhouse gas (GHG) emissions.

In spite of the productive aspects and the use of coal, the use of charcoal emerges as a way to contribute significantly to the Brazilian trade balance. Furthermore, the production and use of activated carbon from these wood species represent a sustainable and efficient application of forest resources, contributing to environmental quality and public health.

MATERIALS AND METHODS

EVALUATION OF THE PHYSICAL PROPERTIES OF THE CHARCOAL PRODUCED FROM THE SELECTED SPECIES, THAT IS: DENSITY, POROSITY AND MOISTURE CONTENT

To analyze the physical properties of the coal, the carbonization procedure was developed in the laboratory. For each species, ten test elements with approximate dimensions of 2.5cm x 2.5cm x 2.5cm were used.

The samples were weighed and measured before carbonization to determine the apparent specific mass. Subsequently, the evidence was covered with aluminum foil, sorted and inserted into muffle furnace for carbonization.

For the carbonizations, the chips were previously dried in an oven at 105±3°C, up to constant weight. The carbonizations were conducted in reproduction for each material, using a muffle furnace with electric heating.

The final carbonization temperature was 550 °C, considering 50°C every 30 minutes, recovering the pyroligneous liquor by condensation with water. The defined carbonization temperature of 550°C was indicated because it is close to that which has been used in industrial retort systems, which are the most suitable for carbonization of products in the form of chips.

After carbonization and cooling, the weight of the evidence was verified by measuring them again, to calculate the gravimetric and volumetric yield of the coal. The gravimetric yield is the ratio between the final weight of the charcoal and the dry weight of the wood (before carbonization), expressed as a percentage.

The volumetric yield is the ratio between the final weight of the coal and its volume before carbonization, also presented as a percentage.

In addition, immediate thermogravimetric (TGA) analyses were performed. The TGA test, or Thermogravimetry, measures the variation in the mass of the sample (loss and/or gain) as a function of the temperature variation imposed on the analyzed material.

A gravimetric scale was used, following the ASTM D 1762 standard (American Society for Testing and Materials, 2007), with temperatures of 900 °C for the percentage of volatiles and fixed carbon and 525 °C for ash.

The charcoal samples obtained to characterize the physical properties were treated and analyzed in this study, determining the density, porosity and moisture content.

To determine the **basic density,** two methods were used, namely: the so-called immersion and displacement method and the so-called Maximum Moisture Content method (SMITH, 1954).

To obtain the values referring to the porosity of the charcoal of the species in question, laboratory analyses were first carried out to determine the apparent density of the charcoal. And the true density was determined according to the ABNT NBR 9165 (1985) Standard. By relating the true density to the apparent density, the measurement of the porosity of the coal was obtained (PENEDO, 1980).

Thus, the porosity of the charcoal was obtained from the data of apparent and true densities, through the formula:

PO (%) = 100 - (DRA*100) /DRV , onde:

PO (%) = Porosity in (%);

DRA = Apparent Relative Density (g/cm³);

DRV = True Relative Density (g/cm³).

The moisture content was determined by the so-called traditional, gravimetric method, in accordance with NBR 14929 (ABNT, 2003).

DETERMINATION OF THE CHEMICAL PROPERTIES OF THE CHARCOAL OF THE SPECIES UNDER STUDY, I.E.: THE CHEMICAL COMPOSITION (PERCENTAGE OF CARBON, HYDROGEN, OXYGEN, NITROGEN AND SULFUR), CALORIFIC VALUE, VOLATILE AND ASH CONTENT, PH AND FIXED CARBON CONTENT

Thermal decomposition and characterization of charcoal are fundamental processes in the production of charcoal from organic matter, such as plant waste.

This process involves pyrolysis, which is the thermal decomposition of biomass in the absence of oxygen, resulting in the conversion of wood or other plant parts into charcoal.

- **Thermal decomposition.**

Thermal decomposition is a transformation process that involves breaking chemical bonds in organic materials when subjected to high temperatures.

- **Characterization of Charcoal.**

After the thermal decomposition process, the charcoal produced must be characterized to understand its properties and potential applications.

- **Chemical composition:**

Analysis of chemical constituents, including the amount of carbon, hydrogen, oxygen, nitrogen, and sulfur, is critical to determining the calorific value of coal. Carbon is primarily responsible for the energy released in burning.

The values of chemical composition (carbon, hydrogen, oxygen, nitrogen and sulfur) of the plant species Tachigali vulgaris, Amburana cearensis and Myracrodruon urundeuva may vary according to different factors, such as growing conditions, extraction methods and analysis of charcoal. However, previous studies often report compositions typical for such species.

The immediate chemical analysis was performed according to ABNT NBR 8112 (1986), with determinations of ash content, volatile materials and fixed carbon content on a dry basis. The coal densities were calculated according to ASTM-D-167-93, adapted by Oliveira, Gomes and Almeida (1982).

- **Calorific value**

This is one of the main parameters to be measured. The higher calorific value (PCS) and the lower calorific value (PCI) are important for assessing the efficiency of coal for energy purposes.

The calorific value is divided into upper (PCS) and lower (PCI). The calorific value is said to be higher when there is condensation of water (or liquefaction that occurs when the vapor or gas reaches a temperature lower than its boiling point).

In the case of water vapor, for example, condensation begins when the temperature is below 100 degrees Celsius, after the complete process of combustion at a constant pressure and in a standard state (FIGUEREDO, 2009).

The calorific value is said to be lower when there is no condensation of the water. PCI comes from combustion at constant pressure, in the open, without the condensation of H_2O formed (DOAT, 1977).

The calorific value is not directly linked to the density of the wood, but is influenced by the chemical composition and directly affected by the moisture content. Even the PCI is reduced with the increase in humidity (DOAT, 1977).

Wood expresses a PCS of around 4,500 kcal/kg (KOLLMAN & CÔTÉ, 1984). (NUMAZAWA, 2000), on the other hand, says that tropical wood expresses a SWP between 4,171.68 and 5,106.53 kcal/kg.

The information was obtained through bibliographic research of the values of the amount of internal energy available in technical compendia and some calculated by the Institute of Forest Studies Research - EPEF - Forest Products Laboratory - LPF - IBAMA.

The tests carried out at LPF/IBAMA, to determine the PCS (Higher Calorific Value), were carried out according to the guidelines of NBR 8633-ABNT (1984), Charcoal – Determination of Calorific Value and the manual of the calorimeter PARAR 1201. The upper calorific value (SSP), dry mass basis, was determined using a digital calorimeter, brand IKA - C 200, according to ABNT NBR 8633 (1984) (Figure 2).

While the lower calorific value (PCI), dry mass basis, was estimated according to the equation below (BRAND, 2010).

PCI = PCS – (600x9H/100), where: PCI is the lowest calorific value (Kcal/Kg); PCS is the highest calorific value (Kcal/Kg; H is the Hydrogen content (%) on the dry basis of the wood.

Figure 2 - Digital calorimeter, brand IKA-C 200

Source: Unip/Uniplan Laboratory.

The samples used to determine the PCS were prepared as follows:

- **Crushing**: for chip extraction;

- **Grinding**: for conversion to sawdust;
- **Screening**: for particle selection;
- **Drying**: ground wood with an index of less than 60 mesch was dried in an oven at 105 ± 2ºC until a constant amount.

➢ **Teor de cinzas**

The ash content was determined by ASTM D1102-84 (2007), and was carried out in the wood chemistry laboratory of INPA, using porcelain crucibles for calcination of the samples in a muffle furnace at a temperature of 580~600°C. The ash content was obtained by the ratio between the weight of the ash obtained in calcination (a procedure performed in the laboratory.

An electric muffle furnace, Bunsen burner, analytical balance, porcelain crucibles, desiccant, crucible tweezers and inkil) and the mass of the sample dried in an inkil, expressed as a percentage, and calculated by Equation 2 were used.

The determination of the ash content was made using equation 2, below:

$C = mc/ms \times 100\ (\%)$ – Equation 2

Where: C = Ash content (%); mc = Ash mass (g); ms = Dry wood mass (g).

➢ **Volatile content**

Knowing that the volatile content expresses the ease of burning a material, it is defined as the mass fraction of the fuel that volatilizes during the heating of a standard sample, in an immobile atmosphere, up to a temperature of around 850 ºC, for seven minutes.

After the measurements, the amounts of volatile and non-volatile substances were calculated as follows:

Total Volatile Solids Content = (Weight of Container and Substance Before Being Dried in the Oven - Weight of Container and Substance After Incineration) x Volume of Sample in Milliliters.

➢ **Hydrogen Potential (PH)**

The pH of the soil where species such as Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis develop varies significantly with respect to geographic location, environmental conditions and how much soil they have. These species in question are associated with soils that have a pH that varies from acid to neutral.

The species Tachigali vulgaris is found in soils with a pH that usually varies between 5.0 and 6.5. While the species Myracrodruon urundeuva grows in soils with a pH ranging from 5.0 to 7.0, although it can adapt to a wide range of soil conditions. The species Amburana cearensis, on the other hand, prefers soils with a pH between 5.0 and 6.5.

- **Fixed carbon content**

Fixed carbon content (TCF) is an indicator of the quality of coal, as it indicates its energy potential:

TCF is calculated by the formula $yCf=100-(yC+yV)$.

Where:

yCf is the fixed carbon content;

yC is the ash content and

yV is the volatile content.

EVALUATION OF THE BIOLOGICAL CHARACTERISTICS OF CHARCOAL PRODUCED FROM THE SELECTED SPECIES, I.E.: DECOMPOSITION, MICROORGANISMS AND ECOLOGICAL IMPACT

- **Decomposition**

The carbonization process can impact the ability of plant material to decompose in the soil, influencing soil quality and the production of organic carbon in the soil.

The biological decomposition of species such as Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis is a natural and complex process that varies in rate and efficiency, depending on the specific characteristics of each species and the environmental conditions in which they are found.

It involves the degradation of organic matter, which facilitates the recycling of nutrients in the ecosystem and the maintenance of ecosystem health. Thus, each of these species has characteristics that influence the way this process takes place.

To determine the decomposition rate (k), the following equation was used: C = Co. and ^(-Kt),

Where:

C is the final mass of the samples;

C0 is the initial mass (30 g);

T is the time elapsed in the experiment (360 days) and

K is defined as the decomposition constant (PARDO et al., 1997).

To measure the half-life period or essential period for 50% of the biomass to be transformed, the following equation was used: $t0.5 = \ln.2/K$ (COSTA; ATAPATTU, 2001).

- **Microorganisms**

The presence of microorganisms in wood, including species such as Tachigali vulgaris, Myracrodruon urundeova, and Amburana cearensis, can have a significant impact on the efficiency of carbonization and the quality of the charcoal produced.

The quality of the charcoal produced is influenced by the chemical composition of the wood, which in turn can be altered by the activity of microorganisms.

The presence of microorganisms that promote degradation can result in a charcoal with lower calorific value and higher ash content.

Charcoal produced from healthy wood free of microbial infestation is more likely to have desirable characteristics such as: higher energy density, lower contaminant content and better energy performance.

To optimize charcoal carbonization and quality, forest management practices that minimize colonization by decomposer organisms are recommended. This can include the use of wood with rapid processing after harvest, and storage in dry conditions to prevent the proliferation of microorganisms.

The application of preservation methods, such as drying and chemical treatment, can help protect the wood from the action of microorganisms, increasing the efficiency of carbonization and improving the final quality of the charcoal.

In summary, the presence of microorganisms can significantly affect both the carbonization efficiency and the quality of charcoal produced from the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis. The practice of sustainable management and control of microbial infestation are fundamental to optimize these processes.

- **Ecological Impact**

Assessing the effects of the removal of species from the Cerrado biome for charcoal production purposes on local biodiversity and ecosystem services is important.

The removal of native species of the Cerrado biome, such as Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, for charcoal production purposes, can have significant ecological impacts that affect local biodiversity and ecosystem services.

1. Impact on Biodiversity

- Habitat Loss; - Reduction of Native Species; - Change in Microbial Communities.

2. Impact on Ecosystem Services

- Nutrient Cycle; - Carbon Storage; - Microclimate regulation; - Water Conservation.

To mitigate these impacts, it is essential to consider sustainable management methods and alternatives to charcoal production that minimize the removal of native species, such as the use of agricultural residues or the implementation of silvicultural systems that seek conservation.

The dismissal of the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis from the Cerrado biome for charcoal production purposes can have severe consequences for local biodiversity and essential ecosystem services, leading to environmental degradation and the loss of natural resources.

The preservation of these species is essential to maintain the health of the ecosystem and the functionality of the Cerrado.

ANALYSIS OF ENERGY PROPERTIES

Evaluation of the calorific value and energy efficiency of charcoals of the three species, in order to determine their viability as an energy source for the steel industry.

STUDY OF THERMAL DECOMPOSITION

Conducting thermal decomposition analyses (Thermal Difference Thermogravimetry) in order to understand the thermal conduct of materials with pyrolysis.

PRODUCTION AND CHARACTERIZATION OF ACTIVATED CHARCOAL:

Development and optimization of processes for the production of activated charcoal from the coals obtained, and characterize their properties (porosity, surface area, adsorption capacity).

SUSTAINABILITY ANALYSIS

Evaluation of the sustainability of charcoal and activated charcoal production, considering economic, social and environmental aspects associated with the use of native species of the Cerrado biome.

COMPARISON BETWEEN SPECIES

Comparison of the properties of charcoal produced from the three species in terms of quality, yield and applicability, both for energy purposes and for the production of activated carbon.

STUDY OF COMPATIBILITY WITH INDUSTRIAL PROCESSES

Investigation of the compatibility and effectiveness of charcoals obtained in existing industrial processes in the steel sector, identifying possible necessary adaptations.

SUSTAINABLE FOREST MANAGEMENT PROPOSALS

Suggestion of sustainable management practices for the harvest and use of the species studied, promoting the conservation of the Cerrado biome while taking advantage of its resources.

RESULTS AND DISCUSSION

EVALUATION OF THE PHYSICAL PROPERTIES OF CHARCOAL PRODUCED FROM THE SELECTED SPECIES, I.E.: DENSITY, POROSITY AND MOISTURE CONTENT

Results

Density

To determine the **basic density** (Table 1), two methods were used, namely: One that consists of the ratio between the dry mass and the saturated volume, called the immersion and displacement method, and the other called the Maximum Moisture Content method (SMITH, 1954).

Table 1 - Physical Properties – Basic Density

Basic Density (g/cm³)			
Samples	Species	Immersion/Displacement	Max. Moisture Content
MU - A	Myracrodruon Urundeuva	0,73	0,77
MU - B	Myracrodruon Urundeuva	0,75	0,73
Average	Myracrodruon Urundeuva	0,74	0,75
DP	Myracrodruon Urundeuva	0,13	0,01
CV	Myracrodruon Urundeuva	1,30	1,02
TV – A	Tachigali Vulgaris	0,47	0,44
TV - B	Tachigali Vulgaris	0,41	0,42
Average	Tachigali Vulgaris	0,44	0,43
DP	Tachigali Vulgaris	0,02	0,02
CV	Tachigali Vulgaris	1,06	1,02
AC – A	Amburana Cearensis	0,60	0,61
AC - B	Amburana Cearensis	0,62	0.62
Average	Amburana Cearensis	0,61	0,61
DP	Amburana Cearensis	0,02	0,01
CV	Amburana Cearensis	0,99	1,00

Source: The author.

Caption:
MU-A – Sample A of the Species Myracrodruon Urundeuva (%).
MU- B – Sample B of the Species Myracrodruon Urundeuva (%).
TV - A - Sample A of the Tachigali Vulgaris Species (%).
TV - B - Sample B of the Species Tachigali Vulgaris (%).
AC - A - Sample A of the Amburana Cearensis Species (%).
AC - B - Sample B of the Amburana Cearensis Species (%).
SD - Standard Deviation.
CV - Coefficient of Variation (%).

Regarding the physical characterization of the smut shown in table 1, it was found that the values of the basic density of the species under study were reasonably higher for the species Myracrodruon Urundeuva, with very similar results for the two methods used.

Discussion

Density

The shape and density of charcoal influence its burning and storage. Well-compacted coals burn more efficiently.

It is verified that the values of the basic density obtained were, in general, higher than those presented in the bibliography for specimens and varieties.

This aspect is very positive in view of the main applications in industries and homes of charcoal, because in addition to representing a higher concentration of useful material, it can also result in a greater physical resistance of the product.

The basic density of charcoal is an important characteristic that signifies diverse conceptions in terms of the physical and chemical properties of the material, with implications for functional biomaterials, activated carbon, and other industrial uses.

Thus, for greater basic density, it can be inferred:

Physical Properties:

- Charcoal with a higher basic density indicates a more compact structure and a greater amount of accumulated organic material. This results in greater carbon storage capacity.

Heat Energy:

- Charcoals of higher density have a higher fixed carbon content and, consequently, a higher heat energy. This is desirable in applications such as boiler or barbecue fuels.

Functional biomaterials:

- Applications in Materials Engineering: In biomaterials, a charcoal with a higher density can offer better mechanical strength. This is important in applications such as composites and building materials, where durability and strength are essential.
- Functionality: Charcoal can be treated or modified to create biomaterials with specific functions, such as absorption of pollutants or controlled delivery of drugs.

Activated Carbon:

- Surface: Coals with higher basic density have a porous structure that favors the production of activated carbon. This is important because activated carbon is used for adsorption of pollutants, purification of water and air, and in chemical separation processes.
- Adsorption Capacity: A carbon with a higher base density may have a larger surface area, which typically results in a better adsorption capacity in activated

carbon applications.

Environmental Impacts and Sustainability:

- Sustainability: Using species with higher basic density for charcoal production can be more sustainable, as it can result in better use of biomass, leading to less waste and greater efficiency in resource use.

In short, the higher basic density of charcoal is indicative of its physical and chemical properties that can improve its applications in several areas, from efficient combustion to its use in biomaterials and activated carbon. This characteristic is therefore highly valued in industrial and environmental contexts.

Therefore, verifying the values obtained for the basic density of the charcoal samples of the analyzed species, as shown in Table 1, the species Myracrodruon Urundeuva stood out, presenting the highest values for the basic density, which makes it the greatest holder of the qualities described above, for those results. In order, the best species were: Myracrodruon Urundeuva, Amburana Cearensis and Tachigali Vulgaris.

Results

Porosity

The mass of 1.0 m³ of charcoal is called bulk density, given per kg/m³, called bulk density by ISO. By definition, this value is around 300kg/m³ for charcoal.

If, from this measure of volume, the volume of the voids between the various pieces of coal is reduced, without considering that the internal pores are occupied by air, we will have the so-called apparent density.

The true density is the measure of the density of the substance that makes up the charcoal, that is, it is the apparent density discounting the volume of the internal porosity.

Thus, by relating the true density to the apparent density, the measurement of the porosity of the coal was obtained (PENEDO, 1980).

Table 2 - Presentation of the results for physical tests of the charcoal of the species studied, Apparent Relative Density (DRA), True Relative Density (DRV) and Porosity (PO).

SPECIES	DRA (g/cm³)	DRV (g/cm³)	OP (%)
Myracrodruon Urundeuva	0,329	1,430	76,98
Tachigali Vulgaris	0,269	1,363	79,54
Amburana Cearensis	0,329	1,430	76,98

Source: The author

Thus, the species:

- Tachigali vulgaris: presented a higher porosity, which results in a greater capacity for liquid absorption and a more efficient burning, due to the greater surface area available.

- Myracrodruon urundeuva: presented an intermediate porosity, balancing durability and efficiency in combustion.
- Amburana cearensis: presented a porosity similar to that of Tachigali vulgaris, but its specific characteristics of burning and gas emission differentiate it in terms of its performance as charcoal.

Discussion

Porosity

The determination of the porosity of charcoal produced from the wood species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, is an important aspect to understand its properties and potential applications.

The results obtained, for the species under study, are important for the charcoal industry, as they influence the choices in terms of tree species to be cultivated for charcoal production, in addition to affecting both the properties of the charcoal itself and the efficiency of its use.

Results

Moisture content

The moisture content was determined by the so-called traditional, gravimetric method, in accordance with NBR 14929 (ABNT, 2003).

Thus, the difference in the mass of samples was considered, before and after being subjected to drying at 103 ± 2°C in an oven with forced air circulation up to constant mass, using the equation:

$$Tu = \frac{(Mu - Ms)}{Ms} \times 100$$

Where: Tu = Equilibrium moisture content on a dry basis (%);

Mu = mass úmida (g);

Ms = massa seca (g).

Table 3 - Moisture content calculated.

Samples	Species	YOU	
		By sample	Average
MU – A	Myracrodruon Urundeuva	14,71	13,97
MU – B	Myracrodruon Urundeuva	13,23	
DP	Myracrodruon Urundeuva	1,29	
CV	Myracrodruon Urundeuva	1,00	
TV – A	Tachigali Vulgaris	13,72	13,10
TV – B	Tachigali Vulgaris	12,48	
DP	Tachigali Vulgaris	1,65	
CV	Tachigali Vulgaris	0,89	
AC – A	Amburana Cearensis	14,90	16,45
AC – B	Amburana Cearensis	18,00	
DP	Amburana Cearensis	6,93	
CV	Amburana Cearensis	11,26	

Source: The author.

Legend
MU-A – Sample A of the Species Myracrodruon Urundeuva (%).
MU- B – Sample B of the Species Myracrodruon Urundeuva (%).
TV – A – Sample A of the Tachigali Vulgaris Species (%).
TV – B – Sample B of the Species Tachigali Vulgaris (%).
AC – A – Sample A of the Amburana Cearensis Species (%).
AC – B – Sample B of the Amburana Cearensis Species (%).
TU – Moisture Content (%)
SD – Standard Deviation.
CV – Coefficient of Variation (%).

Discussion

Moisture content

The average values for the moisture content of different wood species can vary depending on the growing conditions, collection location, and method of analysis.

Whereas the lower the moisture content, the higher the quality of the charcoal, as coals with high moisture burn less efficiently and produce less energy.

Thus, for the results obtained, the species of best quality for charcoal considering the moisture content is Tachigali Vulgaris (13.10%), which presented a similar moisture content Myracrodruon Urundeuva (13.97%). In order, the best species were: Tachigali Vulgaris, Myracrodruon Urundeuva and Amburana Cearensis.

DETERMINATION OF THE CHEMICAL PROPERTIES OF THE CHARCOAL OF THE SPECIES UNDER STUDY, I.E.: CHEMICAL COMPOSITION (PERCENTAGE OF CARBON, HYDROGEN, OXYGEN, NITROGEN AND SULFUR), CALORIFIC VALUE, VOLATILE AND ASH CONTENT, PH AND FIXED CARBON CONTENT.

Results

The chemical composition

Table 4 - Summary of the analyses of the chemical composition of the charcoal extracted from the Species identified in column 1.

Species	C (%)	H (%)	O (%)	N (%)	S (%)	CV
Amburana cearensis	50,00	5,50	40,00	0,55	0,60	1,60
Myracrodruo Urundeuva	72,50	6,00	20,00	1,25	0,27	3,72
Tachigali Vulgaris	77,50	4,50	12,5	1,25	0,50	6,45

Source: The Author

Caption
C – Carbono (%);
H – Hydrogen (%);
O – Oxygen (%);
N - Nitrogênio (%);
S – Enxofre (%).
CV – Coefficient of Variation (%).

Discussion

The chemical composition

Charcoal is an organic material obtained from the carbonization of wood and other plant materials. Its chemical composition can vary depending on the origin of the raw material, the carbonization process, and the storage conditions.

In addition to these main elements, charcoal can contain volatile organic compounds, and its composition can be affected by contaminants, depending on the production process and the raw material used.

The exact concentration of these elements can vary depending on the production conditions and the source of the wood used.

The presence of undesirable substances, such as sulfur and heavy metals, should be minimal, as these components can generate pollutants and reduce the quality of the coal.

The analysis of the data presented in table 4 on the chemical compositions of the plant species Amburana cearensis, Myracrodruon urundeuva and Tachigali vulgaris considers the percentage composition of the main elements (Carbon - C, Hydrogen - H, Oxygen - O, Nitrogen - N and Sulfur - S) and the Coefficient of Variation (CV), which indicates the relative variability of the data.

1. Amburana cearensis:

This species has a significant carbon and oxygen content, which is common in woods and biomass. The percentage of hydrogen is at an expected level, considering the organic composition. The nitrogen and sulfur contents are relatively low, indicating a lower fertility of the soil where it grew or an adaptation to limited nutrients.

2. Myracrodruon urundeuva:

This species showed an even higher carbon content than Amburana, indicating a very high potential for biomass production.

The nitrogen level is higher than in Amburana, indicating a richer soil or a better nutrient absorption capacity. The relatively higher VC may indicate greater variability in the results, which could be investigated in further studies.

3. Tachigali vulgaris:

Tachigali had the highest carbon content among the three species, indicating a high potential for use in biofuels or as a high energy density material. Low oxygen content can be a favorable factor in certain chemical reactions where oxidation is a problem. The CV is the highest among the species, which indicates a greater variation in quality or sampling methods.

General Considerations:

- The high carbon content in the three species suggests a great potential for use in biofuels, wood and other industrial applications.
- Low nitrogen and sulfur content indicates that these species are adapted to environments with limited nutrients or that their leaves or bark are not rich in protein.
- The CV can be used to assess the consistency of the data obtained; High values may suggest the need for more sampling or greater control in measurements.

In conclusion, the three species have chemical characteristics that can be exploited in different applications, mainly in biomass production and in industries that use wood. The study of nutrient elements also provides relevant information about the conditions in which these species develop and their potential for recovery in altered environments.

According to the Brazilian Agricultural Research Corporation (Embrapa), wood with about 50% carbon, 6.2% hydrogen, 42.2% oxygen and 0.4% ash is ideal for the production of good quality charcoal.

Thus, it is observed that the results for the chemical composition, as shown in Table 4, show that the species Amburana Cearensis is the one that comes closest to the production of good quality charcoal.

Results

Calorific value

Table 5 - Calorific value

Samples	Species	PCS (Kcal/Kg)	PCI (Kcal/Kg)
MV - A	Myracrodruon Urundeuva	4372,12	3820,00
MV - B	Myracrodruon Urundeuva	4499,86	3852,68
Average	Myracrodruon Urundeuva	4435,99	3836,34
DP	Myracrodruon Urundeuva	0,28	0,40
CV	Myracrodruon Urundeuva	1,43	0,84
TV – A	Tachigali Vulgaris	4102,22	3528,50
TV - B	Tachigali Vulgaris	4180,58	3796,20
Average	Tachigali Vulgaris	4141,40	3662,35
DP	Tachigali Vulgaris	0,94	0,36
CV	Tachigali Vulgaris	1,54	0,93
AC – A	Amburana Cearensis	4236,02	3844,50
AC - B	Amburana Cearensis	4380,66	3980,48
Average	Amburana Cearensis	4308,34	3912,49
DP	Amburana Cearensis	0,33	0,98
CV	Amburana Cearensis	1,67	1,73

Source: The author

Legend
MU-A – Sample A of the Species Myracrodruon Urundeuva (%).
MU- B – Sample B of the Species Myracrodruon Urundeuva (%).
TV – A – Sample A of the Tachigali Vulgaris Species (%).
TV – B – Sample B of the Species Tachigali Vulgaris (%).
AC – A – Sample A of the Amburana Cearensis Species (%).
AC – B – Sample B of the Amburana Cearensis Species (%).
TU – Moisture Content
SD – Standard Deviation.
CV – Coefficient of Variation (%).

Calorific value is a measure of the amount of energy that coal can release when it is burned. High-quality charcoals have a high calorific value.

Regarding the higher calorific value, there were no significant variations between the average value obtained for the species under study. At a specific level, however, a trend of a higher result was observed for the species Myracrodruon Urundeuva.

Discussion

Calorific value

There was no significant effect of the longitudinal position on the upper calorific value (SCW) of charcoal of the species Amburana Cearensis (Average value of 4,308.34 kcal/Kg) and T. Vulgaris (Average value of 4,141.40 Kcal/Kg).

On the other hand, the species M. urundeuva presented the highest PCS value (average value 4,435.99 Kcal/Kg). For the species Amburana Cearensis, it was observed that the average PCI was 3912.49 Kcal/Kg, and the effect of the longitudinal position was not statistically significant.

The species Myracrodruon urundeuva (mean value of 3836.34 Kcal/Kg) and Tachigali Vulgaris (mean value of 3662.35 Kcal/Kg) showed a tendency to reduce the PCI with the increase in the longitudinal position.

Based on the results found for the calorific value of the three tree species (Myracrodruon Urundeuva, Tachigali Vulgaris and Amburana Cearensis), it is inferred when analyzing the characteristics of each one, the following:

1. Higher Calorific Value (PCS) and Lower Calorific Value (PCI):

All PCS values are higher than PCI values, which is expected. PCS (Kcal/Kg) refers to the energy released by a fuel when burned, including the energy generated by the condensation of water vapor in flue gases, while PCI excludes this energy.

Myracrodruon Urundeuva:

The average of PCS (4435.99 Kcal/Kg) and PCI (3836.34 Kcal/Kg) is the highest among the three species analyzed.

The coefficient of variation (CV) is low for both PCS and PCI (CV of 1.43% and 0.84%, respectively), indicating that the results are consistent and show little variation.

Tachigali Vulgaris:

The average PCS (4141.40 Kcal/Kg) and PCI (3662.35 Kcal/Kg) are intermediate between the three species.

It also presents relatively low VC, especially for PCI (0.93%), demonstrating consistency in the results.

Amburana Cearensis:

This type of wood has an average PCS (4308.34 Kcal/Kg) and PCI (3912.49 Kcal/Kg), which places it below Myracrodruon Urundeuva, but above Tachigali Vulgaris in terms of PCS.

The CV is slightly higher, especially for PCI (1.73%), suggesting that there may be a more significant variation in the samples collected.

General Considerations:

- Potential Uses: Myracrodruon Urundeuva is the best choice for applications that require high calorific value values, such as in industrial processes or power generation.
- Variety: The difference in calorific values between species reflects the diversity in

wood properties, due to factors such as density, chemical composition, moisture, and age of the trees.

- Sustainability: In a broader context, when considering the source of wood, the sustainability of logging and forest management are equally important to ensure ecological balance.

In this way, these inferences help to understand not only the energy characteristics of wood, but also its applicability and importance in the management of forest resources.

Results

Voláteis theor, fixed carbon theor and ash theor

Table 6 - Average values of the characteristics evaluated in charcoal

Species	TMV (%)	TCF (%)	TCz (%)	CV (%)
Myracrodruo Urundeuva	22,93	74,95	2,12	0,91
Amburana cearensis	28,60	66,26	5,14	0,89
Tachigali vulgaris	24,12	72,98	2,90	0,81

Source: The author

Caption
TMV – Volatile Material Content (%)
TCF – Fixed Carbon Content (%)
TCz – Teor de Cinzas (%)
CV – Coefficient of Variation (%).

Immediate analysis of the charcoal of the species under study indicated the highest content of volatile material (28.60%) for the species Amburana Cearensis, for the fixed carbon content the species Myracrodruon urundeuva presented the highest value (74.95%) while the species Amburana Cearensis, presented the value (66.26%) and Tachigali vulgaris (72.98%) for the ash content the species Amburana Cearensis presented the highest value (5.14%) while the species Myracrodruon urundeuva presented the highest value (74.95%) while the species Amburana Cearensis presented the highest value (5.14%) while the species Amburana Cearensis presented the highest value (5.14%) while the species Amburana Cearensis presented the highest value (5.14%) Myracrodruon urundeuva had the lowest index (2.12%).

Discussion

Voláteis theor, fixed carbon theor and ash theor

Considering the results shown in Table 6, the following stand out:

Volatile Material Content (TMV): The species Amburana cearensis has the highest content of volatile materials (28.60%), followed by Tachigali vulgaris (24.12%) and Myracrodruon urundeuva (22.93%).

This indicates that Amburana cearensis is more suitable for applications that require higher combustion capacity and volatile gas production.

Fixed Carbon Content (TCF): Myracrodruon urundeuva has the highest fixed carbon content (74.95%), which means a higher efficiency in energy production compared to other species, because the greater the amount of fixed carbon, the better the quality of the charcoal obtained. Being the situation of activated carbon production. Tachigali vulgaris and Amburana cearensis have lower fixed carbon contents (72.98% and 66.26% respectively), which indicates lower energy power.

Ash Content (TCz): Amburana cearensis also has higher ash content (5.14%), while the other species have lower levels (2.12% for Myracrodruon urundeuva and 2.90% for Tachigali vulgaris). A low percentage of ash is desirable as high ash indicates impurities and reduces the energy efficiency of coal, while a higher ash content may be undesirable in some applications as it implies a greater amount of non-combustible waste.

Coefficient of Variation (CV): The coefficient of variation is relatively low in all three species, indicating a good consistency in the results of the analyses. The smallest variation is observed in Tachigali vulgaris (0.81), while Amburana cearensis presents the highest variation (0.89) in the content of volatile materials. This information is useful for understanding the homogeneity of the products derived from each species.

Final considerations: The choice of species for charcoal production should consider the balance between fixed carbon contents and volatile materials, depending on the purpose of the charcoal use. Myracrodruon urundeuva may be preferred in situations where higher energy efficiency is desired, while Amburana cearensis may be more indicated when the production of volatile materials is more advantageous.

Results

Hydrogen Potential (PH)

In this study it was observed that the soil PH of the Cerrado Biome of the places where the samples were extracted were as follows:

Espécie Myracrodruon urundeuva, PH = 6,0;

Espécie Tachigali vulgaris, PH = 5,0;

Species Amburana cearensis, PH= 5.5.

Discussion

Hydrogen Potential (PH)

Tachigali vulgaris: The charcoals of this species showed characteristics that can be beneficial for soil applications, in addition to having a pH ranging from 5.0 to 6.5, depending on the carbonization process.

Myracrodruon urundeuva: This type of charcoal is known to have a good yield and can exhibit variations in chemical parameters, including pH (ranges from 5.0 to 7.0) and fixed carbon content. Exact values may vary based on carbonization conditions.

Amburana cearensis: Charcoal from this species can present variations in pH levels (varies from 5.0 to 6.5) and in the contents of fixed carbon and volatile materials, and is generally considered of good quality for use in various applications.

The results obtained for these species in question are associated with soils that have a pH that varies from acid to neutral, therefore in accordance with the existing literature for the case.

EVALUATION OF THE BIOLOGICAL CHARACTERISTICS OF CHARCOAL PRODUCED FROM THE SELECTED SPECIES, I.E.: DECOMPOSITION, MICROORGANISMS AND ECOLOGICAL IMPACT

Results

Decomposition

To determine the decomposition rate (k) the following formula was used: C = Co. and ^(-Kt),

Where:

C is the final mass of the samples;

C0 is the initial mass (30 g);

t, the time elapsed in the experimentation (365 days) and

k is the decomposition constant of pardo (PARDO et al., 1997).

To estimate the period required for 50% of the biomass to be transformed, the following equation was applied: $t_{0,5} = \ln \frac{2}{k}$ (COSTA; ATAPATTU, 2001).

For the species under study, the decomposition values were, for the species Amburana cearensis: K = 0.04 per year, for Myracrodruon urundeuva: K = 0.03 per year and for Tachigali vulgaris: K = 0.06 per year.

Discussion

Decomposition

The biological decomposition of species such as Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis is a natural process that involves the degradation of organic matter, which facilitates the recycling of nutrients in the ecosystem and the maintenance of ecosystem health.

Thus, each of these species has characteristics that influence the way this process takes place.

For the species Amburana cearensis, which presented a K index = 0.04 per year, previous studies indicate that the decomposition of foliage of this species may present K values in the range of 0.03 to 0.05 per year, depending on the humidity and temperature conditions in the study region. Known as cumaru, this species is also a hardwood tree.

Its seeds are rich in essential oils and phenolic compounds. The decomposition of Amburana cearensis can be classified as intermediate.

Although the wood is dense and rich in lignin (as in Myracrodruon urundeuva), leaves and other organic materials can decompose more quickly. Soil and moisture also affect the speed of this process.

For the species Tachigali vulgaris, the decomposition constant can vary, presenting values around 0.04 to 0.07 per year frequently cited in the literature, reflecting the specific conditions of the ecosystem.

It is a legume that can contribute to soil fertility, as it has a symbiotic relationship with bacteria of the genus 'Rhizobium', which fix nitrogen.

The decomposition of the leaves and branches of this plant is usually relatively rapid, especially due to its high growth rate and the chemical composition of its biomass. The presence of nitrogenous compounds facilitates the activity of decomposers such as fungi and bacteria.

And in the case of the species Myracrodruon urundeuva, according to the literature, it is a plant that also has a decomposition rate, with K values that are usually between 0.02 and 0.06 per year, depending on the condition of the soil and the humidity of the environment. This is a type of noble, resistant wood, found in Cerrado areas. Its wood has a high density and is rich in lignin and cellulose.

The decomposition of this species is slower compared to less dense species. Lignin and other recalcitrant compounds present in its wood make it difficult to degrade. Thus, the process takes longer and usually requires the action of fungi that can degrade these complex compounds.

It is verified, therefore, that the results obtained for the decomposition rate for the species under study, after due calculations, are compatible, coherent and aligned with what is pointed out in the pertinent literature on the subject.

And also that the carbonization process can impact the ability of plant material to decompose in the soil, influencing soil quality and the production of organic carbon in the soil.

Results

Microorganismos

The interrelationship between plant species and microorganisms, such as fungi, bacteria, and nematodes, is a complex and very important field in soil ecology and microbiology. Each species develops in an environment that is home to a particular set of microorganisms, namely:

Tachigali vulgaris

Mycorrhizal Fungi: This species of plant is associated with arbuscular mycorrhizal fungi, which help in the absorption of nutrients from the soil, such as phosphorus and micronutrients. Arbuscular mycorrhizae are essential for the sustainability of ecosystems and for the establishment of plants in degraded areas.

Soil Bacteria: Nitrogen-fixing bacteria and other beneficial species, which aid in nutrient cycling.

Decomposition Fungi: They can act in the decomposition of organic matter, promoting soil fertility.

Myracrodruo Urundeuva

Pathogenic Fungi: It is susceptible to pathogenic fungi that affect cerrado plants, such as Fusarium and Phytophthora.

Beneficial Bacteria: It associates with beneficial soil bacteria such as Rhizobium, which help in soil nutrition.

Mycorrhizae: Like Tachigali, it can form associations with mycorrhizal fungi.

Amburana cearensis

Mycorrhizal Fungi: This genus is also associated with mycorrhizal fungi, which promote root development.

Antibiotic Bacteria: less susceptible to certain pathogens due to the presence of bacteria that produce antibiotic compounds.

Cellulose Degrading Fungi: It is more subject to the action of fungi that degrade organic matter, since it often grows in soils with high organic matter.

Discussion

Microorganismos

The presence of certain microorganisms in wood, including species such as Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, influences the carbonization efficiency and quality of the charcoal. The biological aspect of charcoal can also impair its interrelationship with the soil and fertility.

Arbuscular mycorrhizal fungi are fungi of the phylum Glomeromycota that associate with plant roots, forming arbuscular mycorrhizae. This symbiosis is mutualistic and occurs endogenously, with arbuscules in the cells of the root cortex.

The types of microorganisms present in the rhizosol of each plant can vary depending on factors such as geographic location, soil type, climate, and interactions with other species. Additionally, the presence of pathogens is a major concern, as it can affect the health and vitality of plants.

Several species of fungi that colonize wood can influence its degradation. These organisms are capable of degrading lignin and cellulose present in plant cells.

However, its activity must be considered in a context that aims at carbonization, since the degradation of wood can alter its chemical composition, reducing the efficiency of carbonization.

Bacterial activity can result in the release of gases that affect the carbonization process, especially if the wood is not in a state suitable for carbonization.

The microbial presence can result in deterioration of the wood before the carbonization process. If the wood is compromised by the action of fungi and bacteria, it may have a lower density and, therefore, a lower efficiency in carbonization.

Microbial activity can generate secondary products, such as organic acids, which can affect the melting point and volatilization of compounds during carbonization.

Thus, the quality of the charcoal produced is influenced by the chemical composition of the wood, which in turn can be altered by the activity of microorganisms. The presence of microorganisms that promote degradation can result in a charcoal with lower calorific value and higher ash content.

Charcoal produced from healthy wood that is free of microbial infestation is more likely to have desirable characteristics, such as higher energy density, lower contaminant content, and better energy performance.

To optimize charcoal carbonization and quality, forest management practices that minimize colonization by decomposer organisms are recommended.

This can include the use of wood with rapid processing after harvest, and storage in dry conditions to prevent the proliferation of microorganisms.

The application of preservation methods, such as drying and chemical treatment, can help protect the wood from the action of microorganisms, increasing the efficiency of carbonization and improving the final quality of the charcoal.

In summary, the presence of microorganisms can significantly affect both the carbonization efficiency and the quality of charcoal produced from the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis. The practice of sustainable management and control of microbial infestation are essential to the processes.

Results

Ecological impact

The removal of native species of the Cerrado biome, such as Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, for charcoal production purposes, can have significant ecological impacts whose results affect both local biodiversity and ecosystem services, namely:

Impact on Biodiversity

- Habitat Loss;
- Reduction of Native Species;
- Change in Microbial Communities.

Impact on Ecosystem Services

- Nutrient Cycling;
- Carbon Storage;
- Microclimate Regulation;
- Water Conservation.

To mitigate these impacts, it is essential to consider sustainable management methods and alternatives to charcoal production

The dismissal of the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis from the Cerrado biome for charcoal production results, according to the results obtained, in severe consequences for local biodiversity and essential ecosystem services.

Discussion

Ecological impact

Assessing the effects of the removal of species from the Cerrado biome for charcoal production purposes on local biodiversity and ecosystem services is of great importance, in view of the impacts described below.

Impact on Biodiversity

- Habitat Loss: The removal of these species leads to the destruction of habitats that support a variety of organisms, from plants to animals. This land use fragments ecosystems, reducing connectivity between natural areas.
- Reduction of Native Species: The removal of these trees can limit the number of plant species that depend on them, influencing the entire food chain. Many animals depend on these plants for food and shelter.
- Alteration in Microbial Communities: Removal and subsequent carbonization can alter soil microorganism communities, which play crucial roles in nutrient cycling and soil health.

Impact on Ecosystem Services

- Nutrient Cycling: The species Myracrodruon urundeuva and Amburana cearensis play an important role in the cycling of soil nutrients. Its removal can compromise soil fertility and the availability of nutrients to other plants, altering the ecological balance.
- Carbon Storage: These tree species are important in carbon sequestration. Their removal not only releases carbon stored in the biomass, but also decreases the ecosystem's ability to sequester carbon in the future.
- Microclimate Regulation: Trees play a vital role in regulating the microclimate by influencing the temperature and humidity of the soil and air. Removal can lead to an increase in local temperatures and changes in precipitation patterns.
- Water Conservation: Native vegetation helps to conserve hydrological cycles, providing infiltration and reducing erosion. Tree removal can result in lower water retention, affecting water quality and availability.

Sustainability and Alternatives

To mitigate these impacts, it is essential to consider sustainable management methods and alternatives to charcoal production that minimize the removal of native species, such as the use of agricultural residues or the implementation of silvicultural systems that seek conservation.

The dismissal of the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis from the Cerrado biome for charcoal production purposes can have severe consequences for local biodiversity and essential ecosystem services, leading to environmental degradation and the loss of natural resources.

The preservation of these species is essential to maintain the health of the ecosystem and the functionality of the Cerrado.

ANALYSIS OF ENERGY PROPERTIES

The calorific value and energy efficiency of the charcoals of the three species were evaluated in order to determine their viability as an energy source for the steel sector.

The results of the analysis of the energy properties of charcoals of the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis showed significant variations in calorific value and energy efficiency.

Compared to the standards required by the steel industry, Myracrodruon urundeuva had the highest Higher Calorific Value (SCW) (4435.99 Kcal/Kg) and a compatible ash content (2.12%), suggesting its viability as a primary energy source.

On the other hand, Amburana cearensis, although with a lower thermal efficiency, showed promise for the sustainability of its extraction and lower environmental impact. Tachigali vulgaris, despite its potential, did not fully meet the standards of Lower Calorific Value (3662.35 Kcal/Kg), which limits its applicability in the sector.

It is recommended that additional studies be carried out to optimize the carbonization conditions and further explore the properties of these coals in industrial applications.

STUDY OF THERMAL DECOMPOSITION

Thermal decomposition analyses (Thermogravimetry and thermal difference analysis) were carried out in order to understand the thermal behavior of the materials during pyrolysis.

Through the thermal decomposition analysis carried out on the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, it was possible to observe that the degradation temperatures varied significantly among the samples, reflecting differences in the chemical compositions and structures of the woods.

The PCS and PCI values obtained showed that all species presented an energy performance that is in line with the standards required for use in the steel sector, with Myracrodruon urundeuva standing out for its higher calorific value.

The energy efficiency observed during the analyses suggests that the use of charcoal from these species is not only feasible, but also potentially advantageous from an economic and environmental point of view, considering aspects such as sustainability and emission reduction.

Finally, it is recommended that future investigations include the evaluation of other parameters of interest, such as the influence of different pyrolysis conditions, to further optimize the viability of these woods as energy sources.

PRODUCTION AND CHARACTERIZATION OF ACTIVATED CHARCOAL

A study was developed on the optimization of processes for the production of activated charcoal from the charcoals obtained, characterizing its properties (porosity, surface area, absorption capacity).

The analysis of the production and characterization of activated charcoal from the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis showed promising results in relation to porosity, surface area and absorption capacity, in line with the standards required for industrial applications.

Innovations in the production process contribute not only to the effectiveness of the material obtained, but also to the sustainability of the sector. Future studies should focus on the continuous optimization and exploitation of new species, ensuring the economic viability and environmental effectiveness of this resource.

SUSTAINABILITY ANALYSIS

Sustainability was evaluated regarding the production of charcoal and activated charcoal, considering economic, social and environmental aspects associated with the use of native species of the Cerrado biome.

The results of the analyses indicate the predominant chemical composition of the coals, evidencing the presence of compounds that can influence the energy and absorption properties. The analysis of moisture, ash, volatiles and fixed carbon were fundamental to evaluate the calorific value of the coals produced from the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis.

Thermal decomposition showed how these materials behave during pyrolysis, revealing information about their thermal stability and the efficiency of the carbonization process.

The production of charcoal from species native to the Cerrado, when carried out in a sustainable manner, minimizes environmental impacts, especially when compared to the use of wood from reforestation or native forests at risk. The analysis of biodiversity and the use of sustainable agricultural practices should be highlighted.

The economic viability of activated and vegetable carbon production can be assessed by comparing production costs and analyzing the market in relation to the demand for coal for different applications, including the steel sector and water purification, for example.

The involvement of local communities in the cultivation and management of native species can promote socioeconomic development, ensuring respect for cultural practices and strengthening the local economy.

Based on the data, the feasibility of using charcoal produced from native species as sources of energy and activated material is encouraging. The porosity, surface area, and absorbency properties obtained in the tests indicate considerable potential for industrial applications.

The sustainable production of charcoal and activated charcoal can occur without compromising local biodiversity, as long as responsible management and collection standards are respected.

It is recommended that there be policies that encourage research and the adoption of sustainable practices in the management of native species, as well as the certification of products.

Investing in more studies that explore different carbonization and activation processes can increase the efficiency and sustainability of production.

Involve local communities in the production and marketing of coal to ensure that the economic benefits are redistributed.

The production of charcoal and activated charcoal from native species of the Cerrado biome presents itself as a sustainable and promising alternative that can meet energy and industrial demands, as long as it is accompanied by a commitment to environmental preservation and social development.

COMPARISON BETWEEN SPECIES

The properties of charcoal produced from the three species were compared in terms of quality, yield and applicability, both for energy purposes and for the production of activated carbon.

After analyzing the properties and yield of charcoals from Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis, it is concluded that: Myracrodruon urundeuva has the highest calorific value, standing out as an excellent energy source, while

Tachigali Vulgaris demonstrates greater potential in the production of activated carbon due to its greater porosity.

In terms of sustainability, the use of these native species not only contributes to the conservation of the Cerrado biome, but also promotes economic and social benefits for local communities. To ensure economic and environmental viability, it is recommended to adopt sustainable forest management practices and continuous research into optimization processes in charcoal production.

STUDY OF COMPATIBILITY WITH INDUSTRIAL PROCESSES:

The compatibility and efficacy of charcoals obtained in existing industrial processes in the steel sector were investigated, identifying possible necessary adaptations.

Thus, one of the objectives of this study was to evaluate the properties of charcoals produced from native species and their compatibility and effectiveness in industrial processes, especially in the steel sector.

The properties analyzed included:

The presence of compounds that can impact the efficiency in combustion and quality of coal was evaluated.

Measurements of density, porosity and surface area were carried out, which influence the energy efficiency and absorption capacity in activated carbon.

Thermal decomposition and thermogravimetric analysis helped to understand the behavior of coals during pyrolysis, which is crucial for optimizing their industrial use.
The comparison between the different species analyzed revealed significant differences in terms of:

Charcoal Quality: Differences in chemical composition directly impacted the calorific value.

Yield: Some species showed higher yield in charcoal production, which can be a decisive factor in the choice of raw material.

Applicability: The versatility of charcoal produced for energy purposes and as a raw material for activated carbon was evaluated, highlighting the best options for industrial uses.

The compatibility analysis revealed which charcoal species proved to be more efficient in their use in steelmaking processes and the adaptations needed to optimize the use of charcoal, including possible modifications in the production process or in the conditions of use to maximize efficiency.

The sustainability of charcoal production was considered, emphasizing the importance of practices that respect environmental, social and economic guidelines, especially in the context of native species of the Cerrado biome.

Suggestions were proposed for improvements in existing processes, such as the adoption of more efficient and sustainable technologies for the production of charcoal and its application in industry.

Recommending the continuity of research on the behavior of charcoals in other industrial contexts and their economic and environmental viability.

The analysis showed that the choice of plant species and the production process play a crucial role in the quality and effectiveness of charcoal. The integrated use of the results will allow an advance in the promotion of sustainability and efficiency of industrial processes in the steel sector.

PROPOSALS FOR SUSTAINABLE FOREST MANAGEMENT:

Suggestion of sustainable management practices for the harvest and use of the species studied, promoting the conservation of the Cerrado biome while taking advantage of its resources.

Sustainable management proposals that ensure the conservation of native species, such as the rotation of harvesting areas, the protection of spring areas, and the restoration of degraded habitats.

Suggestion of techniques that minimize environmental impact, preserving biodiversity and soil, such as the use of agroforestry techniques.

Importance of involving local communities in forest management, ensuring that practices respect traditional knowledge and promote socioeconomic development.

The results of this study can serve as a basis for sustainable forest management policies, promoting the conservation of the Cerrado while using its resources responsibly.

Importance of a balance between economic exploitation and environmental preservation, pointing out the social and economic benefits that sustainable practices can bring to local communities.

Suggestions for further research that explores other native species and their applications, continues the evaluation of the impacts of management practices, and delves deeper into ecological interactions within the Cerrado biome.

CONCLUSIONS

Regarding the physical characterization of the charcoal, it was found that the values of the basic density were reasonably higher for the species Myracrodruon Urundeuva, with very similar results for the two methods used.

The species Tachigali vulgaris showed a higher porosity, resulting in a greater capacity for liquid absorption and a more efficient burning, due to the greater surface area available. The species Myracrodruon urundeuva showed an intermediate porosity, balancing durability and efficiency in combustion and the species Amburana cearensis showed a porosity similar to that of Tachigali vulgaris.

The best quality species for charcoal considering the moisture content is Tachigali Vulgaris (13.10%), which presented a similar moisture content to Myracrodruon Urundeuva (13.97%). In order, the best species were: Tachigali Vulgaris, Myracrodruon Urundeuva and Amburana Cearensis.

For the chemical composition, the species Amburana Cearensis is the one that comes closest to the production of good quality charcoal.

Regarding the higher calorific value, a trend of a higher result was observed for the species Myracrodruon Urundeuva.

Immediate analysis of charcoal indicated the highest volatile material content (28.60%) for the species Amburana Cearensis, for the fixed carbon content the species Myracrodruon urundeuva presented the highest value (74.95%) while the species Amburana Cearensis, presented the value (66.26%) and Tachigali vulgaris (72.98%) for the ash content the species Amburana Cearensis presented the highest value (5.14%) while the species Myracrodruon urundeuva presented the highest value (74.95%) while the species Amburana Cearensis presented the highest value (5.14%) while the species Amburana CearensisMyracrodruon urundeuva had the lowest index (2.12%).

Myracrodruon urundeuva may be preferred in situations where higher energy efficiency is desired, while Amburana cearensis may be more indicated when the production of volatile materials is more advantageous.

The results obtained for the PH are associated with soils that have a pH that varies from acid to neutral, therefore in accordance with the existing literature for the case.

It is verified that the results obtained for the decomposition rate were compatible, coherent and aligned with what is indicated in the pertinent literature on the subject.

The presence of microorganisms significantly affects both the carbonization efficiency and the quality of charcoal produced from the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis. The practice of sustainable management and control of microbial infestation are essential to the processes.

The dismissal of the species Tachigali vulgaris, Myracrodruon urundeuva and Amburana cearensis from the Cerrado biome for charcoal production results, according to the results obtained, in severe consequences for local biodiversity and essential ecosystem services.

To mitigate these impacts, it is essential to consider sustainable management methods and alternatives to charcoal production that minimize the removal of native species, such as the use of agricultural residues or the implementation of silvicultural systems that seek conservation.

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USE OF ETHANOLIC EXTRACT OF PEAR ORANGE PEEL IN THE CRYOPRESERVATION OF BOVINE SPERMATOZOA

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ABSTRACT

Brazil is the country with the largest commercial cattle herd, and with that, there is a need to increasingly improve the efficiency of the processes involved in this sector. For this, biotechniques applied to reproduction, such as cryopreservation, are used. In order to avoid the damage caused by this technique, seminal diluters are used. However, the standard dilutors routinely used have ingredients of animal origin, such as egg yolk and skim milk. These are difficult to standardize and present a risk of contamination. There is therefore a great interest in the development of plant-based extenders. Orange is a fruit rich in secondary metabolites, such as carbohydrates and phenolic compounds, these are related to its antioxidant activity. In Brazil, the pear orange (Citrus sinensis (L.) Osbeck) is the most important citrus variety and its use by the juice industry generates tons of agricultural waste, mainly from its peel. This work seeks to use pear orange peel, a residue with possible bioactive potentials, for the production of crude extract. These can be beneficial within the formulation of a seminal diluter due to their antioxidant and antimicrobial characteristics. Thus, this study aimed to evaluate the use of ethanolic extract from the husk in the production of a new extender for the conservation of bovine spermatozoa. The ethanolic extract of orange peel was obtained and characterized for its phytochemical composition, antioxidant potential and antimicrobial activity. After obtaining, the ethanolic extract was included in sperm freeze thinners, with or without the presence of egg yolk and addition of 10 and 20% of this extract. The results showed that the ethanolic extract of orange peel has alkaloids, steroids, tannins and flavonoids, in addition to a high concentration of reducing sugars and antioxidant potential, however, the sperm evaluations indicated that there was no difference between the standard diluter added to the extract and the standard extender alone. In view of these results, it is concluded that the ethanolic extract of orange peel should be better evaluated for its cryoprotective potential in bovine sperm cells.

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INTRODUCTION

According to the Confederation of Agriculture and Livestock of Brazil, the second place in the ranking of the gross value of production of Brazilian agriculture is occupied by beef cattle, with R$ 183.31 billion, in 2023 (CNA, 2024). To achieve these expressive numbers, biotechniques applied to reproduction are commonly used, such as artificial insemination, embryo transfer and cryopreservation of oocytes, sperm and embryos (CARVALHO; DICK; CARMO, 2023).

Seminal cryopreservation is an important technique within livestock, as it allows the storage of samples from animals with high genetic and commercial value, enabling their use for a long period of time (ZUIDEMA; KERNS; SUTOVSKY, 2021). In addition, it also contributes to the conservation of endangered species (BOLTON *et al.*, 2022), reduces risks and costs with the acquisition and transport of breeding stock and minimizes the possibility of introducing transmissible infections via semen in a region and/or country and the transmission and spread of sexually transmitted infections among herds (QUELHAS *et al.*, 2023).

Even with the best preservation techniques, post-thaw survival rates are still low, with an approximate viability reduction of around 50%, considering the initial population of spermatozoa submitted to freezing. In order to minimize the damage caused by the cryopreservation process, a seminal extender is added to the cells, which must have adequate pH and osmolarity values and also provide protection to the morphological structure of the spermatozoa, keeping it viable even in the face of injuries caused by the cryopreservation process (BUSTANI; BAIEE, 2023).

However, the standard extenders used in these techniques currently use components of animal origin, such as egg yolk and skim milk. These are difficult to standardize and present a risk of microbial contamination. Therefore, it is of great interest to research additives that contribute to the reduction of cryoinjuries and the growth of microorganisms (SOUZA *et al.*, 2023).

Orange (Citrus sinensis), fruit of the tree of the Rutaceae family, is rich in secondary metabolites, such as carbohydrates, phenolic compounds, flavonoids, among others (BERNARDI *et al.*, 2010). In Brazil, the pear orange [Citrus sinensis (L.) Osbeck] is the most important citrus variety, being widely used by the industry, as well as by the domestic and foreign markets of fresh fruit.

As a consequence of the industrial activity of food processing, such as juice extraction, a large volume of waste is generated, whose destination can be problematic, as it occupies large spaces, and when poorly managed can represent environmental risks, such as water and soil pollution, in addition to risks to the health of the population (FARHAT *et al.*, 2011). According to Law No. 12,305 of August 2010, of the National Waste and Solids Policy (BRASIL, 2020), all use alternatives must have been exhausted for a waste to be considered waste.

Therefore, it is increasingly important to develop and apply new technologies that lead to the use and transformation of this waste into co-products. When outlining formulations of extenders for sperm cryopreservation with defined composition and protective activity, the search for residues that could contain cryoprotective properties was considered. In this context, the alternative of using orange-pear peel emerges, representing the residues from the manufacture of juices, as raw material for the production of co-products, such as crude ethanolic extract and essential oil (FERRONATO; ROSSI, 2018).

Based on the above, when considering the economic impact and environmental importance of the use of orange residues, in view of the antioxidant and antimicrobial potential from orange peel, the objective of this work was to evaluate the effect of extenders added to the ethanolic extract of pear orange peel on the conservation of bovine epididymal spermatozoa.

METHODOLOGY

This study was developed in three stages, the first refers to obtaining and characterizing the ethanolic extract of orange peel; the second, the post-dilution tests of the extract in the diluter commonly used for cryopreservation and the third, the tests with the freezing of epididymal spermatozoa from cattle

OBTAINING AND CHARACTERIZING THE ETHANOLIC EXTRACT OF ORANGE PEEL

Obtaining and Preparing Orange Peel

Pear-type orange peels [*Citrus sinensis* (L.) Osbeck] acquired in João Pessoa-PB (7°06'35.5"S 34°49'55.3"W) were used. The peels were washed under running water, dried, weighed and placed in an oven (60 °C) for three days. Subsequently, the dry peels were removed and previously crushed in a mixer, with subsequent crushing in a blender, until the formation of a fine powder, which was weighed, stored and wrapped in aluminum foil, kept at room temperature until its use in the next step.

Elaboration of ethanolic extract from orange peel

127 grams of the dry peel powder obtained in the previous stage were used. The powder was placed in an Erlenmeyer and 1.2 liters of 95% ethanol (v/v) were added, following the approximate ratio of 1:10, referring to the peel and solvent, respectively.

This mixture was filtered every three days. At each filtration, the liquid fraction was separated in another Erlenmeyer and the solid material was maintained, along with it was added another 1.2 liters of ethanol. This process was repeated three times and all liquid fraction obtained was taken to the rotevaporator for drying and obtaining the ethanolic extract.

Phytochemical screening

The phytochemical screening was performed to qualitatively identify the presence/absence of five groups of chemical compounds in the ethanolic extract, namely: alkaloids, steroids, tannins, flavonoids and saponins. For all groups analyzed, the test was performed using 20 mg of the crude extract in glass test tubes. The methodology was used according to the description of Melo *et al.* (2024).

Quantification of reducing sugars by the DNS method

The DNS method is based on the reduction of 3,5-dinitrosalicylic acid to 3-amino-5-nitrosalicylic acid at the same time that the aldehyde group of the sugar is oxidized to the carboxylic group, with the development of a reddish coloration, read in the spectrophotometer at a wavelength of 540 nm (MILLER, 1959).

Different dilutions made with the crude extract previously obtained and distilled water were used. In glass test tubes, 0.5 mL of the sample and 0.5 mL of the DNS reagent were added, this mixture was stirred in vortex and incubated in a thermostabilized bath at 90 °C for 5 minutes. After this period, the sample was cooled in ice water to room temperature. Then, 3.0 mL of distilled water was added (Figure 15) and the absorbance at 540 nm was verified in a UV-visible double-beam spectrophotometer model IL-0082-Y-BI. The white of the analysis was prepared with 0.5 mL of distilled water instead of the sample, following the same procedure.

The absorbance values of the samples at the different dilutions were compared with a standard curve of reducing sugars (glucose and fructose) previously prepared following the same method, allowing the conversion of the absorbance read into glucose concentration in grams per liter or milligrams per milliliter (SANTOS *et al.*, 2017).

Nuclear magnetic resonance (NMR) of hydrogen 1H and carbon 13C

The NMR spectra of 1H hydrogen and 13C carbon in the APT technique were recorded in a nuclear magnetic resonance spectrometer (Bruker, Ascend model), operating at 400 MHz for 1H and 100 MHz for 13C. For the analysis, the sample was prepared by dissolving 20 mg of ethanolic extract in methanol (Cambridge Isotope Laboratories). The sample was placed in the tube suitable for the NMR equipment with an internal diameter of 5 mm, and then it was inserted into the equipment to obtain the spectra (Figure 1).

Figure 1: Materials and equipment used in the nuclear magnetic resonance technique

Source: Authorship (2022).

Determination of total phenolic compounds (CFT) content

The Folin-Ciocalteu method was used, which takes its name from the main reagent used in the technique. This reagent is yellow in color, but when in contact with reducing agents (phenolic compounds) at alkaline pH, there is a change in color to blue. This change allows an estimate of the concentration of these compounds to be obtained. For this, a calibration curve of the standard was used, with gallic acid, in different concentrations. The samples and calibration curve were read on a spectrophotometer at a wavelength of 765 nm. The results were expressed in milligrams of gallic acid equivalent per gram of sample (mg EAG/g sample).

Before starting the test, the reagents used in the analyses (Appendix II) were prepared and the 1.0 mg/mL sample solution of the ethanol extract in methanol was prepared.

For the test, an aliquot of 120 µL of the sample solution and 500 µL of the 10% Folin-Ciocalteu reagent was added to a microtube, this reaction was maintained for 8 minutes. After this period, 400 µL of the 7.5% sodium carbonate solution was added, this reaction was performed and maintained under the shelter of light and at room temperature for two hours. At the end, 200 µL of the samples were transferred to a 96-well plate, which was read on a spectrophotometer at a wavelength of 765nm. The white was prepared with 120 µL of the sample solution of the ethanolic extract plus 900 µL of distilled water.

Determination of antioxidant potential by the DPPH method

To perform the test, plates from 96 flat-bottomed wells were used, in which each well had 100 µL of the samples (including the positive control) added. After that, under a light shelter, 100 µL of DPPH solution (Sigma-Aldrich) at 0.3 mM was added to each well. For the preparation of the blank, 100 µL of the sample and 100 µL of methanol were used, and for the negative control, 100 µL of the DPPH solution at 0.3 mM and 100 µL of methanol were used (BRAND-WILLIAMS *et al.*, 1995).

The plate was kept in the dark for 30 minutes without shaking. After this time, the absorbance was measured in a multidetector microplate reader (Biotek, Synergy HT model), at a wavelength of 517 nm. From the values obtained from the equipment, the value of the percentage of free radical scavenging (% SRL) or also known as percentage of inhibition (% I) was calculated for each sample (Equation 1).

Equation 1: Free Radical Scavenging Percentage Equation

$$\%SRL \ ou \ \%I = \left[\frac{(Absorbância \ do \ controle - Absorbância \ da \ amostra)}{Absorbância \ do \ controle}\right] x100$$

The values of the concentration necessary to reach the IC 50 were also calculated, referring to the concentration necessary to reduce the initial concentration of the DPPH radical in solution by 50%. This value was found from the plot on a graph, in which the X axis was the sample concentration, and the Y axis was the mean percentage of inhibition (% I) (DUARTE-ALMEIDA *et al.*, 2006).

For the ethanolic extract, tests were carried out with stock solutions of 1, 2 and 3 mg/mL in methanol. Finally, for the extenders, the same ones were used as standard solutions already ready in their final dilution, which was used for the sperm evaluations.

POST-DILUTION TESTS OF ETHANOLIC EXTRACT OF ORANGE PEEL IN SEMINAL EXTENDER

Experimental design of tests with ethanolic extract of orange peel

For the tests with the ethanolic extract (n=6), it was diluted in water in a ratio of 1:100. This aqueous solution was used to formulate the tested dilutors. Therefore, the experimental groups used for the ethanolic extract tests were:

- Control Group: Tris-gema;
- Dilute Ethanolic Extract Group 1 (EE1): Tris-yolk + 10% of the aqueous solution of the extract;
- Dilute Ethanolic Extract Group 2 (EE2): Tris-yolk + 20% of the aqueous solution of the extract;
- Dilute Ethanolic Extract Group 3 (EE3): Tris + 10 % of the aqueous solution of the extract;
- Dilute Ethanolic Extract Group 4 (EE4): Tris + 20% of the aqueous solution of the extract;

Microbiological tests

The microbiological tests aimed to evaluate the antimicrobial potential of the orange-pear peel extract included in the cryopreservation diluter, Tris-yolk (3.605 g of Tris-hydroxymethylaminomethane; 2.024 g of citric acid; 1.488 g of fructose; 100 mL of bidistilled water; 20% of egg yolk; 5% of glycerol) or in the buffer solution of Tris (3.605 g of Tris-hydroxymethyl aminomethane; 2.024 g of citric acid; 1.488 g of fructose; 100 mL of bidistilled water; 5% glycerol).

To perform the microbiological tests, the following groups were used: Tris-yolk + 10% ethanolic extract, Tris-yolk + 20% ethanolic extract, Tris + 10% ethanolic extract and Tris + 20% ethanolic extract. The method of microdilution in 96-well flat-bottomed plates was used. A plate was reserved for each bacterium used, namely: the standard strains Staphylococcus aureus UFPEDA02, Klebsiella pneumoniae ATCC-13883, and the isolate Escherichia coli AV12. The three species used in this work are part of the WHO list of priority bacteria (Asokan *et al.*, 2019). The AV12 isolate has a multidrug-resistant characteristic, with resistance to amoxilin, cephalexin and cephalothin, and sensitivity to ciprofloxacin, gentamicin, imipenem, meropenem, norfloxacin and sulfonamide.

The microorganisms were isolated from a recent three-day culture and were suspended in saline solution (0.9% NaCl) until the standardized turbidity of 1.0 on McFarland's scale was obtained.

Determination of the minimum inhibitory concentration (MIC)

Initially, a serial dilution of each diluter was performed to obtain the following concentrations: 20%; 10%; 5%; 2,5%; 1.25% and 0.25% of the ethanolic extract. Each concentration was performed in triplicate.

In each well of the 96-well plate, an aliquot of 100 μL of sterilized Mueller-Hinton juice was added. Soon after, 100 μL of the test diluter was added to the first well and with the highest concentration of the serial dilution, at a concentration of 40%, so that the concentration in this well reached 20%. A volume of 100 μL was then removed from the well, being taken to the next one, following the concentrations already mentioned above. At the end, a 10 μL aliquot of the bacterial cell suspension to be analyzed was added to each well. The plates were wrapped by plastic film and were kept for 48 h in an oven at a temperature of approximately 37 °C.

The value of the minimum inhibitory concentration was determined as the lowest concentration which presented absence of turbidity, which indicates absence of bacterial growth (GENHARTDT *et al.*, 1994).

Determination of the minimum bactericidal concentration (MBC)

To determine the minimum bactericidal concentration, redox reazurin dye was used. This molecule has a blue color, and when it enters the cell that is viable and with normal metabolic activity, this compound undergoes reduction reactions resulting in resorufin, a pink molecule that has fluorescence (GENHARTDT *et al.*, 1994). The test consisted of applying a 10 μL aliquot of resazurin in each well of the plates used in the previous test. After an incubation time of two hours, at room temperature and on a benchtop, the plates were analyzed for their resulting staining.

SPERM FREEZING TESTS WITH THE ADDED EXTENDERS OF ETHANOLIC EXTRACT OF ORANGE PEEL

Obtaining epididymal sperm from bovine animals

Testicle complexes/epididymis of mixed-breed cattle were obtained from a slaughterhouse located in the city of Santa Rita/PB (7°07'10.7"S 34°59'33.7"W) and transported in a cooler to the Laboratory of Biotechnology in Animal Reproduction of the Federal University of Paraíba (Campus I). In the laboratory, the epididymis and vas deferens were separated from the testicle, tied with a string so that there was no extravasation of its internal contents, cut and sanitized with saline solution (0.9% NaCl) at room temperature (FARIAS *et al.*, 2019).

The spermatozoa were isolated by the flotation technique (Figure 2). Initially, the tail of the epididymis was sliced, avoiding the cutting of apparent blood vessels, and then this sliced region was immersed in 2.0 mL of sterile saline solution (0.9% NaCl) at 37 °C contained in slightly inclined Petri dishes.

Figure 2: Flotation technique to obtain bovine epididymal sperm

Source: Authorship (2022).

The spermatozoa obtained in the suspension were evaluated for motility (0-100%) and vigor (0-5). Samples with motility greater than 50% were homogenized in a 15 mL falcon tube for the formation of the pool (spermatozoa diluted in saline solution) in order to avoid alterations or variability between individuals in the experiment (ALMEIDA *et al.*, 2017).

1.0 mL of the pool obtained was distributed in eppendorf tubes, which were taken to the centrifuge (Solab Refrigerated Benchtop Centrifuge, model SL-706) for 10 minutes at 3000 rpm (revolutions per minute), with acceleration and deceleration of 120 seconds and at room temperature. Then, by pipetting, the largest possible volume of the supernatant saline solution was removed, keeping the pellet from the sperm cells. In all replications, the cells were resuspended in a volume of 2.0 mL of the diluter/group to be tested.

Pre-freezing sperm analyses

Evaluation of sperm motility

Sperm motility was performed by subjective evaluation expressed as a percentage, ranging from 0 to 100%, with the average of two evaluators. This analysis was performed using an optical microscope with a 40x objective. An aliquot of 10 µL of the sample was placed between the slide and the coverslip, which was evaluated.

Plasma membrane integrity test

The plasma membrane integrity test was performed using double staining with eosin and nigrosin dyes (CBRA, 2013). Eosin is a supravital dye that is unable to penetrate cells with their plasma membrane intact. On the other hand, in dead or injured cells, where there is no longer an integrity of the plasma membrane, eosin can penetrate the cell, and these have been stained pink. Nigrosin is responsible for giving the darkest contrast of the bottom of the slide, allowing a better visualization of the unstained spermatozoa (SWANSON;

BEARDEN, 1951). The unstained cells indicated the live cells, where there was no entry of the dye, and the pink cells represented cells with non-intact plasma membrane

25 μL of each experimental group, 25 μL of eosin-nigrosine dye solution and 50 μL of saline solution (0.9% NaCl) were added to a microtube. After dilution of these components, the stretching was performed from 10 μL of each sample, this stretching was also done on two glass slides. Next, 200 cells were counted with the aid of a brightfield microscope with a 40x objective. The value of stained and unstained cells was recorded for each experimental group both at 0 h, before freezing, and after thawing.

Plasma membrane functionality test

The hyposmotic test (HOST) was used to evaluate the functional integrity of the plasma membrane. This is based on the properties of maintaining osmotic balance between the intra- and extracellular environment (CBRA, 2013). In this technique, the sperm is incubated in a hyposmotic solution, in which water influxes until osmotic equilibrium is reached. Consequently to the entry and expansion of the membrane, there is the curling of the tail in a physiological process. If the membrane is not intact, either due to damage or death of the sperm, this reaction will not occur, resulting in a stretched tail (JEYENDRAN *et al.*, 1984). We have that, for the experiment, sperm cells with functional plasma membranes were considered those that had their tails curled and cells with non-functional plasma membranes were those that had a stretched tail.

For the test, 10 μL of each experimental group was diluted in a microtube together with 100 μL of the hyposmotic solution (50 mOsm/Kg H2O) (Appendix II). This solution was incubated in a water bath at 37 °C for 30 minutes. After incubation, 50 μL of a formaldehyde saline solution was added in order to stop the osmotic reaction. The evaluation was made by placing 10 μL of each solution on a slide, covered by a coverslip, and this was analyzed under an optical microscope with a 40x objective. 100 cells were counted and the number of cells with curled tails and stretched tails was noted for each experimental group.

Freezing and thawing of bovine epididymal sperm

For freezing (Figure 3), the samples were initially filled in 0.25 mL straws and sealed with polyvinyl alcohol. These straws were then placed in plastic bags and were submerged in a beaker with water at room temperature. This was taken to the refrigerator, kept at a temperature of 5 °C, for the refrigeration curve and subsequent maintenance at 5 °C for four hours, for equilibrium time (ALMEIDA *et al.*, 2017). After this period, they were subjected to a 15-minute liquid nitrogen vapor freezing curve (4 cm distance between the straws and the liquid nitrogen slide). Subsequently, the straws were immersed in liquid nitrogen and transferred to the cylinder, until the moment of evaluation.

Figure 3: Steps of freezing samples

Source: Authorship (2022).

Post-thaw sperm analyses

The samples were thawed at 37 °C in a water bath for 30 seconds and fractionated in microdilution tubes at 10 μL. The samples were diluted in saline solution (0.9% NaCl) in a 1:3 ratio and fluorescent probes were added (except for the samples submitted to kinetic evaluation), which will be described below. All probes were purchased from Sigma-Aldrich (St. Louis, MO, USA). The fluorophore stock solutions were prepared as follows: propidium iodide (25 mg/mL), JC-1 (5 mg/mL), and FITC conjugated with peanut agglutinin (FITC-PNA, 1 mg/mL) in phosphate buffer solution The working solutions were JC-1 (153 μM) in dimethyl sulfoxide (DMSO), FITC-PNA (0.04 mg/mL) and PI (0.5 mg/mL) in PBS and carboxyfluorescein diacetate (DIC; 0.46 mg/mL in DMSO). The evaluations were made soon after thawing and repeated again after 1 h in a dry bath at 37 °C (thermoresistance test).

Assessment of kinetic parameters

Sperm kinetics were analyzed using a computerized sperm analysis system (Sperm Class Analyzer - SCATM software, Microptics, v. 5.1, S.L., Barcelona, Spain). An aliquot (5 µL) of each sample was deposited on a previously heated slide (37 °C), covered with coverslip and analyzed by phase contrast microscope (100x magnification; NikonTM H5505, Eclipse 50i, Tokyo, Japan) and images were captured using a video camera (Basler Vision TechnologyTM A312FC, Ahrensburg, Germany) (Figure 16). For each sample, five non-consecutive fields were analyzed, randomly selected, with a record of at least 2,000 spermatozoa.

The following variables were evaluated: total motility (MT; %), progressive motility (MP; %), curvilinear velocity (VCL; µm/s), straight-line velocity (VSL; µm/s), mean travel velocity (VAP; µm/s), linearity (LIN; %), straightness (STR, %), oscillation index (WOB, %), lateral amplitude of the sperm head (ALH, µm) and flagellar crossbeat (BCF, Hz). The values were measured with the following configurations: temperature of 37 °C; 100x magnification; number of images, 25; images per second, 25; head area, 4 to 75 µm²; VAP: slow 10 µ/s < medium 45 µ/s < fast 90 µm/s; progressivity, 75% STR, 50% LIN(VERSTEGEN; IGUER-OUADA; ONCLIN, 2002).

Plasma membrane integrity (iMP)

Plasma membrane integrity (iMP) was evaluated according to Araújo Silva *et al.* (2019), by the double staining method of propide iodide (IP) and carboxyfluorescein diacetate (DIC) fluorophores, detected by the inclusion of PI in the cell nucleus. The previously diluted sample was stained with 5.0 µL of DIC and 5.0 µL of PI and incubated for a period of seven minutes at 37 °C. Spermatozoa were evaluated using DBP 485/520 nm and DBP 580–630 nm excitation filters. Sperm stained green were found to be intact and those stained red were considered to have a damaged membrane.

Mitochondrial Membrane Potential (PMM)

For this test, 5 µL of JC-1 (5', 6.6' iodide – tetrachlore - 1, 1, 3, 3' – tetraethylbenzimidazolylcarbocyanine; 153 µM) was added to each sample and incubated for 7 minutes, then evaluated under the fluorescence microscope. Green fluorescence (530 nm) indicates the formation of aggregated J monomers and orange (590 nm) indicates the formation of dimers as the mitochondrial membrane becomes more polarized. Thus, cells stained in orange were classified as having high mitochondrial membrane potential, while those stained in green were classified as having low membrane potential (ALMEIDA *et al.*, 2017).

Acrosomal Membrane Integrity (iAC)

The evaluation of acrosome integrity (iAC) was done by Fluorescein Isothiocyanate conjugated to peanut agglutinin (FITC-PNA). A 10 µL aliquot of the sample was used to make an air-dried smear. The slides were stained with aliquots of 20 µL of FITC-PNA and incubated in a humid chamber at 4 °C for 20 minutes in the absence of light. Then, the slides were immersed in PBS (Saline Phosphate Buffer) twice and air-dried. Immediately prior to the evaluation, 5.0 µL of UCD solution (4.5 mL glycerol, 0.5 mL PBS, 5.0 mg p-phenylenediamine, and 5.0 mg sodium azide) were placed on the slide and then covered with a coverslip. Spermatozoa were evaluated using an excitation filter BP 450–490 nm and LP emission 515 nm (ARAÚJO-SILVA *et al.*, 2019).

STATISTICAL ANALYSIS

The data were expressed as the mean and standard deviation of the replicates for each experiment. For the analysis of the data obtained, the T test and analysis of variance (ANOVA) were used for two samples and multiple samples, respectively. Values of $p < 0.05$ were considered statistically significant. The tests were carried out in the Past4 version 4.11 program.

RESULTS AND DISCUSSION

OBTAINING ETHANOLIC EXTRACT FROM ORANGE PEEL

A brown extract was obtained, with high viscosity and smell similar to that of orange peel essential oil.

CHARACTERIZATION OF THE ETHANOLIC EXTRACT OF ORANGE PEEL

Phytochemical screening

The results of the phytochemical screening indicated the absence of saponins and the presence of alkaloids, steroids, tannins and flavonoids. In the evaluation of saponin, there was no foam formation in the system. For alkaloids, steroids and tannins, there was precipitate formation, indicating the presence of these compounds in their respective tests. And for flavonoids, the result was positive due to the presentation of the color change of the system, showing a pink color after performing the test.

Similar data regarding the presence of these compounds in orange peel were described by Pereira *et al.* (2020), Silveira (2019) and Oliveira (2017). The presence of steroids may indicate a possible protection to the plasma membrane, since they have a composition similar to cholesterol, which promotes this protection to spermatozoa submitted to cryopreservation. Flavonoids may have antioxidant activity, which is important in the thawing of seminal samples, as it promotes balance after the high formation of oxidants after cryopreservation. Thus, the ethanolic extract of orange peel has functional characteristics for sperm cryopreservation.

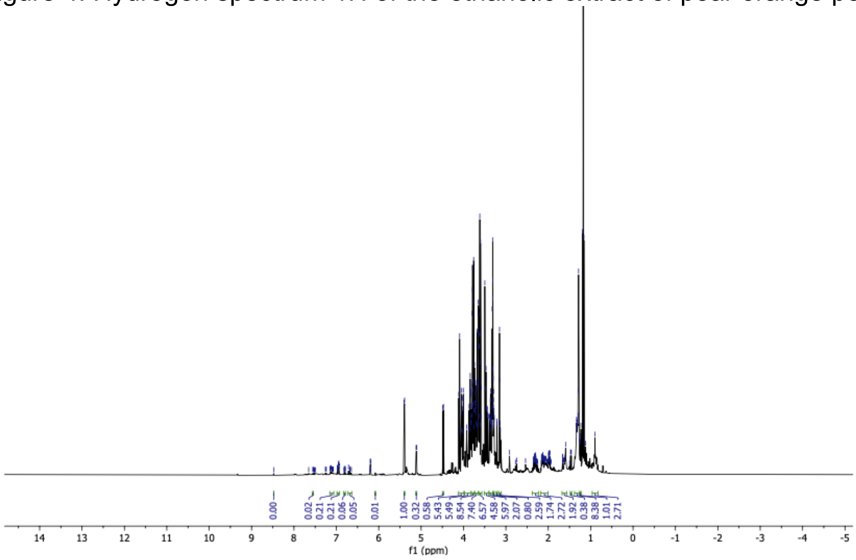
Quantification of reducing sugars by the DNS method

The concentration of reducing sugars found in the orange peel extract was 305±20 mg/mL. The soluble sugars in orange peel vary between 15 and 40% of the total weight, they act as an important substrate for biological processes (Ahmed *et al.*, 2016). Among them, the main sugars found are glucose, fructose and sucrose, but it is possible to find xylose and glycopolysaccharides in smaller quantities (Rivas *et al.*, 2008; Torrado *et al.*, 2011). The data obtained here indicate that the extract produced and used in this work has a high concentration of reducing sugars, this result is in line with other studies that have also performed this technique in different extracts of orange peel (Locatelli, Finkler, Finkler, 2019; Ayala *et al.*, 2021). Under the conditions of this experiment, the presence of sugars in the extract would act in two moments; sucrose, in the refrigeration/freezing phase, which can increase the osmolarity of the medium and promote cellular dehydration, important for the exit of water from the intracellular medium to the extracellular medium, preventing the formation of ice crystals within the sperm and, like glucose and fructose, providing substrate for post-thaw sperm motility, since mitochondria use this energy to convert into ATP and boost flagellar beating.

Nuclear magnetic resonance (NMR) of hydrogen 1H and carbon 13C

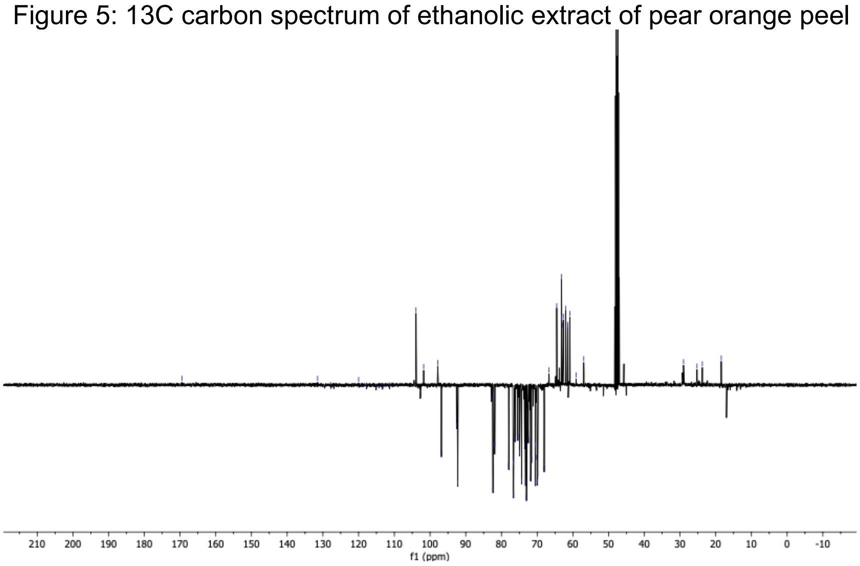
The 1H hydrogen spectrum of the ethanolic extract is indicated in Figure 4 and the 13C carbon spectrum is indicated in Figure 5.

Figure 4: Hydrogen spectrum 1H of the ethanolic extract of pear orange peel



Source: Authorship (2022).

Figure 5: 13C carbon spectrum of ethanolic extract of pear orange peel



Source: Authorship (2022).

Regarding the 1H spectrum, it was possible to perceive the presence of three distinct intervals, which indicate the presence of certain classes of chemical compounds. The first range is between 1.9 and 2.4 ppm (mg/kg), and shows signs of aliphatic hydrogens characteristic of terpene substances. The second range is between 3 and 4 ppm and presents a signal envelope of sugar or glycoside characteristics. The third range is between 6 and 8 ppm, and shows characteristic signs of aromatic substances.

From the 1980s onwards, the presence of carbohydrates began to be established using chemical displacement data, which can be evaluated by the NMR technique. H NMR signals around 4.5 to 5 ppm may indicate the presence of anomeric hydrogens from sugars, associated with the presence of multipets in the range of 3 and 4 ppm. As for the NMR spectra of C, the presence of carbohydrates can be given by the presence of signals between 90 and 115 ppm, corresponding to anomeric carbons, and signals around 70 to 80 ppm, relative to hydroxylated carbons. In addition to these, the presence of glycosides can be highlighted by the existence of a signal around 61 ppm (BORGES, 2008; GIL; GERALDES, 1987). The general aspect of the spectrum obtained in this work is very similar to the spectrum equivalent to the class of carbohydrates observed by Lima (2013), and can be considered as the group of major compounds present in this extract.

According to Pavia *et al.* (2016), hydrogens bonded to aromatic rings can be easily identified within the 1H chemical displacement range between 6.5 and 8 ppm. In this range, few other types of hydrogen will present absorption, thus characterizing a positive correlation when there is the presence of signals in this range, equivalent to the aromatic functional group in organic compounds. In addition, the presence of aromatic compounds, more specifically of the flavonoid class, can be reinforced by the presence of signals with chemical displacements close to 175 and 180 ppm in carbon spectra (Lima, 2013). The presence of this class of compounds in orange peel extracts was also found by Mencherini *et al.* (2012).

A similar result regarding spectrum disposition can be found in Pei *et al.* (2022), which identified and described in detail the presence of 102 orange components, from its peel to its juice, in different varieties of the fruit, based on the evaluation of nuclear magnetic resonance spectra.

Based on the results obtained by the NMR technique and the DNS technique, it can be considered that the ethanolic extract of the evaluated orange peel has a high concentration of carbohydrates, including reducing sugars.

Determination of total phenolic compounds (CFT) content

The spectrophotometric reading of the 1.0 mg/mL solution of the ethanolic extract resulted in an absorbance of 0.191. Thus, from the standard curve of gallic acid, this absorbance value indicated the presence of 340.88 mgEAG/100g of ethanolic extract. Regarding the ethanolic extract solution at a 1:100 dilution, which was used in the formulation of the extenders tested, the absorbance value obtained was 1.335 and, from the same standard curve, it corresponded to 2003.00 mgEAG/100g of crude extract.

The result obtained in this study (equivalent to 1.0 mg/mL) showed a higher CFT value compared to the commercial citrus extracts (142.19±8.35 mgGAE/g of extract) evaluated by Fiorentini *et al.* (2022). Chemically, orange peel extract is characterized by the presence of phenolic compounds with great antioxidant power. In general, there is this positive correlation between the total phenolic content and the antioxidant property of fruits and vegetables (KAUR; KAPOOR, 2002). However, other authors have not evidenced this correlation (ISMAIL; MARJAN; FOONG, 2004). Thus, it is necessary that in order to explain the antioxidant capacity of an extract, one must take into account factors other than its total phenolic content. The characterization of the structure of the active compound and its biological function should be observed (HEINONEN, LEHTONEN, HOPIA, 1998; MELO *et al.* 2018).

Determination of antioxidant potential by the DPPH method

Based on the standard Trolox curve (Appendix A), Tables 1 and 2 present the Trolox equivalent values for each concentration of the extract tested by the DPPH method and the T+10%EB and T+20%EB diluters. The data obtained for the TG+10% and TG+20% extenders are not described because it was not possible to perform this analysis, due to the presence of egg yolk that made it impossible to measure absorbance. The composition of the egg yolk, rich in proteins, when in contact with the DPPH solution diluted in methanol, triggered a protein denaturation, making it impossible to spectrophotometric evaluation of the samples.

Table 1: Antioxidant potential by the DPPH method for ethanolic extract of orange peel

Crude extract concentration	TEAC (µg/mL)
1.0 mg/mL	400,3
2.0 mg/mL	597,1
3.0 mg/mL	768,6

Source: Authorship (2022).

Table 2: Antioxidant potential by the DPPH method for the extenders used in sperm evaluations

Diluters	TEAC (µg/mL)
Tris	0,0
Tris+10%EB	409,0
Tris+20%EB	771,1

Source: Authorship (2022).

The result obtained at the concentration of 1.0 mg/mL already demonstrates that the ethanolic extract of orange peel used in this work has antioxidant activity, which is equivalent to 400 µg/mL of Trolox. As for the extenders that were possible to evaluate, we have that the Tris solution alone did not present antioxidant potential, as expected. On the other hand, the addition of the ethanolic extract solution, at concentrations of 10 and 20%, offered an antioxidant activity. Thus, it is concluded that the antioxidant activity obtained in the Tris+10%EB and Tris+20%EB extenders is due to the action of the crude extract and not to the Tris solution.

The antioxidant potential of fruits is the result of the synergistic action of several compounds, including polyphenols or phenolic compounds. However, the effectiveness of this antioxidant action depends on the chemical structure and concentration of these active ingredients in the extract (Kaur; Kapoor, 2002). The pear orange is described as a fruit with strong antioxidant properties, with a percentage of DPPH radical sequestration of more than 70% (Melo *et al.*, 2018). These data are in agreement with the results obtained here, since the orange peel extract used has a high concentration of phenolic compounds in its composition.

Determination of hydrogen potential

The pH value obtained for the ethanolic extract was initially 5. Table 3 shows the results of the pH measurement of the standard diluter based on Tris and egg yolk (Tris-yolk) and of the extenders formulated with the crude extract (EB), respectively.

Table 3: pH values of extenders with the crude extract of pear orange peel

Groups	**pH**
Tris-gem	7,0
Tris-gema + 10% EB (EB1)	7,0
Tris-gema + 20% EB (EB2)	7,0
Tris + 10% EB (EB3)	6,5
Tris + 20% EB (EB4)	6,5

Source: Authorship (2022).

The diluters added to the extract had higher pH values, being 7 for the groups added to the Tris-yolk, and 6.5 for the groups added to the Tris.

Sperm freezing should occur in the presence of seminal extenders, in order to minimize the damage caused by thermal shock, maintain the pH and adequate osmolarity for these cells (SALAMON; MAXWELL, 2000).

A buffer system must be one of the constituents of these dilutors, allowing the hydrogen ions produced by sperm metabolism to be neutralized, and thus, causing the pH of the solution to be maintained close to neutrality (6.8 to 7.1), optimal pH for spermatozoa (BORGES, 2008).

Since the extenders added to the orange peel extract present acceptable pH values for cryopreservation, maintaining the average pH of the standard extender commonly used, it can be stated that they present a promising alternative for this process.

Microbiological tests

Determination of minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC)

The values obtained for the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) for the extenders with the ethanolic extract of orange peel are shown in Tables 4 and 5, respectively.

Table 4: Minimum inhibitory concentration of extenders plus ethanolic extract of orange peel

	Staphylococcus aureus **UFPEDA02**	***Escherichia coli*** **AV12**	***Klebsiella pneumoniae*** **ATCC-13883**
TG+10%EB	0,75%	-	5,00%
TG+20%EB	1,25%	-	5,00%
T+10%EB	-	5,00%	10,00%
T+20%EB	0,75%	20,00%	20,00%

Source: Authorship (2022).

Table 5: Minimum bactericidal concentration of extenders plus ethanolic extract of orange peel

	Staphylococcus aureus **UFPEDA02**	***Escherichia coli*** **AV12**	***Klebsiella pneumoniae*** **ATCC-13883**
TG+10%EB	0,75%	-	0,75%
TG+20%EB	0,75%	-	1,25%
T+10%EB	5,00%	20,00%	10,00%
T+20%EB	20,00%	20,00%	20,00%

Source: Authorship (2022).

The TG+10%EB and TG+20%EB groups, at the concentrations used in the study (10 and 20%, respectively) inhibited growth and killed the colonies of Staphylococcus aureus UFPEDA02 and Klebsiella pneumoniae ATCC-13883, but not of Escherichia coli AV12. This result may be related to the multidrug-resistant characteristics of the latter species, which is more difficult to inhibit. Despite this, due to their inhibitory and bactericidal properties of the other two bacteria, these groups can be considered to have antimicrobial activity. This potential is interesting for these groups, since the crude extract added to the diluter makes it possible to use the egg yolk, an ingredient that naturally presents high risks of contamination, in a safer way.

As for the T+10% and T+20% groups, these also inhibited bacterial growth and made the cells unviable, this time for the three bacteria tested. However, the concentration values required for this were higher than previously observed. It is then clear that the crude extract of orange peel has antimicrobial activity for the microorganisms tested.

The chemical composition of orange (Citrus sinensis) residues indicates the presence of carbohydrates, flavonoids, glycosides, coumarins, volatile compounds, organic acids and oils (OIKEH; ORIAKHI; OMOREGIE, 2013) Among these groups, phenolic compounds, essential oils, tannins, alkaloids, flavonoids and saponins are the molecules considered responsible for the antimicrobial effect in this plant (RAHMAN *et al.*, 2011) The synergistic action of these compounds is described in terms of inhibition of the growth of pathogens (NWANKWO; ONWUAKOR; ANINWEZE, 2014).

The results of these analyses are similar to those obtained by Shetty *et al.* (2016), El-Desoukey *et al.* (2018), Baba *et al.* (2018) and Oikeh *et al.* (2020), who also investigated the antimicrobial activity of orange peel extract on pathogenic bacteria and different fungi. These authors suggest that the antimicrobial activity of this extract is the result of the synergistic action of the phenolic compounds, flavonoids and tannins present in the sample.

Pre-freeze sperm tests

Evaluation of sperm motility

The mean values of sperm motility in the post-dilution and post-thawing are indicated in Table 6.

Table 6: Total motility (%) of post-dilution and post-thaw bovine epididymal sperm with or without the addition of orange peel extract

	Tris-gem	**TG+10%EB**	**TG+20%EB**	**T+10%EB**	**T+20%EB**
Post-dilution (%)	75,0±5,2aA	79,1±3,7aA	80,8±3,4aA	19.1±13.1 bA	12.5±6.3b A
Post-thaw (%)	48.3±9.9aB	50.8±9.3aB	51.6±9.9aB	0,6±0,5bB	0,0±0,0bB

Source: Authorship (2022). Legend: Lowercase letters indicate difference ($p<0.05$) between the groups of the same condition (0 h or post-thaw) and uppercase letters indicate difference between the same group in the two conditions (0 h and post-thaw).

The addition of 10 and 20% of crude extract of orange peel obtained similar results to the control group (Tris-yolk) regarding sperm motility, both at 0h and post-thaw. There was a loss of motility in all groups after thawing, this process is already expected as a result of the cryoinjuries caused by the cryopreservation process (Silva; Guerra, 2011). The groups that contained only the Tris solution added to the crude extract, both at concentrations of 10 and 20%, did not show protection to bovine epididymal sperm cells, since they presented values well below those of the control group (at time 0h) and almost total loss of motility after thawing.

Plasma membrane integrity test

The mean values of spermatozoa with non-intact plasma membrane in the post-dilution and post-thawing are shown in Table 7.

Table 7: Plasma membrane integrity (%) of post-dilution and post-thaw bovine epididymal sperm with or without the addition of orange peel extract

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-dilution (%)	55,8±10,8aA	57,0±8,8aA	56,8±10,4aA	85.0±23.8bA	110.0±22.3bA
Post-thaw (%)	59,1±6,3aA	55,8±4,8aA	69,8±5,3bB	187,5±6,6cB	197,6±1,3dB

Source: Authorship (2022). Legend: Lowercase letters indicate difference (p<0.05) between the groups of the same condition (0 h or post-thaw) and uppercase letters indicate difference between the same group in the two conditions (0 h and post-thaw).

There was no difference (P>0.05) between the Tris-yolk and TG+10%EB groups, both for the 0 h and post-thawing time, as well as between them. There was an increase in the number of cells with non-intact PM in the TG+20%EB group after thawing, this increase is compared to the control group (Tris-gema) in the same condition and to the group itself at 0 h. As for the groups T+10%EB and T+20%EB, they presented higher values than the other groups, both at 0 h and after thawing.

This increase in the number of cells with non-intact PM indicates that the extract alone, and at these concentrations tested, does not have sufficient membrane protective action for bovine epididymal spermatozoa that will undergo the freezing process.

Plasma membrane functionality test

The mean values of spermatozoa with functional plasma membrane (curled tail) in post-dilution and post-thawing are indicated in Table 8.

Table 8: Plasma membrane functionality (%) of post-dilution and post-thaw bovine epididymal sperm with or without the addition of orange peel extract

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-dilution (%)	80,5±4,2aA	83,5±5,5aA	85,6±4,8aA	69.3±7.1bA	68.6±11.8bA
Post-thaw (%)	46.6±3.6aB	39.6±10.6aB	34.1±6.9aB	8,6±3,9bB	4,6±2,0bB

Source: Authorship (2022). Legend: Lowercase letters indicate difference (p<0.05) between the groups of the same condition (0 h or post-thaw) and uppercase letters indicate difference between the same group in the two conditions (0 h and post-thaw).

At the same time, there was no difference (P>0.05) between the control group and the Tris-yolk groups added to the crude extract, both for 10 and 20%. However, as well as the parameters of motility and membrane integrity, there was a statistical difference between the groups with only the crude extract and without the addition of egg yolk. Regarding plasma membrane functionality, for these two groups, there was a decrease in the number of cells with functional plasma membrane when compared to the control, both for the time 0 h and after thawing.

This result is complementary to the previous ones, and corroborates the understanding that the crude extract alone is not able to protect the plasma membrane of these cells. And since the damage to this structure is directly related to cell death, there is a notable decrease in sperm motility in these groups (MORAES; MEYERS, 2018).

Post-thaw sperm analyses

Assessment of kinetic parameters

From the data obtained, the values of total (Table 9) and progressive motility (Table 10) are described here.

Table 9: Total motility (%) of bovine epididymal sperm after thawing and after 1 h at 37°C, with or without the addition of orange peel extract

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-thaw (%)	55,2±20,0aA	66,7±15,5aA	57,5±9,0aA	8,3±2,6b	7,0±3,4b
1 h post-thaw (%)	40.5±15.7aB	48.6±17.1aB	43,0±8,0aA	0,0±0,0	0,0±0,0

Source: Authorship (2022). Legend: Lowercase letters indicate a difference (p<0.05) between groups of the same condition (post-thawing or after 1 h) and uppercase letters indicate a difference between the same group in both conditions (post-thawing and after 1 h).

Table 10: Progressive motility (%) of bovine epididymal sperm after thawing and after 1 h at 37°C, with or without addition of orange peel extract

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-thaw (%)	23,8±11,7aA	27,2±13,6aA	22,03±6,4aA	0,1±0,3b	0,1±0,2b
1 h post-thaw (%)	14.2±6.5aB	17.4±6.2aB	13.5±7.6aB	0,0±0,0	0,0±0,0

Source: Authorship (2022). Legend: Lowercase letters indicate a difference (p<0.05) between groups of the same condition (post-thawing or after 1 h) and uppercase letters indicate a difference between the same group in both conditions (post-thawing and after 1 h).

It is noted that there was no difference (P>0.05) between the control groups (Tris-yolk) and the TG+10%EB and TG+20%EB, both post-thawing and in the analysis after 1 h at 37 °C. On the other hand, there was a difference (P<0.05) between the same group in terms of time, and for the groups mentioned, there was a decrease in progressive and total motility in the evaluation after 1 h. Only the TG+20%EB group did not obtain statistical difference for total motility between the post-thaw analysis and after 1 h.

The T+10%EB and T+20%EB groups had both total and progressive motility lower than the control group, reaching values close to zero in terms of progressive motility. This evaluation, unlike the sperm motility previously assessed, was performed using a computerized and more robust method (ARRUDA *et al.* 2011). However, a correlation can be observed between the two results obtained, in which both show a decrease in sperm motility in the post-freezing condition.

Plasma membrane integrity (iMP)

The mean values of spermatozoa with non-intact plasma membrane (stained in red) after thawing and after 1 h are shown in Table 11.

Table 11: Plasma membrane integrity of post-thaw and post-1 h epididymal sperm at 37 °C

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-descong.	47,1±7,6aA	39,3±9,6aA	34.1±16.5bA	3,3±2,7c	1,0±2,4c
After 1h	42,7±11,4aA	41,0±14,4aA	33,8±11,3aA	-	-

Source: Authorship (2022). Legend: Post-descong. – Average of cells stained in post-thaw red; After 1h – Average of cells stained red after 1h; Data presented regarding the number of non-intact cells in 200 cells counted; Lowercase letters indicate a difference (p<0.05) between the groups of the same condition (post-thawing or after 1h) and uppercase letters indicate a difference between the same group in both conditions (post-thawing and after 1h).

There was no difference (P>0.05) between the control group (Tris-yolk) and the TG+10%EB group, both after thawing and in the evaluation after 1 hour. For the TG+20%EB group, in the post-thawing group, there was an increase, when compared to the control group, in the number of cells with non-intact plasma membrane. This statistical difference did not appear in the data obtained in the time after 1h. For T+10%EB and T+20%EB, there was an increase (P<0.05) in the number of cells stained red, indicating loss of plasma membrane integrity in these groups. This result presents an interpretation similar to the plasma membrane integrity test previously evaluated.

Mitochondrial Membrane Potential (PMM)

The mean values of spermatozoa with high mitochondrial membrane potential (stained orange) after thawing and after 1 hour are shown in Table 12.

Table 12: Mitochondrial membrane potential (MPP) of post-thaw and post-thaw epididymal sperm 1 h at 37 °C

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-descong.	64,0±28,9aA	65,5±17,7aA	68,9±22,5aA	4,8±3,4b	1,3±1,2b
After 1h	64,5±28,4aA	66,8±18,3aA	64,6±26,9aA	-	-

Source: Authorship (2022). Caption: Post descong. – Average of cells stained in post-thaw orange; After 1h – Average of cells stained orange after 1h; Lowercase letters indicate a difference (p<0.05) between the groups of the same condition (post-thawing or after 1h) and uppercase letters indicate a difference between the same group in both conditions (post-thawing and after 1h).

For PPM, there was no difference (P>0.05) between the control groups (Tris-yolk), TG+10%EB and TG+20%EB, both for post-thawing evaluation and for the time after 1h. There was also no difference between these two halves for the same group. Only the T+10%EB and T+20%EB groups showed statistical differences from the others, characterizing a decrease in the number of cells with high membrane potential.

Acrosomal Membrane Integrity (iAC)

The mean values of spermatozoa with intact acrosomal membrane (stained bright green) after thawing and after 1 h are shown in Table 13.

Table 13: Acrosomal membrane integrity (iAC) of post-thaw and post-thaw epididymal sperm 1 h at 37 °C

	Tris-gem	TG+10%EB	TG+20%EB	T+10%EB	T+20%EB
Post-descong.	69,5±17,3aA	73,4±14,8aA	74,5±16,8aA	49,1±19,0b	39,1±19,9b
After 1h	68,2±19,8aA	70,9±12,8aA	71,9±17,4aA	-	-

Source: Authorship (2022). Caption: Post descong. – Average of cells with intact acrosome after thawing; After 1h – Average of cells with intact acrosome after 1h; Lowercase letters indicate a difference ($p<0.05$) between the groups of the same condition (post-thawing or after 1h) and uppercase letters indicate a difference between the same group in both conditions (post-thawing and after 1h).

As in the previous test, there was no difference ($P>0.05$) between the control groups (Tris-yolk), TG+10%EB and TG+20%EB, both immediately after thawing, as well as in the evaluation after 1h. There was also no difference ($P>0.05$) for these groups between the values in the two times. There was a statistical difference for the T+10%EB and T+20%EB groups, with a decrease in the number of spermatozoa with intact acrosomal membrane.

From the data obtained in the post-thaw kinetic evaluations, it is concluded that the addition of pear orange peel extract, both at 10 and 20% concentrations, in general, did not present statistical difference to the control group (Tris-yolk).

In addition, it was possible to perceive that the groups with only the crude extract (10 and 20%), and that there was no presence of the yolk, showed that they did not protect bovine epididymal spermatozoa regarding the integrity and functionality of their plasma membrane, integrity of the acrosomal membrane and mitochondrial membrane potential.

The lack of protection for these structures (plasma membrane, acrosome and mitochondria) is related to the loss of motility (total and progressive) of these cells, especially when subjected to the freezing technique (SILVA; GUERRA, 2011).

The addition of antioxidant substances in the seminal extender is one of the factors that influence the improvement of sperm evaluation parameters, especially regarding sperm motility (total and progressive) (BOZZI, 2017; DANELUZ, 2016; TONIOLLI, 2012). The increase in these parameters indicates an increase in the quality of semen after thawing (KALTHUR *et al.*, 2011).

FINAL CONSIDERATIONS

The ethanolic extract of orange-pear peel has a high concentration of carbohydrates, including reducing sugars, a high concentration of total phenolic compounds, as well as antioxidant activity. Despite the antioxidant potential, the extenders formulated with 10 and 20% of the extract added to Tris-yolk did not show improvement compared to their absence regarding the parameters of post-thaw sperm evaluation. Extenders formulated only with Tris and the addition of crude extract (10 and 20%) are not efficient in the conservation of epididymal spermatozoa submitted to cryopreservation. Although the extenders tested in this study do not present cryoprotective activity, it is necessary to improve the methodologies used in the preparation of the extenders, in addition to new tests with different concentrations of the ethanolic extract, to evaluate its cryoprotective potential more deeply.

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PRODUCTIVE EFFICIENCY AND AGRICULTURAL SUSTAINABILITY: INTEGRATION OF QUANTITATIVE DATA FOR STRATEGIC PLANNING

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ABSTRACT

Modern agriculture faces challenges related to increasing productivity, conserving natural resources, and reducing environmental impacts. This study uses the robust *Agriculture and Farming Dataset*, available on the Kaggle platform, to explore yield efficiency and sustainability in different combinations of soil type and growing season. Data on agricultural practices, inputs, yield, and economic and environmental sustainability were analyzed. He focused on two contrasting combinations: Loamy-Zaid and Peaty-Kharif. The results indicate that Loamy-Zaid has higher absolute productivity (33.38 tons), but at the expense of higher input consumption (6.36 tons of fertilizers and 68,033.80 m³ of water). On the other hand, Peaty-Kharif demonstrates greater efficiency in the use of fertilizers (5.85 tons per ton of fertilizer) and water (0.00064 tons per m³), with lower cost per ton produced (163.20 currency units, against 197.11 for Loamy-Zaid). These results highlight the trade-offs between productivity and resource efficiency. The analysis of specific soil and season combinations revealed that edaphic and seasonal factors significantly influence yield. The Silty soil in Rabi proved to be ideal, reaching an average yield of 48.02 tons, while Peaty in Rabi exhibited severe limitations (3.86 tons), demonstrating the importance of customized management strategies. In addition, modern irrigation methods such as *drip* and *sprinkler* have shown higher water efficiency, although traditional methods such as manual irrigation have obtained higher yields in small farming systems.

The findings provide subsidies for more sustainable and productive agricultural practices. Optimized management strategies, such as soil amendment, use of biofertilizers, and advanced irrigation techniques, can align productivity, resource savings, and environmental sustainability. This study offers valuable guidance for researchers, farmers, and policymakers, promoting resilient and competitive agriculture in response to growing global demands for food and natural resources.

Keywords: Productive Efficiency. Agricultural Sustainability. Resource Management.

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INTRODUCTION

Agriculture plays an essential role in the global economy and in ensuring food security, being crucial to meet the demands of a growing population against a backdrop of climate change and limited natural resources (Domene et al., 2023). Faced with complex challenges, such as increasing productivity, conserving resources, and mitigating environmental impacts, the agricultural sector requires solutions based on integrated and detailed analysis. In this context, the use of data and quantitative models has become indispensable to understand the dynamics of agricultural systems, support decision-making, and promote practices that combine productive efficiency and sustainability.

This study is based on the *Agriculture and Farming Dataset*, available on the *Kaggle* platform, which offers a wide range of information on agricultural practices, crop yields, input utilization, and economic and environmental indicators. The dataset covers key variables such as crop types, soil characteristics, irrigation methods, and growing seasons, allowing for an in-depth analysis of the interactions between these factors and their effects on agricultural productivity. The wealth of information contained in this dataset provides a unique opportunity to identify patterns and propose strategies that balance productivity and environmental conservation.

Key aspects covered include:

1. Crop types: analysis of the predominant crops and their respective yield rates, considering different conditions.
2. Use of resources: evaluation of the allocation and efficiency in the use of water and fertilizers, with a focus on sustainability.
3. Sustainability indicators: examination of environmental impacts and economic viability of agricultural practices.
4. Economic data: detailed study of costs, revenues and profit margins, offering an integrated view of economic competitiveness.

The main objective of this work is to investigate how soil type and season combinations influence agricultural productivity, efficiency in the use of inputs and the sustainability of adopted practices, proposing strategies to optimize these interactions. To this end, the specific objectives include:

1. Evaluate the efficiency in the use of inputs such as fertilizers and water in relation to the production obtained.
2. Compare operating costs and sustainability between different combinations, identifying critical trade-offs.

3. Propose recommendations that maximize productivity while minimizing economic and environmental impacts.

The analysis focuses on two contrasting combinations of soil and season: Loamy-Zaid and Peaty-Kharif, selected for their distinct characteristics in productivity, input consumption and economic viability. The descriptive and inferential approach adopted explores patterns of resource use, operating costs and production efficiency, seeking to understand determinant factors for agricultural performance and propose practices that optimize the relationship between productivity and sustainability.

The results highlight that Loamy-Zaid has higher absolute productivity, although with high operating costs and significant consumption of inputs. On the other hand, Peaty-Kharif demonstrates greater efficiency in the use of resources, reduced costs per ton produced and greater economic sustainability, proving to be a viable alternative in scenarios of resource constraint. The interaction between soil characteristics and seasonal conditions proved to be decisive, reinforcing the importance of personalized approaches in agricultural management.

This study offers a significant contribution by deepening the understanding of the factors that affect agricultural performance, guiding farmers, researchers, and policymakers in building more resilient, productive, and sustainable agricultural systems. By integrating agronomic, economic, and environmental perspectives, the results provide a solid foundation for practices that meet the growing global demands for environmentally responsible food and economic competitiveness.

LITERATURE REVIEW

The literature on productive efficiency and agricultural sustainability highlights the need for integrated approaches that balance productivity, resource use, and mitigation of environmental impacts. In this context, sustainable management practices, the management of essential inputs, and climate-adaptive strategies emerge as fundamental pillars for building resilient agricultural systems. The analysis of recent studies highlights the complexity and opportunities of the Brazilian agricultural sector, reinforcing the role of strategic planning in promoting solutions that combine economic development with environmental preservation.

Ogino et al. (2021) analyze the interrelationships between mineral fertilizer prices, producers' purchasing power, and consumption in the Midwest of Brazil. Fertilizers are described as crucial inputs for productivity in poor soils, such as those in the Cerrado, but their dependence on imports exposes the sector to market volatility. Policies to stabilize prices and encourage research into alternative technologies are recommended to strengthen productive sustainability.

Castro et al. (2017) investigate the relationship between production value, productivity, and input use in Brazilian states, highlighting that the increase in fertilizer use between 1990 and 2012 boosted agricultural productivity, even in the face of territorial expansion limitations. This intensification, although essential, reinforces the need for practices that maximize efficiency gains without compromising natural resources.

Paz et al. (2002) emphasize the importance of uniformity in sprinkler irrigation as a determining factor to maximize economic efficiency and reduce environmental impact. Optimized water management, saving up to 18.64% of water, is essential to sustain productivity in scenarios of resource scarcity and climate variability.

Montoya and Finamore (2020) discuss the relationship between water resources and agribusiness, highlighting the water dependence of the agricultural sector, responsible for 90% of water consumption in Brazil. The study reinforces the need for practices that optimize the use of water, ensuring greater economic and environmental efficiency in the face of a scenario of growing water scarcity.

Novak et al. (2021) highlight that sustainable management practices, such as planting native species and the absence of mechanization, are key to restoring soil chemical quality and promoting long-term agricultural sustainability. These practices reinforce the importance of ecological stability in productive performance.

França et al. (2021) point out the relevance of soil physical properties, such as texture and porosity, for maintaining fertility and reducing erosion. Proper management of organic matter and preservation of soil aggregates are crucial for production efficiency and environmental balance.

Oliveira et al. (2022) analyze climate change adaptation measures in Nova Friburgo, RJ, highlighting conservation practices such as no-till farming and green manure. These strategies promote climate resilience and minimize environmental impacts, integrating environmental conservation and productivity in a scenario of regional vulnerability.

Magalhães et al. (2021) highlight the relevance of practices such as agroclimatic zoning and sustainable crop management to increase the resilience of the agricultural sector in the face of climate change. Productive diversification and the adoption of innovative technologies are pointed out as strategies to align productivity and environmental preservation.

This literature review shows that productive efficiency and agricultural sustainability depend on strategies based on the integration of technical knowledge, technological innovation and adaptive management. The literature reinforces the importance of public policies and private actions that encourage responsible agricultural practices, consolidating the sector as a pillar of sustainable development

METHODOLOGY

This study was conducted with the objective of evaluating productive efficiency and agricultural sustainability in different combinations of soil types and growing seasons. For this, the *Agriculture and Farming Dataset* was used, obtained from the *Kaggle* platform, which contains comprehensive information on management practices, crop yield, use of inputs and economic indicators. This dataset was essential to identify interactions between agricultural variables and to propose strategies that promote greater efficiency and sustainability.

The variables analyzed included numerical data, such as cultivated area (in acres), fertilizer consumption (in tons), pesticide application (in kilograms), total production (in tons), and water use (in cubic meters), as well as categorical variables, such as crop type, irrigation method, soil type, and growing season. This broad granularity allowed for a detailed study, highlighting the Loamy-Zaid and Peaty-Kharif combinations due to their distinct characteristics in terms of productivity and resource consumption.

The first stage of the study consisted of importing and processing the data using the Python language, with the support of the Pandas and NumPy libraries. Data cleansing techniques were applied to correct inconsistencies, such as missing or outlier values, which were retained if relevant to the analysis. Categorical variables were coded by *label encoding* to enable quantitative and statistical analyses.

The descriptive analysis of the numerical variables was performed using histograms, with the objective of identifying general trends and patterns in the distributions. A Pearson correlation matrix was generated to evaluate relationships between numerical variables, being visualized by heat maps, which allowed to highlight significant interactions, such as the impact of water consumption on productivity. For categorical variables, bar graphs were used to explore distributions and calculate the average productivity associated with different soil types and irrigation methods.

A cross-analysis between soil types and growing seasons was conducted to identify the most productive combinations. Heat mapping was used to represent the interactions between these variables, focusing on the Loamy-Zaid and Peaty-Kharif configurations. These combinations were subjected to detailed analyses of average fertilizer consumption, water use and productivity. The efficiency in the use of inputs was calculated by the ratio between the total production and the inputs applied, allowing the evaluation of the effectiveness of each combination in transforming resources into productive yield.

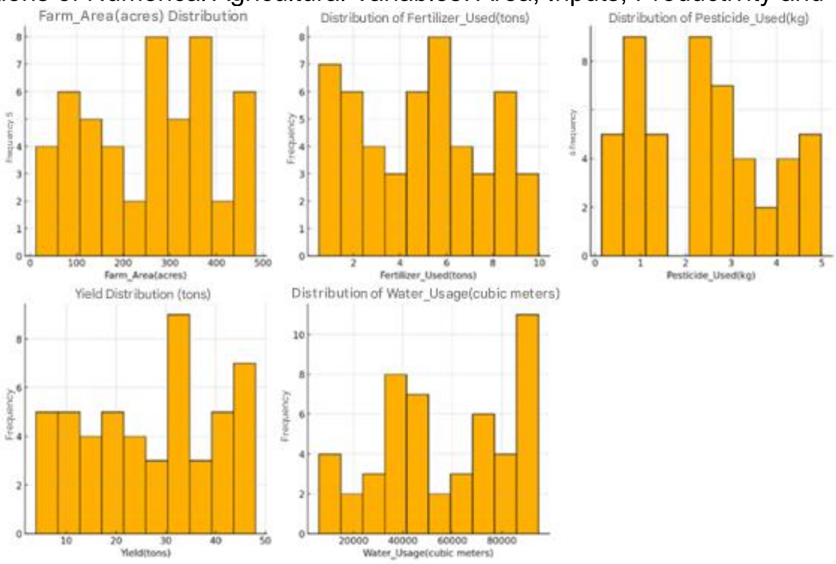
The methodology adopted followed strict principles of scientific reproducibility and ethical compliance, ensuring the proper treatment of data according to the terms of the original platform. Despite limitations, such as the absence of climate variables or agricultural policies, the results obtained provide robust bases for understanding and improving efficient and sustainable agricultural practices in various production contexts.

RESULTS AND DISCUSSION

This chapter presents a detailed analysis of the results obtained from the adjusted model, focusing on agricultural productivity, resource use, and efficiency in different soil and season combinations. Numerical and categorical variables were explored to identify significant patterns, correlations, and trends that can guide more sustainable and effective agricultural practices. The analysis considers the performance of the Loamy-Zaid and Peaty-Kharif combinations, highlighting trade-offs between productivity, costs and sustainability, based on empirical data.

Figure 1 presents histograms that illustrate the distributions of the main numerical variables extracted from the analyzed agricultural dataset. These graphs provide an overview of the dispersion and underlying patterns in variables related to agricultural productivity, inputs, and resources, allowing for a detailed analysis of the behavior of the data and possible correlations with the results obtained.

Figure 1: Distributions of Numerical Agricultural Variables: Area, Inputs, Productivity and Use of Resources



Source: Prepared by the author (2024)

The first graph represents the **distribution of Farm_Area (acres),** indicating that most farms have areas between 100 and 400 acres, with a more significant concentration around 200 and 300 acres. This distribution suggests that small and medium-sized farms predominate in the dataset, which may influence the use of inputs and agricultural productivity.

The second graph addresses the **distribution of Fertilizer_Used (tones).** The analysis shows that the use of fertilizers is relatively uniform, with values ranging from 0.5 to 10 tons, and a slightly higher concentration between 5 and 8 tons. This distribution reflects different management strategies, which may be associated with soil characteristics and the types of crops analyzed.

The third graph shows the **distribution of Pesticide_Used (kg),** highlighting that most farms use less than 3 kg of pesticides. However, there is a longer right tail, with some farms applying up to 5 kg. This pattern may indicate selective pest control practices, possibly related to crop diversity and the severity of infestations.

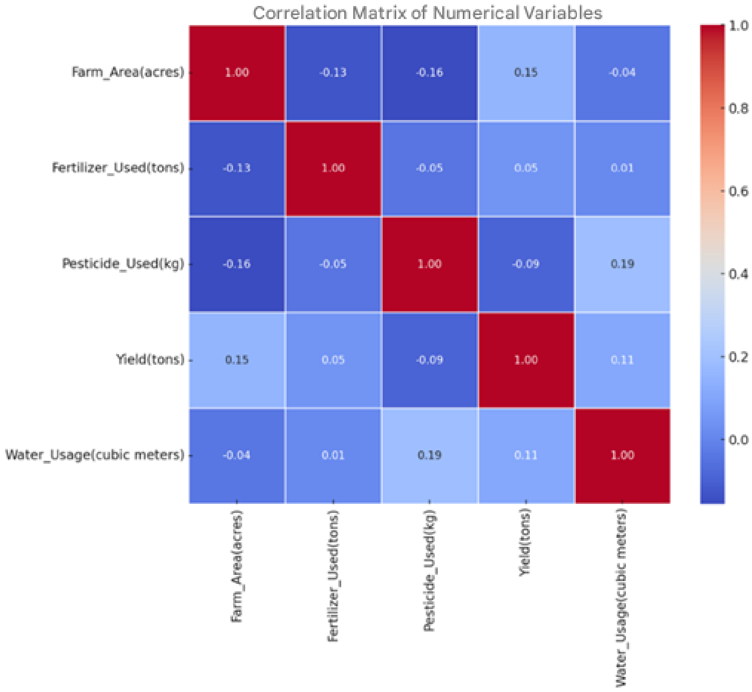
The fourth graph represents the **distribution of Yield (tons),** showing that productivity is predominantly concentrated between 15 and 40 tons, with a more accentuated peak near 30 tons. This result indicates a general consistency in production, although variations can be attributed to differences in management methods and environmental conditions.

Finally, the fifth graph shows the **distribution of Water_Usage cubic meters**, with consumption varying widely between 20,000 and 80,000 cubic meters, but with a slight slope to lower values. This behavior suggests that while water consumption is substantial, there is a considerable fraction of farms that adopt more moderate irrigation practices.

These distributions provide a solid basis for subsequent analyses, allowing us to explore correlations between variables and identify patterns that can guide more efficient and sustainable farming practices. A detailed analysis of the relationships between crop area, inputs and productivity will be key to understanding the trade-offs and proposing strategies that balance economic performance and environmental impact.

Figure 2 presented below consists of a correlation matrix of the numerical variables analyzed in the agricultural dataset. This matrix was constructed using Pearson's correlation coefficient, which measures the strength and direction of linear relationships between variables. The scale ranges from -1 to 1, where positive values indicate direct correlation, negative values indicate inverse correlation, and values close to zero suggest little or no linear relationship.

Figure 2: Correlation Matrix of Numerical Agricultural Variables: Relationships between Inputs, Resources and Productivity



Source: Prepared by the author (2024)

The **Farm_Area (acres)** shows weak correlations with the other variables, with emphasis on its moderate and positive relationship with the **Yield (tones)** (0.15). This suggests that larger farms tend to have slightly higher yields, but other factors may play more significant roles in determining productivity.

The variable **Fertilizer_Used (tons)** shows a weak correlation with **the Yield (tons)** (0.05), indicating that the use of fertilizers has a positive, but not significant, impact on productivity. This observation may reflect the presence of limitations in other production factors, such as soil conditions and water management, which affect the effectiveness of fertilizers.

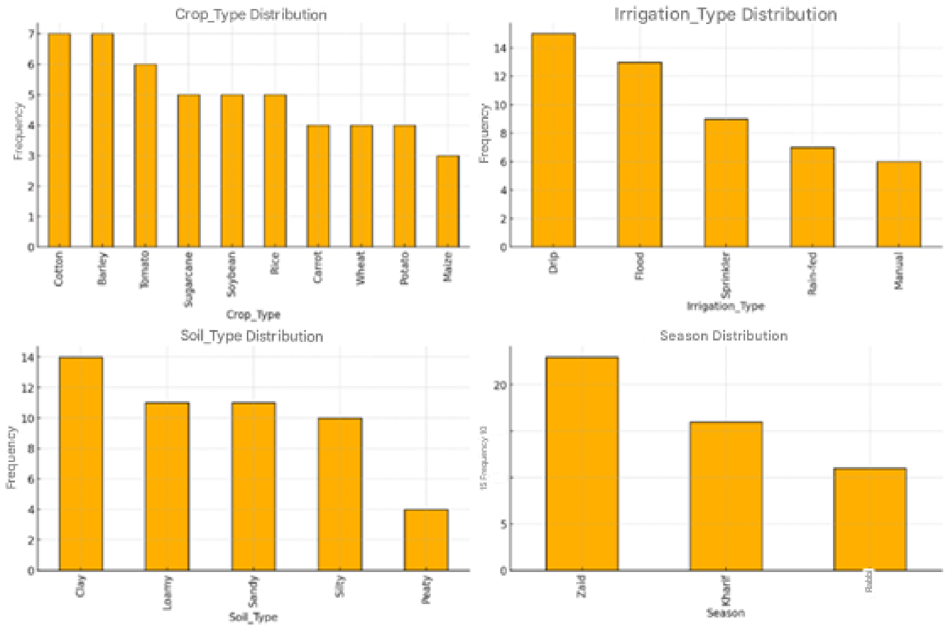
The **Pesticide_Used (kg)** demonstrates a negative, albeit weak, correlation with the **Yield (tones)** (-0.09), suggesting that the increase in pesticide use may not be directly associated with yield gains and, in some cases, may even reflect management problems or pest outbreaks under adverse conditions.

The Water_Usage (cubic meters) shows a weak and positive correlation with the **Yield (tons)** (0.11), indicating that a higher water consumption is related to a slight increase in productivity. However, the low intensity of this relationship reinforces the need for efficient irrigation practices that maximize productivity without significantly increasing water consumption.

The results of the matrix highlight the complexity of the interactions between agricultural variables and suggest that productivity is not defined in isolation by any specific input, but rather by an integrated set of factors. This analysis substantiates the need for multifactorial approaches to optimize agricultural production, considering economic, environmental and resource management aspects. In addition, the low correlation between inputs suggests opportunities for more sustainable practices, where the rational use of resources can be implemented without compromising productivity.

Figure 3 presented below contains four graphs illustrating the distributions of the main categorical variables in the agricultural dataset, addressing **crop type (Crop_Type), irrigation method (Irrigation_Type**), **soil type (Soil_Type)** and **growing season (season)**. Each graph contributes to a better understanding of the relative frequency and predominance of the different categorical factors that influence agricultural productivity.

Figure 2: Distribution of Categorical Variables in Agricultural Systems: Crops, Irrigation, Soil Types, and Growing Seasons



Source: Prepared by the author (2024)

The first graph, referring to the **distribution of Crop_Type**, reveals that the most predominant crops in the data set are *Cotton* and *Barley*, followed by *Tomato* and *Sugarcane*. Crops such as *Rice*, *Wheat*, and *Maize* are less represented. This pattern may reflect prevailing agricultural practices in certain regions or cultural and economic preferences related to market demand.

The second graph, which deals with the **distribution of Irrigation_Type**, shows that the *Drip* irrigation method is the most used, followed by *Flood* and *Sprinkler*. More traditional methods, such as *Manual*, have a lower frequency, indicating a possible transition to more automated and efficient systems. This may be associated with the search for greater efficiency in the use of water, especially in areas where this resource is scarce.

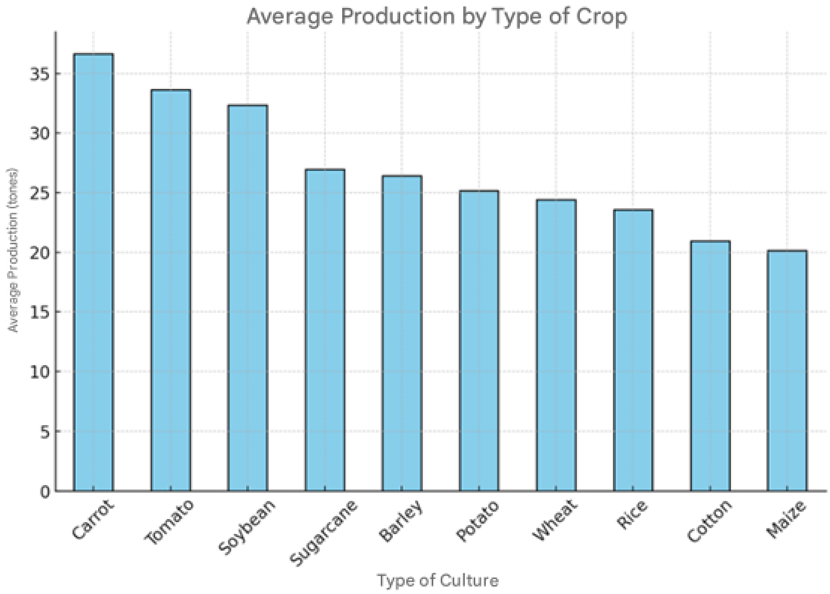
The **Soil_Type distribution**, shown in the third graph, highlights that *Clay* and *Loamy* solos are the most frequent in the dataset, while *Peaty* is the least represented. This distribution can be attributed to the agronomic characteristics of the soils, with *Clay* and *Loamy* often associated with favorable conditions for cultivation. The low frequency of *Peaty soils* suggests that this type of soil is less commonly used or presents specific restrictions for agricultural management.

Finally, the fourth chart addresses the **distribution of Season**, indicating that the *Zaid season* has the highest frequency, followed by *Kharif* and *Rabi*. This prevalence of *Zaid* may be related to favorable water and climate availability during this period, while differences in frequencies at other stations may reflect regional practices or limitations imposed by environmental conditions.

These graphs allow us to understand the predominance of certain categorical factors in the data set and raise hypotheses about how these factors can influence yield and agricultural management. The analysis of these distributions is essential to identify patterns and plan strategies that maximize efficiency and sustainability in agricultural practices.

The graph shown in Figure 4 illustrates the average production (in tonnes) associated with different crop types included in the agricultural dataset. This analysis is essential to understand the variations in yield performance between crops, allowing us to identify those with the highest yield potential and analyze the factors that can influence these differences.

Figure 4: Average Productivity by Crop Type: Comparative Analysis of Agricultural Yield



Source: Prepared by the author (2024)

The results indicate that *Carrot* has the highest average productivity, over 35 tons, followed by *Tomato* and *Soybean*, which also exhibit high yield rates. These crops stand out for their ability to respond more efficiently to the management conditions and inputs used, becoming attractive options for maximizing production in certain regions.

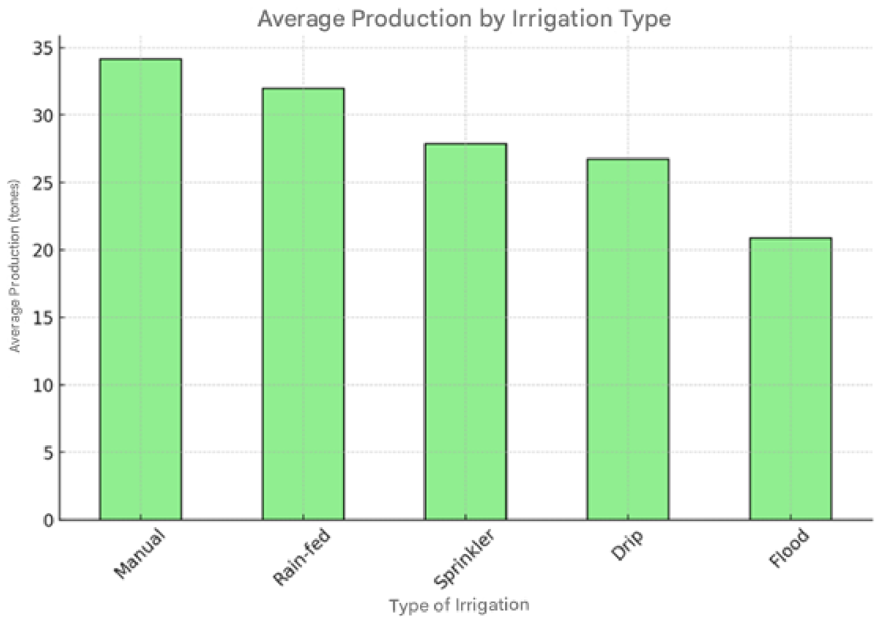
Crops such as *Sugarcane*, *Barley* and *Potato* occupy intermediate positions, with average yields ranging between 25 and 30 tons. These results reflect the competitive potential of these crops, which can be explored in specific contexts depending on economic viability and edaphoclimatic conditions.

At the lower end are *Rice*, *Cotton* and *Maize*, with average yields below 25 tons. The lower productivity of these crops may be associated with factors such as lower input intensity, intrinsic limitations of cultivation, or less advanced agricultural practices. However, these crops have strategic importance in many regions, due to their economic relevance and market demand.

This chart highlights the disparities in productivity between different crops, suggesting that strategic choices should be made based on regional analyses, resource availability, and economic demand. In addition, crops with lower average productivity present opportunities for optimization through the introduction of more advanced technologies and management practices. This analysis reinforces the importance of integrated agricultural strategies to maximize yield and sustainability in diverse production contexts.

The graph presented in Figure 5 analyzes the average productivity (in tons) as a function of the different types of irrigation used in agricultural practices. This graph provides relevant insights into how water management methods can influence yield efficiency in the crops analyzed.

Figure 5: Average Productivity by Type of Irrigation: Analysis of the Impact of Irrigation Techniques on Agricultural Production



Source: Prepared by the author (2024)

The Manual irrigation method has the highest average productivity, reaching values above 35 tons. Despite being a traditional technique, its high productivity may be related to the direct control of water management, allowing precise adjustments to the specific needs of crops. However, it is important to consider that this method can be more labor-intensive, limiting its applicability on a large scale.

The *Rain-fed* system emerges as the second most productive, with an average close to 30 tons. This method, which relies on natural rainfall, can be advantageous in regions with regular rainfall and well distributed throughout the crop cycle. However, its dependence on climatic factors limits its effectiveness in regions with water variability or scarcity.

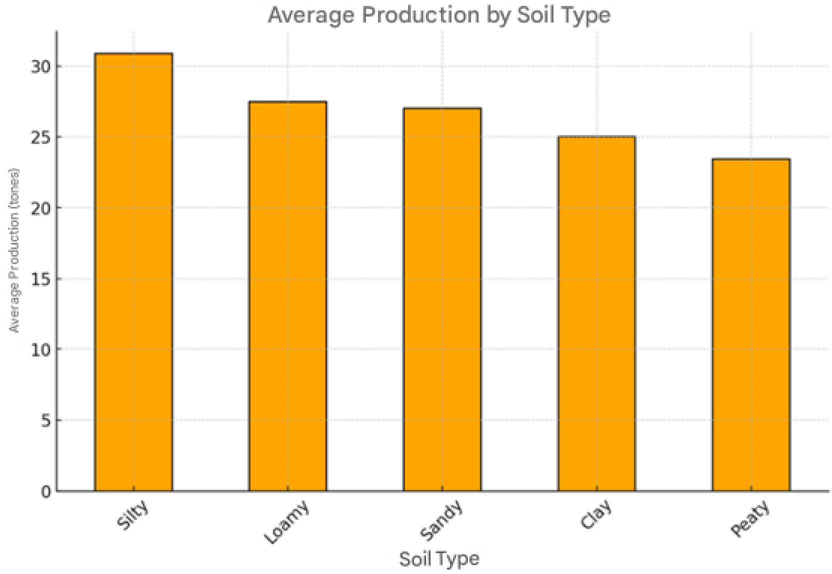
The *Sprinkler* and *Drip* systems exhibit similar average yields, in the range between 25 and 30 tons. Both represent modern and highly efficient methods in the use of water, reducing waste and improving irrigation uniformity. The moderate productivity observed in these methods can be attributed to external variables, such as soil type and crop cultivated, which affect the response to management.

On the other hand, the Flood irrigation method has the lowest average productivity, below 25 tons. This technique, characterized by large volumes of water flooding the cultivated area, is often associated with significant water losses and an increased risk of nutrient leaching. Although it is widely used in certain crops, such as rice, its low water efficiency can compromise production results in other contexts.

The analysis presented in the graph highlights the importance of aligning irrigation methods with the characteristics of crops, soil and environment, seeking to maximize water efficiency and productivity. Methods such as *Sprinkler* and *Drip* offer sustainable alternatives to traditional water management, while practices such as manual irrigation can be optimized in specific situations. Thus, the choice of the ideal irrigation system depends on an integrated assessment of agricultural needs and resource availability.

The graph shown in Figure 6 below shows the average production (in tons) as a function of the different soil types included in the data set. The analysis highlights the influence of soil physical and chemical characteristics on agricultural yield, offering valuable insights for management practices and soil selection for specific crops.

Figure 6: Average Productivity by Soil Type: Impact of Soil Characteristics on Agricultural Yield



Source: Prepared by the author (2024)

Silty *soil* has the highest average productivity, exceeding 30 tons. This type of soil is widely recognized for its fine texture and excellent water and nutrient retention capacity, characteristics that favor the healthy development of plants and, consequently, a high productive yield. This superiority suggests that, when available, *Silty* soil may be a preferred option for intensive crops.

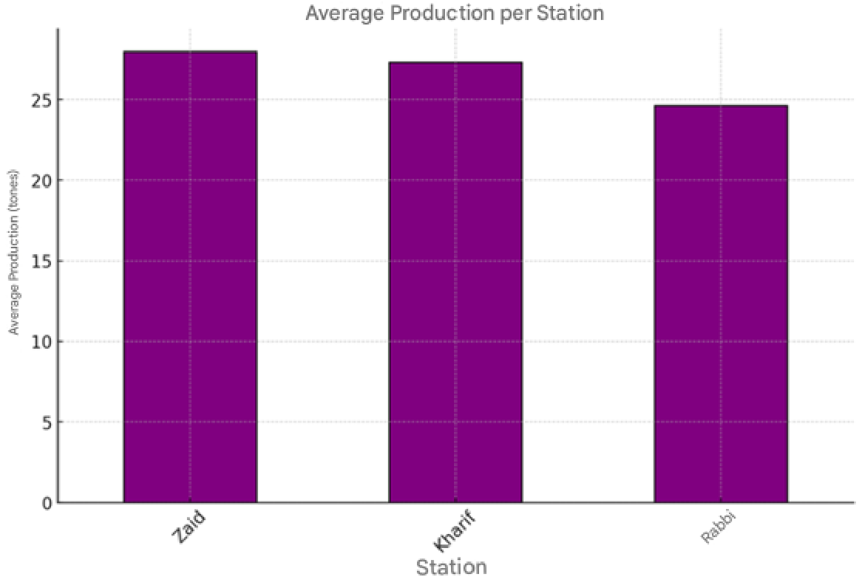
The *Loamy* and *Sandy* soils continue to be productive, with average values around 27 to 28 tons. *Loamy* soil is often considered ideal for agriculture due to its balance of sand, silt, and clay, providing good drainage and nutrient retention. The *Sandy* soil, in turn, despite having low water retention, can be advantageous in crops that require good drainage and efficient water management.

The Clay *and* Peaty *soils* exhibit the lowest average yields, with yields of less than 27 tons. *Clay* soil, due to its heavy texture and low permeability, can hinder root growth and water infiltration, especially in improper management conditions. *Peaty soil*, on the other hand, although rich in organic matter, presents challenges such as high acidity and lower availability of essential nutrients, which can limit its productive potential in certain crops.

These results highlight the importance of aligning soil type with specific crop demands and management practices. High-productivity soils, such as *Silty* and *Loamy*, may be preferred for maximizing yield in intensive farming systems, while soils with limitations, such as *Clay* and *Peaty*, require specific interventions, such as pH corrections, proper fertilization, and conservation practices. Thus, the choice of soil must be based on detailed edaphic analyses, considering both the productive potential and the economic and environmental viability.

Figure 7 shows the average yield (in tons) associated with the three main growing seasons: *Zaid*, *Kharif* and *Rabi*. This analysis allows us to understand how seasonal conditions influence the yield of agricultural crops, providing subsidies for the strategic planning of management practices and resource allocation.

Figure 7: Average Productivity by Growing Season: Analysis of the Seasonal Influence on Agricultural Yield



Source: Prepared by the author (2024)

The *Zaid* station has the highest average productivity, slightly over 25 tons. This performance can be attributed to the favorable climatic conditions of this season, characterized by moderate temperatures and adequate water availability, which favor plant development. Additionally, the lower incidence of pests and diseases during *Zaid* can contribute to the increase of production efficiency.

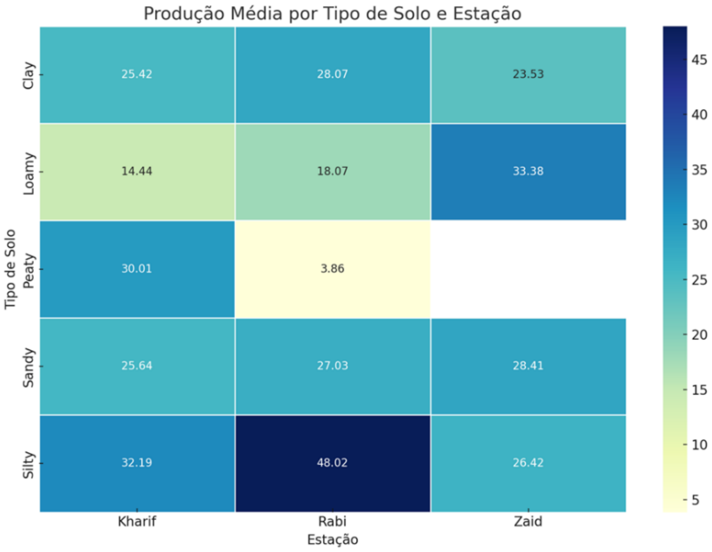
Kharif *Station* closely follows *Zaid*, with a similar average yield. *Kharif* coincides with the monsoon season in many regions, providing plenty of water through the rains. However, challenges associated with excess precipitation, such as soil waterlogging and nutrient leaching, can limit the performance of some crops. Additionally, the high humidity during *Kharif* can increase the incidence of pests and diseases, which necessitates more stringent management strategies.

The Rabi *station* has the lowest average productivity, although the difference in relation to the other stations is relatively small. *Rabi* is characterized by lower temperatures and lower water availability, which can restrict the growth of crops sensitive to these conditions. However, irrigation systems and management practices adapted for this season can partially mitigate the impacts of climate limitations, allowing for competitive yield in many situations.

This chart highlights the importance of considering seasonal characteristics in crop choice and crop management strategies. While *Zaid* and *Kharif* offer ideal conditions for many crops, *Rabi* calls for greater attention to the availability of resources and irrigation techniques to achieve satisfactory productive results. Seasonal analysis, therefore, is essential to optimize agricultural planning and promote sustainability in different production contexts.

The heat graph shown in Figure 8 illustrates the average yield (in tons) for different combinations of soil types and growing seasons. This visual representation facilitates integrated analysis by highlighting the interactions between edaphic and seasonal conditions in agricultural yield. Each cell of the graph reflects the productive average of a specific combination, allowing the identification of ideal scenarios and limitations associated with these variables.

Figure 8: Interaction between Soil Type and Growing Season: Average Productivity by Combination



Source: Prepared by the author (2024)

The Silty *soil combination* during the *Rabi* season has the highest average yield, reaching 48.02 tons. This result highlights the excellent ability of *Silty soil* to retain nutrients and water, combined with Rabi's moderate climatic conditions, which favor crop development. However, Silty's performance in other seasons, such as *Kharif* and *Zaid*, is less expressive, suggesting that its productive response depends on adequate seasonal management.

Loamy *soil*, recognized for its balance between drainage and nutrient retention, has the highest average productivity during *Zaid* (33.38 tons). This combination benefits from this season's favorable weather conditions and the consistent performance of *Loamy* soil, demonstrating its versatility as an agricultural substrate. On the other hand, *Loamy's yield* in *Kharif* and *Rabi* is considerably lower, at 14.44 and 18.07 tons, respectively, indicating that his productivity may be limited in harsher conditions.

Peaty *soil* exhibits contrasting behavior, with its highest productivity observed in *Kharif* (30.01 tons) but an extremely reduced performance in *Rabi* (3.86 tons). This suggests that *Peaty* soil, while rich in organic matter, faces significant limitations under Rabi's drier climatic conditions, likely due to low water-holding capacity and high acidity.

The Clay *and* Sandy *soils* show moderate and relatively consistent yields between seasons, with slight variations. However, in *Zaid*, the Clay soil shows a drop in productivity (23.53 tons), while *Sandy* shows a slight improvement (28.41 tons). These variations reflect the physical characteristics of these soils, such as the low permeability of *Clay* and the good drainage of *Sandy*, which respond differently to seasonal conditions.

This heat chart provides an integrated view on how soil type and season combinations influence agricultural productivity. The results highlight that strategic decisions about crop allocation must consider both edaphic and seasonal conditions to maximize production and efficiency. In addition, specific combinations, such as *Silty* in *Rabi* and *Loamy* in *Zaid*, represent ideal scenarios for optimized farming systems, while soils such as *Peaty* in unfavorable seasons require specific management strategies to mitigate their limitations. The analysis underscores the importance of tailored approaches in modern agriculture, promoting a balance between productivity, sustainability, and economic viability.

Table 1 compares the resources employed and the productive results for two distinct combinations of soil and season: *Loamy-Zaid* and *Peaty-Kharif*. The variables analyzed include average fertilizer use (in tons), water consumption (in cubic meters), and average productivity (in tons), providing a clear view of trade-offs between inputs and agricultural yield.

Table 1: Comparison of Resource Usage and Productivity Between Loamy-Zaid and Peaty-Kharif Combinations

Combination	Fertilizer_Used(tons)	Water_Usage(cubic m)	Yield(tons)
Loamy-Zaid	6,355714	68033,7957	33,38
Peaty-Kharif	5,133333	46602,47333	30,006667

Source: Prepared by the author (2024)

The *Loamy-Zaid* combination has the highest average yield, reaching 33.38 tons. However, this productive advantage is associated with a higher consumption of inputs, such as 6.36 tons of fertilizers and 68,033.80 cubic meters of water. These values indicate a high demand for resources to sustain superior productivity, which can negatively impact operating costs and environmental sustainability, especially in regions with water resource constraints.

On the other hand, the *Peaty-Kharif* combination demonstrates slightly lower productivity, averaging 30.01 tons, but uses significantly fewer resources. The consumption of fertilizers is 5.13 tons, while the use of water is 46,602.47 cubic meters. These data reflect a comparatively higher efficiency in the use of inputs, making this combination an attractive alternative in scenarios where costs or resource availability are limiting.

The comparative analysis shows that the *Loamy-Zaid* combination, despite being the most productive, has a lower efficiency in the use of resources. For every ton of fertilizer applied, the yield is approximately 5.25 tons in *Loamy-Zaid*, while *Peaty-Kharif* achieves an efficiency of 5.85 tons. The same pattern is repeated in water consumption, where *Peaty-Kharif* also surpasses *Loamy-Zaid* in terms of water efficiency.

These results raise important considerations about the feasibility of each combination. *Loamy-Zaid* is ideal for maximizing production in conditions where inputs are readily available and environmental impact is not a critical factor. *Peaty-Kharif*, on the other hand , stands out as a more sustainable and economical choice, especially in regions where resource conservation is a priority.

The table highlights the need for a balanced approach to agricultural decision-making. Strategies that optimize fertilizer and water use in *Loamy-Zaid* can improve its efficiency and reduce its environmental impacts. On the other hand, investments in technologies and specific management can raise the performance of *Peaty-Kharif*, making it even more competitive. These insights reinforce the importance of integrated analytics to align productivity, cost, and sustainability across diverse farming systems.

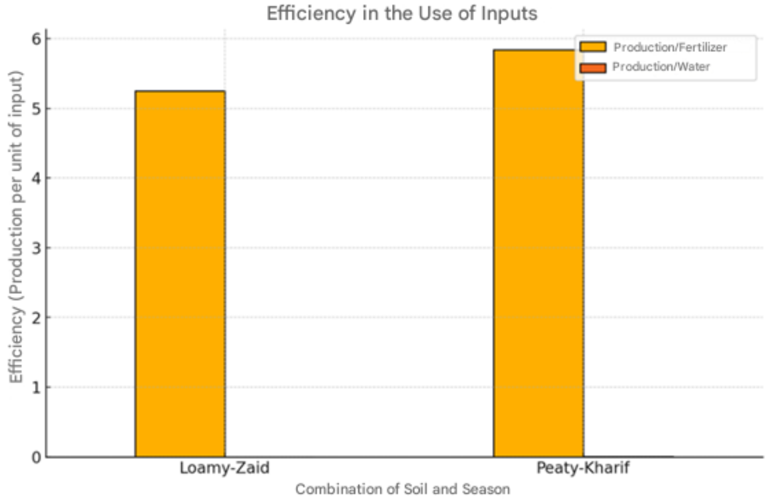
Table 2 and Graph 9 below analyze the efficiency in the use of inputs for two distinct combinations of soil and season: *Loamy-Zaid* and *Peaty-Kharif*. The table quantifies the production per ton of fertilizer (*Yield_per_Fertilizer*) and per cubic meter of water (*Yield_per_Water*), while the graph comparatively visualizes these efficiency indexes, highlighting the disparities between the combinations.

Table 2: Efficiency in the Use of Inputs: Comparison between Loamy-Zaid and Peaty-Kharif

Combination	Fertilizer_Used (tons)	Water_usage (cubic m)	Yield (tons)	Yiel_per_Fertilize	Yield_per_Water
Loamy-Zaid	6,3557	68033,7957	33,38	5,2519	0,00049
Peaty-Kharif	5,1333	46602,4733	30,0066	5,8454	0,00064

Source: Prepared by the author (2024)

Graph 9: Comparative Efficiency in Fertilizer and Water Use Between Soil and Season Combinations



Source: Prepared by the author (2024)

In the *Loamy-Zaid* combination, the production per ton of fertilizer is 5.22 tons, while the water efficiency is 0.00049 tons per cubic meter of water. These values reflect a high productivity, but associated with a considerably higher use of inputs, indicating that, although effective in maximizing absolute production, *Loamy-Zaid* has a limited efficiency in the use of the resources employed.

On the other hand, the *Peaty-Kharif* combination demonstrates greater efficiency in both metrics. For each ton of fertilizer used, the average yield is 5.85 tons, surpassing *Loamy-Zaid*. Similarly, water use efficiency reaches 0.00064 tons per cubic meter, representing a significant improvement over the other combination. This data highlights *Peaty-Kharif* as a more sustainable alternative in scenarios where resource availability is limited.

Graph 9 visually reinforces the differences pointed out by the table, showing that *Peaty-Kharif* consistently outperforms *Loamy-Zaid* in both efficiency metrics. The disparity is particularly pronounced in water efficiency, suggesting that *Peaty-Kharif* may be a more viable choice in regions where access to water is restricted or where sustainable agricultural practices are a priority.

The analysis presented emphasizes the trade-offs between absolute productivity and efficiency in the use of inputs. While *Loamy-Zaid* is best suited for contexts where maximizing yield is the primary goal, *Peaty-Kharif* offers a balanced approach between production and resource conservation. Strategies that combine optimized management practices in both combinations can help align sustainability and economic competitiveness, promoting more resilient and efficient agricultural systems.

Table 3 and Graph 10 presented below provide a detailed view of the costs associated with the use of fertilizers and water, as well as the productive efficiency of the

Loamy-Zaid and *Peaty-Kharif combinations*. The analysis examines total costs, costs per ton produced, and sustainability factors that guide agricultural practices.

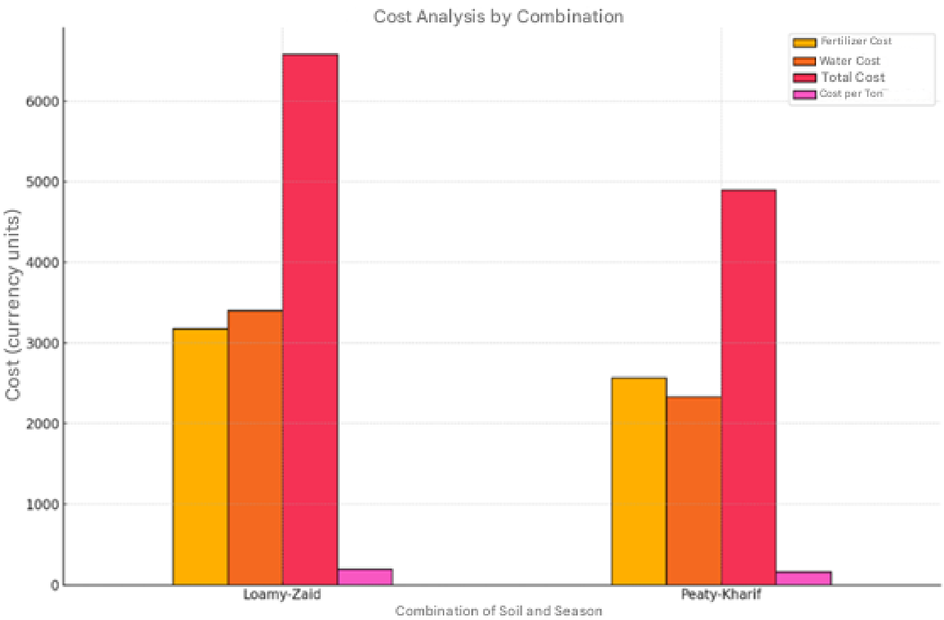
Table 3: Cost and Sustainability Analysis for the Loamy-Zaid and Peaty-Kharif Combinations

Combination	**Fertilizer_Used (tons)**	**Water_Usage (cubic meters)**	**Yield (tons)**	**Yield_per_Fertilizer**	**Yield_per_Water**	**Fertilizer_Cost**	**Water_Cost**	**Total_Cost**	**Cost_per_Ton**
Loamy-Zaid	6,36	68033,80	33,38	5,22	0,00049	3177,86	3401,69	6579,55	197,11
Peaty-Kharif	5,13	46602,47	30,00	5,85	0,00064	2566,67	2330,12	4896,79	163,20

Source: Prepared by the author (2024)

Table 3 highlights that the *Loamy-Zaid* combination has a total cost of 6,579.55 monetary units, significantly higher than the total cost of 4,896.79 *Peaty-Kharif* monetary units. This difference is mainly due to the higher consumption of water (68,033.80 cubic meters against 46,602.47 cubic meters) and fertilizers (6.36 tons against 5.13 tons) in *Loamy-Zaid*. Consequently, the cost per ton produced in *Loamy-Zaid* (197.11 currency units) is higher compared to *Peaty-Kharif* (163.20 currency units), which reinforces the lower economic efficiency of this combination.

Graph 10: Comparison of Costs and Efficiency by Soil and Station Combination



Source: Prepared by the author (2024)

Graph 10 shows the distribution of costs in each combination, showing that *Loamy-Zaid* has higher expenses in all categories: fertilizer cost, water cost and total cost. Despite this, the production of 33.38 tons at *Loamy-Zaid* is only slightly higher than the 30.00 tons seen at *Peaty-Kharif*. This disparity between costs and production reinforces *Loamy-Zaid's lower overall efficiency*.

Peaty-Kharif's *sustainable efficiency* stands out especially in the cost per ton produced, which is approximately 17% lower than *Loamy-Zaid*'s. This combination also demonstrates greater efficiency in the use of inputs, with a better relationship between inputs applied and productivity achieved, as already highlighted in previous analyses.

These results have important practical implications. While *Loamy-Zaid* may be preferred in scenarios where the priority is to maximize absolute production, *Peaty-Kharif* offers a more balanced alternative between cost, efficiency, and sustainability. In contexts where water resources are limited or where cost reduction is crucial, *Peaty-Kharif* has clear advantages.

The analysis in Graph 10 reinforces the importance of adapting agricultural strategies to local conditions. Investments in practices that optimize the use of resources in *Loamy-Zaid* can make it more competitive, while additional techniques such as biofertilizers can further increase the efficiency of *Peaty-Kharif*. The decision between these combinations must consider not only productivity, but also economic costs and environmental impact.

The analyses presented throughout the graphs and tables provide a comprehensive view on the factors that influence agricultural productivity, input use, and economic and environmental sustainability across different combinations of soil, season, and agricultural practices. This integrated approach allows you to identify fundamental patterns and trade-offs for the optimization of agricultural systems.

The distribution graphs **of categorical variables** highlighted the predominance of certain types of crops, soils and irrigation methods, suggesting that regional practices and agronomic characteristics influence the choice of inputs and management. Crops such as *Carrot* and *Tomato* had the highest average yields, reinforcing their economic relevance. More traditional irrigation methods, such as *Manual*, have shown high yields, but raise questions about scalability and resource efficiency. Silty soil and *Rabi* station stood out as scenarios of high productivity in their respective contexts.

Analysis of the correlation matrix revealed weak interactions between inputs such as fertilizers and pesticides with yield, suggesting that yield efficiency depends on a broader set of factors, including soil characteristics and seasonal conditions. This complexity reinforces the need for customized management practices to maximize yields.

Analyses of specific combinations, such as *Loamy-Zaid* and *Peaty-Kharif*, showed significant contrasts. *Loamy-Zaid* stood out for the highest absolute productivity, but at the expense of higher resource consumption and operating costs. On the other hand, *Peaty-*

Kharif demonstrated greater efficiency in the use of fertilizers and water, in addition to significantly lower total costs and per ton produced, evidencing its feasibility in scenarios where sustainability and resource savings are a priority.

The heat graphs that crossed the soil type and the growing season illustrated that productivity does not depend on one factor alone, but on specific combinations. The performance of *Silty soil* in *Rabi* and *Loamy soil* in *Zaid* are examples of optimal interactions that can guide agricultural planning in different regions.

Finally, the analysis of costs and sustainability showed that economic and environmental efficiency varies substantially between the combinations. The higher productivity of *Loamy-Zaid* was achieved at a considerably higher cost, while *Peaty-Kharif* proved to be a more sustainable alternative, with lower operating costs and lower environmental impact. These results emphasize the need to balance productivity, costs, and sustainability to meet modern agricultural demands.

The results show that the Loamy-Zaid combination offers higher absolute productivity, but presents high demand for inputs, especially water and fertilizers. On the other hand, Peaty-Kharif stands out for its efficiency in the use of resources and lower cost per ton produced, emerging as a more sustainable alternative. The analyses suggest that strategic decisions must balance productivity and sustainability, considering specific contexts of resource availability and economic priorities. These conclusions provide valuable subsidies for efficient agricultural planning.

However, the analyses reinforce that there is no single or universal solution for maximizing agricultural productivity. Choosing the ideal combinations of soil, season, and farming practices should take into account local conditions, resource availability, and the producer's priorities, whether economic or environmental. Additionally, adaptive management strategies and the use of innovative technologies, such as biofertilizers and optimized irrigation systems, can improve the overall performance of the analyzed combinations.

These results provide a valuable guide for researchers, farmers, and policymakers, allowing for more informed decisions to be made in pursuit of sustainable and competitive agriculture. The next step will be to apply these analyses in other contexts, validating the findings and expanding the possibilities for different agricultural production systems.

CONCLUSIONS

This study comprehensively analyzed the interactions between agricultural productivity, input use, and sustainability across different combinations of soil types and growing seasons. The results elucidated critical patterns that guide strategic decisions aimed at productive efficiency and resource conservation.

The analyses revealed that categorical variables, such as soil type and irrigation method, exert a determining influence on productivity. Crops such as *Carrot* and *Tomato* demonstrated higher average yield, evidencing their adaptability and economic relevance. *Silty* and *Loamy* soils stood out as suitable substrates for intensive crops, while *Peaty* soil showed significant limitations in less favorable conditions, such as in the Rabi season. The Zaid station emerged as the most conducive to maximizing yield, reinforcing the importance of suitable climatic conditions.

The specific interactions between soil and season reinforced the need for personalized management strategies. The *Silty* soil at the Rabi station showed the highest absolute yield, while the Loamy-Zaid combination was balanced in terms of inputs and yield. On the other hand, combinations such as Peaty-Rabi highlighted the urgency of adjustments in management or the strategic replacement with soils more suitable for challenging conditions.

Regarding the efficiency in the use of inputs, the differences between combinations were striking. Although Loamy-Zaid achieved higher absolute productivity, its efficiency per unit of input was lower than that of Peaty-Kharif, which demonstrated greater efficiency in the use of fertilizers (5.85 tons per ton of fertilizer) and water (0.00064 tons per cubic meter). Thus, Peaty-Kharif emerges as a more sustainable choice in resource-constrained settings.

The cost analysis reinforced Peaty-Kharif's economic superiority in terms of feasibility, with total costs 34% lower than Loamy-Zaid's. The cost per ton of Peaty-Kharif (163.20 currency units) was significantly lower, standing out in contexts where economic efficiency is a priority.

The findings indicate that Peaty-Kharif is ideal for systems that prioritize sustainability and resource savings, while Loamy-Zaid may be advantageous in scenarios where maximizing productivity is essential, as long as it is offset by higher added value. Investments in management technologies, such as biofertilizers, optimized irrigation, and soil amendments, are recommended to increase the efficiency of these combinations in different production scenarios.

The contributions of this study provide a solid basis for data-driven agricultural decisions, with applicability for producers and public policy makers. However, it is necessary to validate the results in other regions and cropping systems to ensure their generalization. The integration of productivity, sustainability, and economic viability is indispensable to promote resilient agricultural systems in line with the growing global demands for food and natural resources.

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MARATIMBA SUSTAINABILITY IN COMPARATIVE ANALYSIS WITH THE 10 EXAMPLE CITIES ON A GLOBAL SCALE

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ABSTRACT

This article aims at a comparative analysis between the characteristics of the city of Marataízes, which is located on the coast of Espírito Santo, with the 10 cities considered the most sustainable and intelligent in the world. They are: Tokyo, London, New York, Paris, Geneva, Osaka, Seoul, Frankfurt, Oslo, Sydney. Curitiba is the featured city in Brazil when it comes to sustainability, based on a bibliographic inspection it was possible to verify the advances and challenges that Marataízes faces in relation to these cities such as economic growth, quality education, land life, urban mobility and zero hunger with sustainable agriculture. Great action that the city Maratimba has is to ensure the preservation of its beaches, lagoons, mangroves and fishing, as they are part that makes it known touristically and economically, however it is important to invest in new technologies aimed at the urban and rural sphere, and in public policies to adopt strategic and effective measures to improve the city's classification in the SDG index (development and sustainability goals) so far it is considered medium.

Keywords: Sustainability. City. Preservation. Investment. Public policies.

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INTRODUCTION

Sustainability is the need to see occurrences that may compromise future generations; that is, to have the ability to understand the demand for adequate and conscious use of natural, environmental **and** social resources, in a totalitarian context (MAULEN; MARINHO; ELEROVIC, 2019).

On the planet, the lack of sustainability of one place reaches the other. Thus, it is important to compare cities, whether municipal, state, national or international, so that there is an evaluation of good practices, innovations, recognition of problems, attraction of investments and review of public policies, aiming to reach new times.

In this context, the sustainable development goal is directly linked to the 2030 Agenda, where, in 2015, the United Nations (UN) General Assembly established the seventeen measures in favor of global development by the year 2030. As described in the preamble of its document, the realization of such an agenda will only take place with the adequacy of the countries and parties involved.

The growing advances of cities make urban planning constantly outdated, since changes occur in a slight and accelerated way. Throughout this growth, population obstacles, sustainability of natural resources, and insufficient waste management arise. Urban development is an unprecedented fact around the world and cities need to be prepared to receive such advancement.

DEVELOPMENT

THE 10 SMARTEST AND MOST SUSTAINABLE CITIES IN THE WORLD

First of all, there is the large city of Tokyo (Japan), a smart city that uses all its technology depending on its population, in which it has the most impressive garbage collection in the world, where people can leave their waste in the baskets and their homes, which will be separated and collected properly. There are sensors scattered throughout the city so that energy consumption is monitored, and also air quality. They apply the culture of innovation, where they encourage the creativity of their young people and, therefore, receive and value constant ideas for solutions to problems and challenges in their city.

The second best-placed city when it comes to sustainability is London (England), presenting an innovative form of public transport. It contains a metro system that connects the entire city, providing compatible bicycles and demonstrates to the world its great innovative intention to become the first carbon-free city by the year 2050. New York, in the United States, is in the third position in the ranking of this survey, presenting to the world its quality system in public transport, well-structured recycling and investments in renewable energy, which is one of the needs for a city to be considered sustainable (PEREIRA; SIMPLICIO; DONAD, 2019).

Paris (France), with its stunning beauty, is highlighted not only for its culture, but for the appreciation of the planting of trees on its avenues, which contributes to air circulation, thus solving the process of verticalization resulting from the foundation of many buildings (MAULEN, I.; MARINHO, C.; ELEROVIC, J., 2019). This city also has efficient transportation, with the implementation of several subways, trains and bike racks, thus reducing the use of fuel and traffic, adequate recycling, composting and encouraging the empowerment of electric cars on its streets.

Geneva (Switzerland), also known for being the European headquarters of the UN, where the United Nations office opened, is highlighted for its various bike lanes, contributing to the population, offering shared bicycles for well-being, promoting health and reducing carbon monoxide gas, in addition to its very efficient recycling program. Many materials, such as aluminum, can be recycled with a 400% reuse level, melted, it returns to the production lines of the packaging industries, reducing costs for companies (FONSECA, Lúcia Helena Araújo, 2013, p. 3).

Osaka, as the sixth runner-up, presents its successful electric bus project, which balances environmental protection and economic growth. They also use their streets and avenues for shared bicycles, garbage collection through sensors, encouragement of the so-called "Smart Community Forum" and the implementation of parks and gardens. These places tend to promote a healthy lifestyle for the entire community (SEIAS, E.; SEIXAS, P.; LOPES, J., 2023).

The city of Seoul (South Korea), known worldwide today through dramas, Korean series that have gained prominence in several countries, features smart street lighting by sensors, virtual medical care preventing patients from leaving their homes, surveillance cameras with facial identification, taxis with robot drivers, electric buses and subways, and all this is revealed, including through his teledramas to the whole world. Frankfurt, Germany, bets on electricity for public transport, such as buses, subways and cars, and also invests in sustainable buildings and the use of renewable energy. It is essential that the sustainable city presents a development plan prioritizing its resources and aiming to prolong the life of its citizens (STEFANI; CORREA; PROCIDONIO, 2022).

Oslo (Norway), on the other hand, is primarily known for its museums and green areas. It is a city concerned with the environment, seeks to reduce pollution, as it aims at the well-being of its population. Some of its actions to achieve the goal are smart street lighting, boats powered by renewable energy, sustainable public transport, shared bicycles and the implementation of parks. Urban gardens and parks are the spaces that most promote the human-nature connection (VIDAL; GEORGE; BARROS; MARIA, 2020).

The tenth place is the city of Sydney, Australia, owner of one of the largest natural ports in the world, which presents its transport system with ferries that cross the entire city, a precious project for reducing CO_2 carbon emissions, green buildings and solar energy. The deployment of solar energy is known as the use of clean energy, and its demand is higher than the global demand for electricity. Studies point to a growing increase in the share of this energy source on a global scale (BEZERRA, Francisco Diniz, 2021).

SUSTAINABLE FEATURED CITY IN BRAZIL

In 2023, the Brazilian city of Curitiba, capital of the State of Paraná, received the smart city award in Spain, thus becoming known worldwide. Some of its highlights are the treatment of the water and sewage network, electric buses, solar roofs and, currently, half of the public buildings are supplied by 8,500 solar panels. Around 1996, the population rate of the city of Curitiba was around 400 thousand people, making it necessary to have a project to support the growth of the city and, therefore, an urban expansion. During this period, a comprehensive vision was initiated where the circulation of citizens was considered, whether for work, recreation or housing. This whole revolution has always been surrounded by a population with the environmental issue, which is not only materialized in the preservation of greenery, but also in the environmental education of its population.

Curitiba then began to create its sustainable city with the implementation of avenues, economic transformation projects, flood prevention and equitable access to public services. One point that attracts attention is that this city took the initiative to bring together in the same place its sectors of public service to the population (regional administrations of the municipality).

Curitiba is based on a structure called the basic tripod, which is defined as its model of urban expansion, which is subdivided into three points. They are: legislation, soil and transport. But it was at the end of the 80s that the city acquired the projection of an ecological city, and its entire population has since received all its projects as a daily action. Parts were created in various regions of the city, which assumed an important role in confronting and reducing polluting gases that increase global warming, in addition to the implementation of bike lanes on their roads. The use of bicycles as transport is evaluated in a sustainable way for the environment and also as a modality that offers physical and mental health to its fans. In addition to having flexibility, it occupies less space on the streets and for storage, has low maintenance costs compared to other transports and does not offer pollution (MIRANDA; VIEIRA, 2019). It is worth mentioning that:

> It is important to always remember that the city is built continuously and in each citizen. Public interventions, then, find meaning when the population appropriates them, incorporating them into their daily lives, which is a fundamental condition for the harmonious development of the city over time. (SEQUINEL, Maria Carmem Mattana, 2002, p. 54).

SUSTAINABILITY IN CITIES OR URBAN SUSTAINABILITY

Urbanization is at an increasing level. Increasingly, energy consumption, for example, will increase, as well as CO2 emissions, which are largely responsible for the increase in temperatures on the planet, which leads to a great environmental imbalance. Therefore, it is necessary that containment measures be carried out. Among the various positions is the implementation of policies aimed at the sustainable issue, which can assertively link the economy with society and the environment (MAULEN; MARINE; ETEROVIC, 2019).

Every change requires the creation of a new operating logistics. Therefore, each stage of a sustainable urbanization project needs to be thoroughly planned and worked on with the awareness that every project aimed at sustainability needs to be prepared for long-term action, as they are not quick projects.

In the same way, sustainability aims, above all, at the quality of human life, prioritizing the evolution of its means aimed at improving its services for the full use and development of its population. It is the right of the individual to basic sanitation, safe transportation, drinking water, clean air and safety. Public policies must work according to these particularities, improving strategies for such services to be offered, safeguarding all environmental practices through short, medium and long-term sustainable measures. It is at this point that the critical and scientific debate can accompany and boost the commitment of cities to the evolution of sustainability in its various aspects (BOTTON; PINE; OLIVE TREE; LOPES, 2021).

THE 17 SDGS AND THE MARATIMBA CLASSIFICATION.

The Global Compact was established 24 years ago and since then it has proven effective in its objectives and adopted measures. The United Nations has adopted such measures so that economic growth is valued, prioritizing the common good of the planet and its inhabitants. Before the Sustainable Development Goals were described, 10 principles were implemented in the Global Compact. They are: Respect and support for human rights at the international level; monitor companies to ensure that they do not violate rights; Freedom of collective bargaining; Eradication of forced labor; Total abolition of child labor; Elimination of all forms of discrimination in the employment environment; Environmental preventive approach; Initiatives that promote accountability; Encouraging the sustainable diffusion of technology and fighting corruption in a totalitarian way.

After certain measures, the 17 SDGs appear in the 2030 agenda to add their objectives to the Global Compact (COUTINHO, JEANDO DE MATOS. Dec 2021,

p. 503. 508). Such objectives are the result of more than two years of public research, a decision made by major representatives of governments and states.

Because much is not said, it is that a city to become sustainable, not only needs to prioritize the environment, but also fight for inclusion, equality, justice, safety and protection, that is, prioritizing human rights and environmental preservation will become a graceful consequence. The 17 SDGs are: Eradicate poverty; Eradicate hunger Quality health; Quality education Gender equality; Drinking water and sanitation; Renewable and affordable energy; Decent work and economic growth; Industry, innovation and infrastructure; Reduce inequalities; Cities and communities; Sustainable production and consumption Climate action Protecting marine life; Protect life; Peace, justice and institutions and Partnerships for the implementation of the goals.

Within this context, the cities of Marataízes are classified at the level of medium sustainable development. The maximum score is 100, while the city points to 53.34 and its overall rating is 780 out of a total of 5,570.

Based on an assumption between very high, high, medium, low and very low classification, the city of Marataízes points out the need for improvements in several sectors such as poverty eradication, quality of education offered to citizens, dignity at work and development of its economy, sustainability of consumption, production, eradication of hunger and sustainable community. Representing a fully alarming situation are the SDGs in very low classification, represented by the Institute of Sustainable Cities by the color red. They are: gender equality, industry, innovation and infrastructure, protection of life on land, peace, justice and effective institutions, and also partnerships for the implementation of the objectives (IDSC-BR).

It is believed that the creation of the so-called Public Policies can become a compass in search of effective results, recognizing and guiding positive actions to achieve and develop changes. As seen in a comparative analysis with the 10 smartest and most sustainable cities in the world, added to Curitiba – PR, Marataízes has a lot to develop, but it has in its characteristics important points as in other countries (Paris, Geneva, France), its culture makes it known for its beautiful beaches and lagoons (Lagoa do Siri, Praia de Boa vista do Sul, Centro Areia Preta, Falésia, Praia das Rosas, Micinho and Pitas Gomes), are some examples, with summer being the season of greatest economic movement for receiving tourists from several other cities in Brazil and the world. Economic development is one of the indicative factors in the recognition of urban growth and the need for improvements in the city's infrastructure (STEFANI, PROCIDONIO RAIFUS and CHÍUSOLI, 2023).

As it was found, several cities (London, New York, Oslo, Frankfurt) have urban conditions favorable to the population and sustainability. They are mirrors for the city of Maratimba: electric buses, the creation of subways using reusable energy, which stimulates public transport, public bike racks that, in addition to doing good to the health of the planet by not producing carbon monoxide, reduce traffic on the Avenues, generating agility and reducing accident rates. As well as Seoul (South Korea) use public lighting by sensors and with LED lamps, as they are recyclable, which also helps to reduce carbon emissions (MAULEN, MARINHO, ETEROVIC, 2019).

Quality education is part of sustainable planning, through which it is possible to work on good environmental education.

In Marataízes, an award entitled "environmental sustainability of water resources in Marataízes" has been taking place since 2016, it is an event designed in partnership between the Municipal Department of the Environment and the Municipal Department of Education, where students receive prizes in categories such as children's drawing, poetry and even environmental letters (O Jornal Online, 2023).

Many cities have implemented parks, gardens and commas tree-lined avenues (Osaka, Sydney), and Marataízes can be mirrored by developing reforestation, sustainable agriculture, protection of endangered animal species and conservation of their ecosystem, since the most prominent product in the municipality is the pineapple "Sweet, Sweet as Honey", there could be incentive programs to partner with farmers offering a line of credit for access and proper use of equipment in the soil irrigation without wasting water and support for the use of organic fertilizers (VILELA, BENTES, OLIVEIRA, MARQUES, SILVA, 2020).

Citing ecosystem, as well as, the city of Marataízes is located on the coast of Espírito Santo, and has a vast aquatic area, which also moves the city's economy through fishing. In February 2024, the magazine Caderno Pedagógico published an article mentioning the environmental effects caused by fishing waste in the city of Maratimba, and unfortunately the municipality has not yet created an infrastructure for proper waste disposal and informative education aimed at fishermen, this being the justification of the observed workers (ABREU, 2020).

To conclude this article of the literature review, it is notable to transcribe renewable energy, better known as clean energy.

Curitiba stands out in Brazil in sustainability, and its investment tool in this sector is solar energy, where in its city it is even used to supply energy to its public buildings. Solar energy, a natural source, is inexhaustible with a low acquisition cost (FERREIRA, COSTA. 2021).

Such points, therefore, show the city of Marataízes a comprehensive and effective need for analysis in its classification in the sustainable objectives towards the fulfillment of the 2030 Agenda.

FINAL CONSIDERATIONS

In summary, education for sustainable development in the city of Marataízes emerges with an ethical and moral imperative in the face of the environmental and social challenges it faces.

Sustainability is a principle that aims to balance the exploitation of natural resources with the preservation of the environment and the quality of life of the population. Environmental sustainability, for example, seeks that human activities respect the limits of nature and enable its ability to regenerate. From the reflections, it is possible to envision a path to the construction of a more equitable, just and sustainable city.

Marataízes, has adopted initiatives to promote sustainability in several areas, such as artisanal fishing, architecture and the environment: Water is life program, where the Municipality of Marataízes participated in a contest in the Sustainable Municipalities category with the "water is life" program, from the Department of Environment, Fishing registration booklets, the city distributed booklets to the

fishermen to record their catches. The objective is to monitor and control fishing activity, in addition to facilitating access to public policies and social benefits and the Sustainable Residence Architectural Project.

Finally, it is important to calculate the environmental impact of each action and reduce it. Some sustainable actions that can be adopted are: reuse of environmental resources, such as selective collection, use of non-polluting means of transport, among others to contribute to the sustainability of the municipality.

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CRITICAL EVALUATION OF SMART AND SUSTAINABLE CITIES: COMPARING TRÊS LAGOAS (MS) AND CURITIBA

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ABSTRACT

This article critically analyzes the characteristics of smart and sustainable cities, focusing on the comparison between Três Lagoas, in Mato Grosso do Sul, and Curitiba, in Paraná. Curitiba is internationally recognized for its innovative practices in urban mobility, waste management and environmental planning, standing out as a model of sustainability. On the other hand, Três Lagoas, which is experiencing rapid economic growth due to its pulp and paper industry, faces significant challenges, such as pressure on natural resources and the lack of an efficient public transportation system. The study emphasizes the importance of integrated public policies that consider sustainability, economic development and social inclusion. For Três Lagoas to become a smart and sustainable city, it is essential that there is greater collaboration between the government, the private sector, and civil society. The work concludes that the transformation of Três Lagoas into a model of sustainable city is possible, as long as policies are implemented that prioritize environmental preservation and the quality of life of the inhabitants, inspired by successful experiences such as that of Curitiba.

Keywords: Smart Cities. Urban Sustainability. Urban Mobility. Public Policies.

INTRODUCTION

The concept of "smart city" has been gaining prominence worldwide due to the growing demands for urban solutions that integrate advanced technologies, sustainable planning, and quality of life. Cities such as Curitiba, known for its pioneering spirit in urban mobility and environmental management, and other global metropolises cited as "smart cities", have been a reference in this field. The use of innovative technologies, the promotion of sustainable practices, and the prioritization of quality of life are common characteristics of these cities, which seek to balance economic growth with the preservation of natural resources and social inclusion. This article seeks to compare the characteristics of these smart cities, highlighted in the analyzed videos, with the reality of Três Lagoas, in Mato Grosso do Sul. Known for its rapid economic growth and importance in the industrial sector, Três Lagoas presents a challenging context in terms of sustainable development.

By analyzing aspects such as mobility, environmental management, technology and governance, this study aims to understand how much the city is aligned with the best practices of sustainability and urban intelligence, using Curitiba as a comparative parameter. In this way, a critical analysis of the qualities and challenges of Três Lagoas in areas such as infrastructure, technological innovation and public services will be made, highlighting its potentialities and weaknesses in the face of examples of sustainable cities. Finally, we will discuss the necessary conditions for Três Lagoas to be recognized as a sustainable city, pointing to more integrated and responsible development paths.

For a city to be considered smart and sustainable, it must meet a series of criteria that involve the efficient use of natural resources, the integration of cutting-edge technologies, and the promotion of economic development that takes into account the social and environmental needs of the population. According to Harrison and Donnelly (2011), smart cities are those that use information and communication technologies (ICTs) to optimize urban processes, promote innovation, and improve the quality of life of citizens, while reducing environmental impact.

Curitiba, one of the most notable examples of a smart city in Brazil, is internationally recognized for its innovative solutions in public transportation, waste management, and urban planning. The creation of the bus rapid transit (BRT) system and the integration of urban green areas are examples of successful policies that combine urban development and sustainability (Rabinovitch, 1992**)**. The city also stands out for its high recycling rate and policies that encourage environmental education among its inhabitants. On the other hand, Três Lagoas, despite its recent economic growth, especially in the pulp and paper sector, faces considerable challenges in adapting to these sustainability standards. Although it has consolidated itself as an industrial hub, the city still lacks efficient solutions in terms of urban mobility and environmental management. Rapid industrial growth has brought economic benefits, but also pressures on urban infrastructure and local natural resources, such as the excessive use of water for industrial production and the need for proper management of waste generated by these activities.

When comparing Três Lagoas with Curitiba, some gaps become evident. Curitiba knew how to reconcile population growth with sustainable urban planning, prioritizing quality public transport and the preservation of green spaces. By contrast, Três Lagoas has not yet been able to implement an effective public transportation system that meets the needs of its expanding population, and environmental preservation has been compromised by rapid industrial advancement, raising concerns about long-term sustainability.

Castells (1996) points out that a truly smart city must be able to integrate the economic, social and environmental dimensions in a balanced way. For Três Lagoas to move in this direction, it is essential that there is public management that promotes not only industrial growth, but also sustainability policies that involve the local community, such as improving public transport, efficient solid waste management and the conscious use of natural resources, especially water.

Cities have become the focus of discussions on sustainable development and innovation, particularly as they face complex urban challenges such as population growth, resource scarcity, and climate change. The smart city concept emerges as a response to these challenges, integrating digital technologies with urban infrastructure to optimize the quality of life of citizens. Cities such as Curitiba are often cited as examples of success in this context, having implemented innovative solutions that promote sustainable urban mobility and efficient waste management. The public transport system, which prioritizes the use of buses over cars, in addition to the preservation of green areas, demonstrates how smart urban planning can bring social and environmental benefits. Curitiba's experience not only highlights the importance of using technologies, but also the need for a political and social commitment to sustainability, creating a model that other cities can follow. On the other hand, cities such as Três Lagoas, which stand out for their economic growth, often face difficulties in keeping up with the demands of sustainable development. With an accelerated growth driven by the pulp and paper industry, Três Lagoas presents a reality that contrasts with the principles of smart cities. Pressure on natural resources, especially water, and inadequate waste management are issues that need to be urgently addressed. This situation demands a critical look at how Três Lagoas can adapt to sustainability and urban intelligence practices, using the experience of Curitiba as a guide. The challenge lies in finding a balance between economic development and environmental responsibility, promoting social inclusion and quality of life. Therefore, the comparative analysis between these two cities is essential to understand the different approaches and the results that can be achieved, highlighting the importance of integrated public policies and community participation in the urban transformation process.

In short, the city of Três Lagoas has the potential to become a reference in sustainability, as long as it manages to implement public policies that promote sustainable development, in line with the best practices observed in cities like Curitiba. To this end, it is necessary not only the use of innovative technologies, but also the involvement of civil society, the environmental responsibility of local industries, and the strengthening of urban infrastructures aimed at social inclusion and environmental preservation.

METHODOLOGY

This article uses a bibliographic research approach for the critical analysis of the characteristics of smart and sustainable cities, comparing the reality of Três Lagoas (MS) with that of Curitiba (PR). The bibliographic research allows an in-depth understanding of the theoretical and practical concepts related to the theme of "smart cities" and urban sustainability practices, through the review and analysis of works and studies already published.

The methodology adopted in this work follows the following steps:

1. Survey of Theoretical References: Academic works, scientific articles, institutional reports and documentaries relevant to the understanding of the concept of smart and sustainable cities were selected. Among the most cited authors are Harrison and Donnelly (2011), who discuss the role of ICTs in smart cities, and Castells (1996), who addresses the integration of economic, social and environmental development. In addition, case studies on Curitiba, internationally recognized for its innovative practices, and data on Três Lagoas, a city in industrial expansion, were consulted.
2. Comparative Analysis of Cities: To make the comparison between Três Lagoas and Curitiba, an analysis of articles and reports that detail the public policies and sustainable development strategies adopted in Curitiba was carried out, such as the studies by Rabinovitch (1992) on urban mobility and environmental planning. In parallel, reports and data on Três Lagoas were used, focusing on its industrial growth, environmental impact and urban infrastructure.
3. Identification of Sustainable City Criteria: From the reviewed literature, the main

criteria that characterize a smart and sustainable city were defined, including: efficient urban mobility, solid waste management, preservation of natural resources, use of innovative technologies, social inclusion and citizen participation. These criteria are used to evaluate and compare the practices adopted by Curitiba and Três Lagoas.

4. Critical Analysis: Based on the reviewed material, a critical analysis was carried out, identifying the strengths and weaknesses of Três Lagoas in relation to sustainability and urban intelligence practices. From this analysis, the challenges faced by the city on its path to becoming sustainable were discussed, based on the example of Curitiba.

Discussion of Paths to Sustainability: Finally, the study presents suggestions for public policies and strategies that can be adopted by Três Lagoas, with the objective of aligning its economic growth with sustainable practices, inspired by the example of Curitiba and the characteristics identified in smart cities.

By opting for the bibliographic methodology, this work seeks to integrate theoretical and practical knowledge already consolidated in the literature, providing a comparative view that helps in understanding the challenges and opportunities of Três Lagoas towards sustainability.

STATE OF THE ART

The concept of smart and sustainable cities has evolved over the past few decades, driven by the growing demand for urban solutions that integrate technology, innovation, and sustainability. The term "smart city" involves the use of Information and Communication Technologies (ICTs) to optimize urban services, improve resource efficiency, and increase the quality of life of citizens. Authors such as Harrison and Donnelly (2011) argue that these cities should be able to use data and integrated systems to promote real-time solutions to issues such as mobility, safety, and the environment. At the same time, the concept of urban sustainability involves the implementation of practices aimed at economic and social development in harmony with environmental preservation. Castells (1996) argues that true sustainability is only achieved when there is a balance between economic growth, social inclusion and environmental responsibility. Several studies have analyzed examples of cities that apply these practices, such as Curitiba, known for its innovative transportation system and the efficient management of its natural resources and solid waste (Rabinovitch, 1992). Cities such as Barcelona and Amsterdam are also often cited as models of "smart cities" for integrating cutting-edge technologies with sustainability and citizen participation policies. In contrast, many cities in developing countries, such as Três Lagoas, face the challenge of balancing rapid economic growth, often driven by industrialization, with the urgent need to adopt sustainable practices. The state of the art of research on smart and sustainable cities reveals an expanding field, with growing interest in solutions that combine urban planning, technological innovation and environmental responsibility, and it is essential to understand the adaptations needed for specific urban contexts, such as that of Três Lagoas, in Mato Grosso do Sul.

RESULTS AND DISCUSSION

The results of the comparative analysis between Três Lagoas and Curitiba reveal important differences and similarities in relation to sustainable development and the adoption of characteristics of a smart city. Curitiba, widely recognized for its efficiency in public transport and environmental management, stands out for initiatives such as the bus rapid transit (BRT) system, considered a world reference for its low cost and high impact on the reduction of polluting gas emissions (Rabinovitch, 1992). In addition, Curitiba's urban planning has always taken into account the preservation of green areas, with more than 52 m^2 of green areas per inhabitant, a factor that directly contributes to the quality of life and sustainability of the city. These aspects demonstrate how much the integration between governance, strategic planning, and effective environmental policies can transform a city into an example of urban sustainability. On the other hand, Três Lagoas, although showing robust economic growth, especially in the industrial sector, faces significant challenges in terms of urban infrastructure and sustainability policies. The rapid advancement of the city as an industrial hub in Brazil, especially in the pulp and paper sector, has brought economic benefits, but also environmental pressures, such as excessive water consumption and increased production of solid waste, which is still not treated optimally. The report by the SOS Mata Atlântica Foundation (2018) highlights that the preservation of natural resources in the region is a critical point, since industrial growth has generated significant impacts on rivers and local biodiversity.

While Curitiba implements solutions that align urban development and environmental preservation, Três Lagoas still lacks effective urban mobility and waste management strategies. According to Harvey (1996), cities that do not plan economic growth and sustainability in an integrated way end up creating "exclusion zones", where the benefits of progress are not distributed equitably. This is reflected in the lack of robust policies to include the population in an efficient public transport system or in recycling and environmental education programs in Três Lagoas. This lack puts at risk the possibility of the city aligning itself with the criteria of a smart and sustainable city, as defined by Harrison and Donnelly (2011). However, Três Lagoas has great potential to implement sustainability practices, if there is political will and community engagement. The experience of Curitiba shows that effective public policies can be transformative, and the city of Mato Grosso do Sul could follow this example by prioritizing the creation of green areas, investing in quality public transport and promoting environmental awareness policies. As Castells (1996) argues, true sustainability is only achieved when the social, economic and environmental spheres are treated in a balanced way. In this sense, the industrial growth of Três Lagoas needs to be accompanied by an agenda of public policies that ensure the responsible use of natural resources and social inclusion, enabling the recognition of the city as an example of sustainability in Brazil.

The study shows that Três Lagoas, although still far from the standards of Curitiba, has the potential to follow the path of sustainability. Investment in green infrastructure, public transport, and the promotion of inclusive environmental practices are fundamental steps for the city to become a model of sustainable development, capable of harmonizing economic growth and environmental preservation. In order for Três Lagoas to follow the path of sustainability effectively, it is necessary to consider the strategic role of public policies and citizen engagement. Curitiba, for example, has managed to consolidate itself as a reference city over decades of planning, focusing on the integration of social, environmental and economic issues. According to Lindau, Hidalgo and Facchini (2010),

> Curitiba's success as a model of sustainable and smart city is directly related to the government's strong commitment to long-term public policies, which prioritized sustainable urban mobility, the creation of green areas, and the inclusion of the population in participatory decision-making processes.

This vision is crucial, as it reflects the need for coordinated and planned long-term actions, something that Três Lagoas should consider in its future policies. Also according to the authors,

> the challenge for Brazilian cities, especially those in a process of accelerated growth such as Três Lagoas, is to align economic development with the preservation of natural resources, ensuring that progress meets present needs without compromising future generations

Três Lagoas, when focusing on industrial development, needs to balance this growth with practices that minimize environmental impact and promote greater social inclusion. The experience of Curitiba, which since the 1970s has been implementing practices such as the use of efficient public transport and the expansion of green areas, is an example that shows how sustainable planning can be transformative and accessible, even in cities with great population challenges. A key aspect of the transformation of Três Lagoas into a more sustainable city lies in the involvement of local industries in socio-environmental responsibility practices. Many of the cities considered smart and sustainable in the world, such as Amsterdam and Copenhagen, incorporate the private sector in the process of sustainable urban development, requiring practices to mitigate environmental impacts and greater investment in green infrastructure. As Satterthwaite (1997) points out in his study on sustainable cities,

> Collaboration between the public and private sector, along with raising awareness among the population, is one of the key factors in transforming cities into smarter and more sustainable environments. The responsibility cannot fall on the government alone; It is essential that industries and civil society are an active part of this process.

The urban transformation of Três Lagoas therefore needs an integrated strategy, which involves both effective public policies and the commitment of the private sector and the local population. Just as Curitiba has implemented a series of coordinated actions over time, Três Lagoas can adopt practices such as the creation of an efficient public transport system, which would reduce the use of private vehicles and CO_2 emissions, in addition to improving urban mobility. As mentioned by Gehl (2010), cities that prioritize sustainable urban mobility, creating people-oriented spaces and reducing the dominance of automobiles, tend to be more lively, attractive, and environmentally balanced. This perspective is directly applicable to Três Lagoas, where the absence of a robust public transport system limits the mobility of the population and increases the environmental impacts of excessive car use. In addition, the creation of green areas and the responsible management of water resources are essential for Três Lagoas to align with the standards of a sustainable city. Curitiba, for example, implemented a system of linear parks along its rivers to combat flooding and create recreational areas for the population, a practice that could be adapted to the context of Três Lagoas, especially considering the local challenges with wastewater management and river preservation.

According to Hall (2014), linear parks are one of the most innovative solutions to promote sustainable coexistence in urban areas, as they combine the need for environmental protection with the creation of public spaces that foster the well-being of the population. Therefore, for Três Lagoas to approach the sustainability standards observed in Curitiba, a paradigm shift in urban planning will be essential, with an emphasis on creating a greener, more efficient and inclusive infrastructure. Economic development, although essential, must be linked to clear strategies for environmental preservation and sustainable urban mobility, promoting a long-term vision that can consolidate the city as an example of balanced development in the Brazilian context.

FINAL CONSIDERATIONS

The comparative analysis between Três Lagoas and Curitiba highlights the complexities and challenges faced by cities that seek to align with the principles of sustainability and urban intelligence. Curitiba, widely recognized as a model of a sustainable city, demonstrates how consistent public policies, long-term planning, and social engagement can transform urban development, resulting in a more inclusive, green, and efficient city. Its innovative solutions in public transport, waste management and environmental preservation offer a valuable lesson for other Brazilian cities, such as Três Lagoas, which is in a phase of rapid economic growth. Três Lagoas, as it emerges as an important industrial hub, has faced challenges in balancing economic advancement with environmental protection and the development of sustainable urban infrastructure. The lack of an efficient public transport system, the increasing pressure on natural resources, and the need for responsible management of industrial waste are critical issues that need to be addressed so that the city can evolve towards a more sustainable reality. The experience of Curitiba serves as a beacon for Três Lagoas, showing that it is possible to reconcile development and preservation through well-implemented public policies and commitment to the well-being of the population and the environment.

The final considerations of this study reinforce the importance of integrating governance, technological innovation and environmental preservation practices into any urban development strategy. Três Lagoas has great potential to become an example of a sustainable city in Brazil, but for this, it will require a greater commitment from both the public and private sectors, in addition to the active engagement of civil society. As highlighted throughout this work, initiatives such as investment in public transport, the creation of green areas and the adoption of more sustainable industrial practices are fundamental for Três Lagoas to follow the same path as Curitiba. The urgency and importance of Três Lagoas adopting a proactive approach towards sustainable development and transformation into a smart city is highlighted. The comparison with Curitiba reveals that, although Três Lagoas has stood out in economic growth, especially in the industrial sector, this should not occur at the expense of the environment and the quality of life of its citizens. Curitiba's experience demonstrates that effective urban planning, which includes the creation of green infrastructure, an efficient public transport system, and sound waste management policies, is crucial to ensuring a sustainable future. Thus, Três Lagoas should consider implementing similar practices, adapting them to its local context.

In addition, it is essential that the development of Três Lagoas does not occur in isolation, but in collaboration with all stakeholders, including the government, the private sector, and civil society. A joint effort can facilitate the creation of an urban environment that prioritizes sustainability and inclusion. For example, promoting environmental education in schools and communities, in addition to encouraging the participation of the population in decision-making processes, can result in more transparent and effective urban management. It can also foster a sense of belonging and responsibility among citizens, which are critical to the success of any urban transformation initiative.

Another important point to be considered is the need for continuous monitoring of the policies implemented. The ability to assess the impact of actions taken in Três Lagoas will allow for adjustments and improvements over time, ensuring that the city not only achieves but maintains the standards of a smart and sustainable city. In addition, the adaptation to new technologies and the integration of innovative solutions in urban planning can provide a significant advance, positioning Três Lagoas as a model for other cities facing similar challenges. Finally, they reaffirm that the transformation of Três Lagoas into a sustainable and smart city is a viable goal. With commitment, strategic planning, and the collaboration of all sectors of society, it is possible to create a future that not only preserves the environment but also promotes social justice and equity, ensuring that all citizens have access to a dignified quality of life. This path is not only a necessity, but a collective responsibility that will determine the legacy we will leave for future generations.

Ultimately, the transformation of Três Lagoas into a smart and sustainable city will not only depend on economic growth, but also on the ability to implement policies that promote social equity, the preservation of natural resources, and the quality of life of its inhabitants. The success of Curitiba demonstrates that, with vision, planning and active participation of all the actors involved, it is possible to achieve a balanced, sustainable and intelligent urban development.

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TOWARDS SUSTAINABILITY: THE EVOLUTION OF GUANAMBI COMPARED TO CURITIBA

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ABSTRACT
This article performs a comparative analysis between Curitiba and Guanambi, with the objective of identifying the sustainable urban practices adopted by Curitiba that can serve as a reference for the development of Guanambi. Through a bibliographic research, fundamental areas such as urban mobility, waste management, citizen participation and the use of technologies are examined, highlighting the opportunities and challenges for Guanambi. Curitiba, widely recognized as a sustainable city, has implemented innovative solutions that have transformed its urban structure and quality of life. By contrast, Guanambi still faces significant obstacles, especially in terms of public transport, environmental management and infrastructure. The objective of the article is to propose alternatives for Guanambi to adopt sustainability practices adapted to its regional characteristics, strengthening public management, promoting environmental education and encouraging the participation of the population. Throughout the analysis, it is concluded that Guanambi has the potential to follow a sustainable development trajectory, as long as it invests in innovative solutions and integrated public policies, with the active participation of its community. In this way, the city can walk its path towards sustainability and promote a more balanced and inclusive future.

Keywords: Sustainability. Town planning. Mobility. Citizen Participation.

INTRODUCTION

In recent years, the concept of smart cities has gained prominence in discussions about urbanism and sustainability. Cities like Curitiba, recognized for its innovative initiatives in public transportation and urban planning, serve as examples of how technology and efficient management can transform urban environments into more livable and sustainable spaces. On the other hand, Guanambi, a city in the interior of Bahia, has characteristics that reflect both challenges and opportunities in its journey towards sustainability. The videos analyzed, "Smart Cities" and "Curitiba: The Ecological City", highlight fundamental attributes that define the success of these cities, such as efficient urban mobility, waste management, social inclusion and the use of technology to improve the quality of life of citizens. In contrast, Guanambi still faces significant obstacles, such as the lack of adequate infrastructure, the scarcity of public services, and the need to promote community participation in decision-making processes.

Analysis of the characteristics of smart and sustainable cities, such as those presented in the videos, reveals a number of elements that are fundamental to the success of a modern urban environment. Curitiba, with its innovations in public transportation, such as the express bus system and bike lanes, as well as robust recycling programs and green spaces, exemplifies how urban planning can be oriented towards the well-being of the population and environmental protection. The city is often cited as a model to be followed, not only in Brazil but also in other countries, highlighting the importance of an integrated approach that considers the social, economic, and environmental. On the other hand, Guanambi, although it has the potential to develop as a smart city, faces significant challenges that hinder its evolution in this regard. The city still lacks adequate basic infrastructure, such as paving, basic sanitation, and access to quality health and education services. These factors directly impact the quality of life of citizens and limit the effective use of technologies that could improve urban management and civic participation.

The lack of a clear public policy and investments in crucial areas, such as transport and waste, makes Guanambi lag behind more advanced cities. However, the city has a strong foundation in terms of engaged community and a growing awareness of the importance of sustainability. There are, therefore, opportunities for Guanambi to learn from the experiences of Curitiba, seeking to implement practices that integrate technology and sustainable development. One of the most critical aspects to consider is urban mobility. The implementation of an efficient public transport system, similar to that of Curitiba, can not only improve the circulation of people, but also reduce pollution and promote social inclusion. The creation of bike lanes and the promotion of alternative transport initiatives, such as the use of bicycles, are actions that can be immediately explored.

In addition, Guanambi can benefit from environmental education programs, encouraging the population to actively participate in waste management and the conscious use of natural resources. Education is a powerful tool that can catalyze behavior change and foster a culture of sustainability among citizens. Community participation in urban planning is essential. The inclusion of residents in decision-making processes ensures that the proposed solutions meet the real needs of the population, increasing the effectiveness of the initiatives and fostering a sense of belonging. The exchange of experiences and knowledge with cities like Curitiba can serve as an impetus for Guanambi to become an example of a sustainable city, taking advantage of its unique characteristics and the potential of its population.

Analysis of the characteristics of smart and sustainable cities, such as those presented in the videos, reveals a number of elements that are fundamental to the success of a modern urban environment. Curitiba, often cited as a model of urban planning, stands out for the implementation of an innovative public transport system that prioritizes mobility and accessibility. Architect and urban planner Jaime Lerner, one of those responsible for the development of Curitiba's transport system, emphasized that transport should be a facilitator of urban life, promoting displacement and social integration.

On the other hand, Guanambi, although it has the potential to develop as a smart city, faces significant challenges that hinder its evolution in this regard. The city still lacks adequate basic infrastructure, such as paving, basic sanitation, and access to quality health and education services. Studies indicate that the lack of investment in infrastructure in cities in the interior of Brazil generates a cycle of exclusion and marginalization that prevents the population from having access to essential services and limits its development potential. One of the most critical aspects to consider is urban mobility. The Institute for Transportation and Development Policy argues that urban planning should be people-centered, prioritizing the creation of public transport systems that are accessible and efficient. The implementation of an efficient public transport system, similar to that of Curitiba, can not only improve the circulation of people, but also reduce pollution and promote social inclusion. The creation of bike lanes and the promotion of alternative transport initiatives, such as the use of bicycles, are actions that can be immediately explored.

Guanambi can benefit from environmental education programs, encouraging the population to actively participate in waste management and the conscious use of natural resources. The United Nations highlights that environmental education is essential for sustainable development, as it allows citizens to understand the impacts of their actions on the environment and promote positive change in their communities. Education is a powerful tool that can catalyze behavior change and foster a culture of sustainability among citizens. Solid waste management is also worth mentioning, since Curitiba has become a reference on the subject by implementing a selective collection system that involves the community and generates income for waste pickers. The research carried out by the Brazilian Institute of Geography and Statistics shows that cities that adopt integrated waste management practices are able to significantly reduce the amount of garbage that goes to landfills. This is an area in which Guanambi can advance, establishing partnerships with the population to promote recycling and composting, in addition to creating awareness campaigns on the importance of correct waste disposal.

Community participation in urban planning is essential. The inclusion of residents in decision-making processes ensures that the proposed solutions meet the real needs of the population, increasing the effectiveness of the initiatives and fostering a sense of belonging. The Sustainable Cities survey, carried out by Rede Nossa São Paulo, highlights that citizen participation is one of the pillars for building fairer and more sustainable cities. The exchange of experiences and knowledge with cities like Curitiba can serve as an impetus for Guanambi to become an example of a sustainable city, taking advantage of its unique characteristics and the potential of its population.

In this article, we will discuss these aspects in detail, drawing a parallel between the two cities and highlighting the lessons that Guanambi can learn from the Curitiba model, aiming at a sustainable evolution that benefits all its inhabitants. Building a more sustainable future for Guanambi depends not only on financial investments, but also on a collective commitment to promote changes that prioritize the well-being of the community and the preservation of the environment. In addition, it is essential that there is a continuous engagement of the population in sustainability initiatives, ensuring that each citizen feels part of the urban transformation process and that their voices are heard in the decisions that impact their lives, we propose a critical analysis of the characteristics of the cities mentioned in the videos in relation to Guanambi, exploring the initiatives that could be adopted to transform the city into an example of sustainability. The positive and negative characteristics of Guanambi will be addressed, in order to identify viable paths that allow the city to advance in the search for a more sustainable and inclusive future. The comparison with Curitiba will allow an in-depth reflection on how the lessons learned in already established cities can be applied to the context of Guanambi, promoting a more balanced and sustainable urban development.

METHODOLOGY

This article will be developed from a bibliographic research, based on the analysis of specialized literature on urbanism, smart cities and sustainability, as well as on case studies of Brazilian cities that have stood out in these areas. Bibliographic research, according to Marconi and Lakatos, is an essential method for data collection and analysis, since it allows to explore, interpret and synthesize information from different sources, offering a comprehensive overview of the topic addressed. To this end, books, academic articles, official documents and reports from national and international organizations that deal with urban planning, mobility, waste management and citizen participation will be used.

Gil argues that bibliographic research is appropriate when it is intended to carry out a theoretical review on a given topic, allowing the construction of a solid theoretical framework that will serve as a basis for the proposed analyses. In this study, the bibliographic methodology will be essential to identify the main characteristics of smart and sustainable cities, such as Curitiba, and compare them to the current context of Guanambi, highlighting the challenges and opportunities for the sustainable development of the city of Bahia. The sources used will be selected based on their relevance to the theme, following the criteria proposed by Severino for the choice of scientific literature. The works and articles must present a critical and reasoned view of the issues addressed, such as sustainable urban mobility and solid waste management. In this way, it will be possible to carry out a comparative analysis that takes into account not only the theoretical aspects, but also the practical application of urban solutions in different Brazilian realities.

Comparative analysis, according to Yin, is an effective methodological strategy for case studies, as it enables a deeper understanding of the particularities of each city and how they align or diverge in relation to the practices of sustainable cities. To this end, a dialogue will be established between the innovative practices implemented in Curitiba and the challenges faced by Guanambi, based on the existing literature. The comparison will be made based on parameters such as urban infrastructure, mobility, waste management policies and citizen participation, recurring themes in discussions about smart and sustainable cities. In addition, reports from international organizations, such as the United Nations and the World Bank, which offer guidelines on sustainable development in small and medium-sized cities, such as Guanambi, will be considered. These documents will serve to contextualize the city within a global scenario of urban transformation, allowing a reflection on the necessary adaptations so that Guanambi can approach the sustainability standards defended by such organizations. According to Minayo, the qualitative research applied here seeks to understand the urban reality in a more subjective way, relating social, economic and environmental factors to sustainable development.

Based on this set of sources and approaches, the article will seek not only to describe the current situation in Guanambi, but also to propose solutions based on successful experiences, offering a relevant theoretical contribution to studies on urban sustainability in Brazilian cities.

RESULTS AND DISCUSSION

The comparative analysis between Curitiba and Guanambi, based on bibliographic studies, reveals marked differences with regard to urban planning, mobility, waste management and the involvement of the population in public policies. By using Curitiba as a reference, it was possible to identify a series of innovative practices that contributed to the city becoming an example of sustainability. These practices have not only raised the quality of life of citizens, but also reduced the environmental impact caused by urbanization. Guanambi, in turn, despite having significant potential, still faces considerable challenges to reach a similar level.

One of the main factors that differentiate the two cities is the urban infrastructure aimed at sustainable mobility. Curitiba stands out for the creation of an integrated public transport system, planned since the 1970s, which prioritizes high-capacity public transport and the use of bi-articulated buses in exclusive corridors. According to the guidelines proposed by the Institute for Transport and Development Policies, one of the most important characteristics of a sustainable city is the ability to offer efficient and accessible public transport, promoting the reduction of the use of private vehicles and, consequently, reducing pollution levels. On the other hand, Guanambi faces great difficulties in the urban mobility sector. The city does not have an efficient public transportation system, and the options available are limited, which increases residents' reliance on private vehicles and motorcycles. The lack of bike lanes and integrated urban planning aggravates the problem, making it difficult for pedestrians and cyclists to circulate. Therefore, the city could benefit immensely from investments aimed at creating a more inclusive and sustainable public transport system, following the example of Curitiba.

Another relevant aspect is waste management. Curitiba implemented one of the first selective collection programs in Brazil, promoting the separation of recyclable materials and the environmental awareness of the population. This model, internationally recognized, includes the active participation of the community and the generation of income for the collectors of recyclable materials, contributing to social inclusion and the reduction of waste destined for landfills. As pointed out by the Brazilian Institute of Geography and Statistics, cities that adopt selective collection and recycling programs significantly reduce environmental impacts and generate economic benefits.

By comparison, Guanambi still has rudimentary waste management practices, with a low recycling rate and a garbage collection system that lacks greater efficiency. The absence of more robust environmental education programs is also an obstacle to the participation of the population. Although there are specific initiatives aimed at raising awareness about the importance of recycling, they are not yet consolidated as public policies. Guanambi, therefore, has a great opportunity to improve its waste management by adopting practices from sustainable cities like Curitiba, which would include the creation of recycling cooperatives and the implementation of a comprehensive selective collection system. With regard to citizen participation, Curitiba demonstrates how the involvement of the population can be a differential in the formulation of more inclusive and sustainable public policies. The city implemented popular consultation mechanisms early on, which allowed for greater engagement of citizens in the urban development process. Severino points out that social participation is crucial for the success of sustainable initiatives, as it ensures that the proposed solutions meet the real needs of the community.

In Guanambi, however, popular participation in urban and environmental planning processes is more limited. Although the city has an engaged community, formal channels of participation, such as municipal councils, still lack greater effectiveness and greater representation. The creation of spaces for dialogue and the inclusion of the population in the decision-making process are fundamental steps for Guanambi to follow the path of smart and sustainable cities. Another point to be discussed is the application of urban technologies, a crucial factor for the evolution of cities in the twenty-first century. Smart cities, such as Curitiba, have invested in the use of technology to monitor and improve public services, such as traffic control, public lighting, and garbage collection. The use of real-time data allows for more efficient management and optimization of available resources, something that is still a distant reality for Guanambi. Still, Guanambi's potential to transform into a more sustainable city is evident. The city has a population that shows an interest in environmental issues and that can be mobilized through effective public policies and environmental education programs. In addition, Guanambi's urban growth is still at a stage where it is possible to plan significant changes, something that larger cities already consolidated, such as Curitiba, face with greater difficulty.

Therefore, the main result of this analysis is the identification of clear opportunities for Guanambi to progress on the path of sustainability, taking advantage of the lessons of cities like Curitiba. Investments in infrastructure, urban mobility policies, waste management and citizen participation are crucial for the city to become a model of sustainable city in the interior of Brazil. Sustainable urban development is a process that requires not only proper planning, but also an ongoing commitment to innovation, popular participation, and environmental education. Curitiba has consolidated itself as a model of sustainable city over decades, through strategic decisions that integrate different dimensions of sustainability, including social, economic and environmental. For Guanambi, the challenge is to adapt these experiences in a way that respects their regional peculiarities and enhances their local resources, without losing sight of the successful practices of other contexts.

According to Carlos Leite, one of the leading scholars of sustainable urbanism in Brazil, cities that invest in green infrastructure, active mobility, and social inclusion tend to thrive faster, as such elements create a virtuous cycle that fuels human and economic development. In the case of Curitiba, the creation of an integrated transport system not only improved the quality of life of the population, but also served as a catalyst for urban growth in a planned manner. The city has been able to combine long-term planning with the gradual implementation of practical and innovative solutions.

In Guanambi, the initial focus should be on strengthening basic infrastructure, such as sanitation and transportation, fundamental aspects for the well-being of the population. It is widely documented by authors such as Lefebvre and Harvey that the right to the city includes access to essential urban services, which allows for the full participation of citizens in the economic and social life of the city. Guanambi, by mirroring Curitiba, can use this concept as a basis to implement solutions that ensure equity in access to these services, especially in the most peripheral areas, where the needs are more evident. The implementation of environmental education programs is another essential pillar for the success of a sustainable city. According to the United Nations, education is the key to sustainable transformation, as it prepares citizens to be agents of change in their own communities. Curitiba has developed a robust environmental education program since the 1990s, promoting awareness in schools and public spaces. In Guanambi, the challenge is to create a participatory environmental culture, which engages the population in the city's daily life and expands the perception of the importance of sustainability.

Waste management is also a topic that deserves to be highlighted in the discussion. Studies conducted by authors such as Fehr indicate that cities that adopt recycling and composting policies not only significantly reduce the volume of waste sent to landfills, but also promote the social inclusion of vulnerable groups, such as waste pickers. Curitiba was a pioneer in this aspect with the Waste that is not Waste program, which not only improves waste management, but also integrates the circular economy into urban life. Guanambi, by adopting similar practices, could reduce its environmental impact and, at the same time, generate employment and income for the local population, especially for groups in situations of social vulnerability. Another relevant aspect is the use of technology to improve urban management. As Manuel Castells states, smart cities depend on the application of communication and information technologies to optimize services and improve the quality of life of citizens. Curitiba has advanced in this direction by integrating technologies for traffic and public transport monitoring, improving the efficiency of services and the user experience. In Guanambi, even though technological resources are limited, the use of simple digital solutions, such as platforms to monitor public transport or apps for garbage collection, could bring direct and low-cost benefits.

Citizen participation is a point that needs to be strengthened in Guanambi. According to Henri Lefebvre's perspective on the right to the city, urban transformation will only be truly sustainable if citizens are active in the decision-making process. Curitiba offers an example of how popular participation can be integrated into urban planning through forums and advisory councils that involve residents in decisions about the future of the city. Guanambi, for its part, still lacks more structured mechanisms to promote the direct involvement of citizens in urban issues, but it can develop community forums, public debates, and partnerships with local organizations to strengthen this crucial aspect.

In the discussion of mobility, the perspective of urban geographers such as David Harvey reinforces that inequalities in cities are often amplified by the absence of accessible and efficient transportation. Curitiba dealt with this issue by creating a system that prioritizes public transport and reduces dependence on private vehicles. This model could be adapted in Guanambi by improving public transport, creating more efficient and accessible routes, as well as building bike lanes and encouraging the use of bicycles, promoting not only mobility, but also public health and the reduction of carbon emissions. It is important to consider the role of integrated public policies in sustainable development. As Sachs argues, sustainability depends on a holistic approach that considers the interactions between the economic, social, and environmental spheres. Curitiba stands out for integrating these elements into its public policies, creating a balance between economic growth, environmental preservation and social well-being. Guanambi can benefit from adopting a similar approach, where urban planning is not just a response to immediate needs, but part of a long-term vision that contemplates sustainable development.

In short, the study of the successful examples of Curitiba, combined with a critical analysis of the current reality of Guanambi, allows us to conclude that urban sustainability is not an unattainable destination, but a continuous process of adaptation and innovation. Guanambi, by aligning its urban plans with the principles of equity, citizen participation and environmental preservation, can walk its path towards sustainable transformation, promoting a fairer and more environmentally responsible future for its inhabitants. It is concluded that, despite the current challenges, Guanambi has the necessary conditions to evolve, as long as measures focused on sustainable urban planning are adopted, in line with the successful experiences observed in cities such as Curitiba. In this way, the city will be able to promote a higher quality of life for its inhabitants, while contributing to the protection of the environment and social development.

FINAL CONSIDERATIONS

From the comparative analysis between Curitiba and Guanambi, it is evident that the path to urban sustainability requires not only political will and resources, but, above all, a long-term strategic vision, supported by the active participation of the population and the adoption of innovative solutions. Curitiba, over decades, has been able to develop a solid and exemplary structure in crucial areas such as urban mobility, waste management and environmental education, consolidating itself as one of the great models of sustainable city in Brazil and in the world. This model is based on integrated planning that balances social, economic, and environmental needs, resulting in lasting benefits for its population. Guanambi, on the other hand, although it presents significant challenges, has remarkable potential to follow a similar trajectory. The city can benefit greatly from adapting and applying the lessons learned from Curitiba, adjusting these practices to its local and contextual particularities. To this end, it is essential that the city invests in priority areas such as urban infrastructure, especially with regard to mobility and basic sanitation, in addition to strengthening waste management and implementing comprehensive environmental education programs. Such measures, when implemented with efficiency and commitment, can not only improve the quality of life of the population, but also position Guanambi as a reference in sustainability in the interior of Bahia.

The need for an efficient and accessible public transport system stands out as one of the main challenges. Curitiba demonstrated that the integration of public transport and the prioritization of sustainable alternatives, such as the use of bicycles and the creation of bike lanes, are essential to reduce the use of private vehicles and, consequently, reduce greenhouse gas emissions. Guanambi, with its current reliance on private transport, can benefit from following this model, implementing solutions that prioritize inclusive, affordable, and environmentally friendly mobility.

Another crucial aspect is solid waste management. Curitiba, by instituting selective collection programs and involving the population in a continuous process of environmental awareness, has become an example of success in this area. Guanambi, still incipient in this regard, can adopt similar practices, promoting recycling, composting and income generation for waste pickers. In addition, long-term public policies, which involve the creation of recycling cooperatives and environmental education campaigns, can drive a significant change in the city's urban and environmental scenario. Citizen participation also presents itself as an area of great opportunity for Guanambi. As pointed out throughout this article, Curitiba is a clear example of how popular involvement in the urban planning process can ensure that solutions meet the real needs of the population. In Guanambi, the creation of discussion forums, advisory councils, and public consultation mechanisms can strengthen democratic governance and ensure that decisions about the city's future reflect the interests and aspirations of its inhabitants.

In addition, the adoption of urban and digital technologies, even if in a modest way, can generate significant improvements in public management in Guanambi. Simple transportation monitoring, waste collection, and energy efficiency systems can be easily implemented and contribute to the creation of a smarter and more sustainable city. The digitalization of public services, based on low-cost technologies, is a strategy that can facilitate urban management and improve the quality of services offered to the population.

Therefore, the conclusions of this article reinforce the idea that Guanambi, despite being at an earlier stage of development compared to Curitiba, is able to tread its own path towards sustainability. The city has a promising scenario and a population that, if properly engaged, can be the protagonist of this transformation process. However, this path requires a firm commitment on the part of public managers and civil society, who must act in a joint and planned manner to ensure that the solutions implemented are sustainable in the long term.

In this way, the sustainability of Guanambi does not depend only on the replication of external models, but on a careful adaptation to its regional particularities. The city's sustainable development potential is directly related to its ability to incorporate innovative practices in critical areas such as transportation, waste management, citizen participation, and the use of technologies. By adopting a strategic and holistic approach, the city can position itself as a benchmark for sustainability on the national stage, promoting a more inclusive, green, and socially just future for its inhabitants. For Guanambi to achieve this transformation, it is essential that public policies are planned in an integrated and coordinated manner, involving different levels of government and promoting partnerships with the private sector and civil society organizations. The adoption of cross-sectoral policies, which consider urban development in its entirety, can ensure that the solutions implemented in areas such as mobility, waste management and urban infrastructure are complementary, maximizing results in terms of sustainability. As Sachs points out, sustainability is only possible when public policies are thought of in a transversal way, focusing on the interactions between environmental, social, and economic aspects.

Finally, the awareness and engagement of the local population will be crucial to the success of any sustainability initiative in Guanambi. Without the support and active participation of citizens, the solutions implemented risk being underutilized or even rejected. The creation of a culture of sustainability, which promotes the responsible use of resources, environmental preservation and a sense of community, will be the foundation for the continuous development of the city.

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IMPACT OF CORPORATE SOCIAL RESPONSIBILITY ON ENVIRONMENTAL GOVERNANCE IN THE WESTERN AMAZON

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ABSTRACT
This study examines the role of Corporate Social Responsibility (CSR) initiatives in promoting environmental governance in the Western Amazon. Using a literature review methodology, the research identifies patterns and trends in CSR practices and their effectiveness in influencing environmental policies and sustainable practices. The objective of the research is to identify which CSR strategies are most effective in promoting environmental governance. This objective was partially achieved, as while the study provided an understanding of current practices and highlighted the importance of partnerships between businesses, governments and NGOs, it also identified significant challenges, such as greenwashing and the difficulty of measuring the impact of these initiatives, which still need to be addressed. The results highlight how companies, by adopting CSR strategies, can address specific regional challenges, contribute to sustainable development and align their corporate interests with global environmental goals. In addition, the study explores the benefits of these partnerships and addresses the associated risks. The discussion section looks at the need for collaborative integration to maximize the effectiveness of CSR practices and mitigate risks, offering insights for companies and policymakers interested in integrating environmental responsibility into business strategies.

Keywords: Corporate Social Responsibility, Environmental Governance, Corporate Sustainability, Western Amazon, Environmental Practices.

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INTRODUCTION

In the contemporary business landscape, social responsibility in the Western Amazon (one of the two parts of the Legal Amazon), with its rich biodiversity and global ecological importance, faces significant challenges related to sustainability and conservation. Corporate Social Responsibility (CSR), exercised by the private sector in the region, plays an instrumental role in promoting effective environmental governance. This article explores how CSR initiatives in the Western Amazon (composed of the states of Amazonas, Acre, Rondônia, and Roraima) can strengthen environmental governance, addressing specific regional challenges and promoting sustainable development. In addition, it offers valuable insights for those interested in fostering sustainable environmental practices.

CSR refers to the commitment and practices adopted by private companies and organizations to operate ethically and contribute positively to society and the environment. This concept goes beyond complying with laws and regulations, adopting a proactive stance towards social, economic, and environmental issues. The research problem of this study consists of investigating how these corporate initiatives impact the effectiveness of environmental governance in the Western Amazon, and what are the specific mechanisms through which these initiatives influence environmental policies, sustainable practices, and awareness of environmental issues, both at the corporate and community levels.

The objective of the survey is to identify which CSR strategies are most effective in promoting environmental governance, aiming to encourage the sector to adopt similar practices and contribute to a more standardized and efficient approach to environmental corporate sustainability. Understanding the impact of companies through CSR on environmental governance can help policymakers develop regulations and incentives that promote sustainable practices in the private sector. Companies, especially large corporations, have a significant reach and can profoundly influence public perception of environmental governance.

Using a literature review methodology, this study analyzes a series of academic publications and corporate reports to identify patterns and trends in CSR practices and their relationship to effective environmental governance. The rationale for this work lies in the growing importance of environmental sustainability in the business world and in society in general. As environmental issues become increasingly urgent, understanding how companies can contribute positively to environmental governance through their CSR practices becomes an issue of global relevance. However, assessing the impact of CSR initiatives on environmental governance can be challenging due to the variety of practices and the difficulty in quantifying long-term environmental benefits.

It is essential to recognize the limitations of this study. The research is predominantly based on secondary sources, which may limit coverage of all the practical and theoretical nuances of CSR. In addition, the risk of *greenwashing*, in which companies exaggerate or misrepresent their environmental practices, is a reality that must be considered when analyzing CSR initiatives. Despite these challenges, the article offers a contribution to understanding the intersection between CSR and environmental governance, paving the way for future research and sustainable practices in the corporate world.

Investigating ways to improve and engage the private sector in environmental governance can also include recommendations for more robust policies, incentives for sustainable business practices, and strategies for better collaboration between the private and public sectors. Integrating sustainable practices into business operations can include the use of renewable resources, reducing waste generation, recycling and energy efficiency, conservation initiatives, investing in green technologies, and supporting sustainable development projects. By implementing these practices, businesses not only reduce their environmental impact but also set an industry standard that can influence other organizations to follow suit.

An important connection between sustainable practices and environmental governance in the private sector can be explored in this context of sustainable resource management. This point of relationship underlines how companies can influence and be influenced by environmental governance through their practices of use and management of natural resources. The effectiveness of CSR initiatives in environmental governance is often scaled up through partnerships with governments, NGOs and other businesses. These collaborations can lead to innovative projects that have a significant impact on the environment, such as reforestation programs, biodiversity conservation, or cleaning up aquatic ecosystems.

Companies that adopt CSR tend to be more transparent about their environmental impact, through sustainability reports that detail their emissions, resource use, and other environmental metrics. This transparency can put pressure on other companies to adopt similar practices and allow external stakeholders to assess the company's commitment to sustainability. Engaged, these companies often play a vital role in educating the public and creating awareness about environmental issues, whether through marketing campaigns, educational programs, or sponsorship of sustainability-focused events.

On the other hand, it is also important to analyze cases of failure or criticism of CSR. In certain cases, these actions can be perceived as *greenwashing*, when a company invests more time and resources in marketing claiming to be sustainable than actually implementing practices that minimize environmental impact. Understanding this counterpoint is key to understanding the limitations of CSR and how it can be improved.

FUNDAMENTALS OF CORPORATE SOCIAL RESPONSIBILITY

In the modern business environment, Corporate Social and Environmental Responsibility (CSR) has established itself as a fundamental component that goes beyond the traditional objective of maximizing profits, adopting practices that are ethical, social, and environmentally sustainable. Its study dates back to the post-World War II period[3].

Conceptually, CSR is a business practice that promotes sustainable development, ensuring a balance between economic, social, and environmental well-being. In this context, companies, in addition to pursuing profit, must evaluate the impact of their activities on communities and the environment, adopting actions that benefit both society and their own corporate structure. This concept not only reflects a response to the growing demand for social responsibility, but also configures itself as an essential strategy in the current era of sustainability[4]. This implies that corporations not only implement and publicize their social and environmental initiatives, but also seek certifications that validate their practices, as highlighted in a study by *Deloitte*[5]:

Companies today are no longer evaluated based only on metrics such as financial performance, or even the quality of their products and services. Instead, organizations today are increasingly judged on the basis of relationships with their employees, consumers, communities, and impact on society as a whole.

On the subject of sustainability, Garcia[6] teaches that:

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[3] OLIVEIRA, L. G. L.; OLIVEIRA, M. C.; PINTO, F. R. Corporate social responsibility: comparative study of social norms. Revista Alcance, v. 15, n. 2, p. 169, 189, 2008.

[4] "Sustainability in a broad sense seeks to capture the three pillars of sustainability: (i) pillar I – ecological sustainability; (ii) pillar II – economic sustainability; (iii) pillar III – social sustainability. From this perspective, sustainability is profiled as a 'unifying concept' (Verbundsbegriff) that has progressively defined the legal, environmental, political, social and economic conditions and assumptions of sustained evolution" (CANOTILHO, José Joaquim Gomes. Sustainability: a novel of culture and science to reinforce democratic sustainability. In Boletim da Faculdade de Direito, Vol. LXXXVIII, Volume I, Coimbra: Universidade de Coimbra, 2012, p. 6).

[5] DELOITTE. The Rise of the Social Enterprise: 2018 Deloitte Global Human Capital Trends. 2018a. Disponível in: https://www2.deloitte.com/content/dam/insights/us/articles/HCTrends2018/2018-HCtrends_Rise-of-the-social-enterprise.pdf. Accessed on: January 30, 2024.

[6] GARCIA, Denise Shmitt Siqueira, orgs. Sustainable debates: Multidimensional analysis and environmental governance [et al] collaborators - Electronic Data - Itajaí: UNIVALI, 2015. Available at: <http://www.univali.br/ppcj/ebook>.. Accessed on February 02, 2024.

> It consists of the thought of global empowerment for the preservation of balanced human life, consequently, of environmental protection, but not only that, but also the extinction or reduction of other social ills that act contrary to the hope of delaying man's survival on Earth.

The private sector is committed to conducting its business ethically and sustainably, considering the social and environmental impacts of its operations. This approach has evolved from philanthropic initiatives to integrated business strategies that balance profit, people, and planet.

The implementation of this model involves the adoption of sustainable business practices, such as the efficient use of resources, reduction of carbon emissions, and promotion of fair working conditions. Companies also engage in community initiatives, support social and environmental projects, and strive to adopt ethical supply chains. In addition to contributing to a sustainable environment and a fairer society, this behavioral bias offers tangible corporate benefits, such as strengthening the brand and reputation, customer and employee loyalty, and potentially, improved financial performance. According to Prado *et al*[7]:

> Therefore, an important link is established between companies and citizens, in which companies are responsible for providing citizens with an ecologically correct consumption alternative, and they to join this cause, increasingly encouraging this "green" movement.

Environmental governance in the Legal Amazon faces significant challenges and it is essential to integrate Corporate Social Responsibility (CSR) practices that align with the Sustainable Development Goals (SDGs), especially SDGs 13 and 15. This alignment is essential to mitigate environmental problems and promote sustainable development in the region. The study by Moia and Diniz (2024)[8] highlights the importance of a robust governance structure that involves local communities and indigenous peoples in the management of natural resources, strengthening sustainability strategies and providing opportunities for innovative solutions.

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[7] PRADO, R. A. D. P., Silva, M. A., Junqueira, M.C., Almeida, L.N.N. (2011). The influence of green marketing on the consumption habits of young university students in business courses. Study in higher education institutions (HEIs). Brazilian marketing magazine. São Paulo, (10:2), pp. 126-145. https:www.redaly c.org/pdf/4717/471747525007.pdf. Accessed on January 25, 2024.

[8] MOIA, Gabriel Costa Maciel; DINIZ, Marcelo Bentes. Environmental governance in the municipalities of the Legal Amazon: challenges to be faced from the perspective of the Sustainable Development Goals. In: XXIX National Meeting of Political Economy. Section 8: Regional and Urban Issues, Federal University of Pará, 2024.

Despite its benefits, the posture in accordance with environmental responsibility faces challenges such as "*greenwashing*", where sustainability practices are promoted more than actually practiced. According to the authors Ribeiro and Epaminondas[9]:

> *Greenwashing* is a term that has been adopted since 2007 in the corporate world and has gradually been introduced into discussions about products. Its best translation would be "green washing", or even "green brushstroke". The term is designated when a company, non-governmental organization (NGO), or even the government itself, propagates positive environmental practices and, in fact, acts contrary to or neutral to environmental interests and goods.

From the study carried out by the Sustainable Amazon Foundation (FAS)[10] it is inferred that companies also engage in community initiatives, support social and environmental projects and strive to adopt ethical supply chains. In addition to contributing to a sustainable environment and a fairer society, this behavioral bias offers tangible corporate benefits, such as strengthening the brand and reputation, customer and employee loyalty, and potentially, improved financial performance.

The concept of social responsibility in the private sector has undergone a remarkable evolution over the years. Initially, it was predominantly associated with philanthropy or charitable actions. However, in recent decades, this view has broadened to encompass business practices that are sustainable, ethical, and transparent.

With increasing public awareness of global issues such as climate change and social inequality, corporations face increasing pressure to adopt more responsible practices. Today, consumers, investors, regulators, and society at large demand that businesses play a more active role in addressing social and environmental challenges.

However, a key part of corporate social responsibility is transparency in operations and accountability to *stakeholders*. Governments have implemented regulations that encourage or require responsible practices, recognizing that the private sector has a key role to play in addressing social and environmental issues. According to Freman *apud* Lyra[11]:

> Stakeholder in an organization is, by definition, any group or individual that can affect or be affected by the achievement of the company's objectives (Freeman, 1984). Stakeholder includes those individuals, groups, and other organizations that

[9] RIBEIRO, R.A.C.; EPAMINONDAS, L.M.R. From greenmarketing strategies to the greenwashing fallacy: the use of environmental discourse in packaging design and product advertising. National Meeting of Anppas- V Annals. Florianópolis/SC, 2010. p. 18.

[10] SUSTAINABLE AMAZON FOUNDATION (FAS). Sociobiodiversity, corporate social responsibility and international cooperation. Technical Course in Sustainable Development Management – Sustainable Amazonas Project, 2021. Available at: https://fas-amazonia.org/wp-content/uploads/2022/12/pas-cartilha-responsabilidade-social-corporativa-fundamentos-compressed.pdf. Accessed on: August 08, 2024.

[11] LYRA, Mariana Galvão [et al]. The Role of Stakeholders in the Company's Sustainability: Contributions to the Construction of an Analysis Model. Curitiba, v. 13, Special Edition, art. 3, p. 39-52, June 2009.

have an interest in a company's actions and who have the ability to influence it (Savage, Nix, Whitehead, & Blair, 1991). By neglecting these groups, some companies have already been devastated or destroyed (Tapscott & Ticoll, 2005).

Companies that adopt social responsibility practices often benefit from innovations and improvements in processes, products, and services. This approach can lead to a competitive advantage, as the company becomes more attractive to conscious consumers and investors who value sustainability. I mention some benefits:

> Reduction of the risk of socio-environmental accidents and their consequent attractiveness to investors; eco-efficiency, a business management philosophy based on an incessant effort to produce more and better at competitive prices, progressively reducing the environmental impact and the consumption of resources to levels at least equivalent to the planet's carrying capacity; the improvement of its reputation; increasing credibility in the company and improving its image; conscious consumption, or "green", with the launch of differentiated products and services on the market at lower environmental costs than their competitors (...); and, finally, the advantages in the area of human resources with regard to hiring, engagement and innovation[12].

Despite the benefits, private sector social responsibility faces challenges, including consistency in the implementation of CSR policies and the difficulty of measuring the real impact of these initiatives. Additionally, companies may face accusations of *greenwashing* when social responsibility actions are perceived as marketing efforts rather than genuine commitments.

The conduct of creating a brand with false or superficial environmental ideologies can cause several losses to companies. Studies show that this attitude, when revealed, ends up generating a loss of trust in the brand, also affecting its market value[13].

Social responsibility in the private sector is increasingly associated with building strategic partnerships with governments, NGOs, and other entities to more effectively and comprehensively address social and environmental challenges.

In the Western Amazon, the implementation of CSR practices can offer multiple benefits to companies. These include improved brand reputation and image, increased customer loyalty, the ability to attract and retain talent, and ultimately, more robust long-term financial performance.

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[12] BUSSLER, Nairana Radtke Caneppele [et al]. Corporate Social Responsibility and Governance: Paths for the creation of value in organizations. Unijuí, 2016.
[13] PIMONENKO, Tetyana et al. Green brand of companies and greenwashing under sustainable development goals. Sustainability, 12(4), 2020, p. 1679.

THE IMPORTANCE OF CORPORATE SOCIAL RESPONSIBILITY IN THE CURRENT BUSINESS CONTEXT OF THE WESTERN AMAZON

The region faces challenges such as deforestation, illegal mining, and biodiversity loss. These issues not only threaten the local environment, but also have global implications, especially in relation to climate change. Companies operating in the Western Amazon[14] have a responsibility to adopt practices that minimize their environmental impact. This includes sustainable resource management, biodiversity protection, and active engagement with local communities.

Governance plays an essential role in the sustainable development of the Amazon, being a key component for the preservation of global ecosystems. Within the scope of ESG (Environmental, Social, and Governance), corporate governance refers to the organizational structure and principles that guide the operations of entities, seeking to harmonize the interests of shareholders, leaders, and the community. In the Amazon, this form of governance is particularly crucial, as it gives companies a competitive advantage by promoting forest conservation, which in turn reduces carbon emissions and contributes to global climate stability.

This research focuses on Corporate Social Responsibility (CSR), and not on the concept of *Environmental, Social and Governance* (ESG). However, some sections use ESG as an example, which is why it is relevant to briefly clarify the similarities and differences between them. This clarification aims to maximize the reader's understanding, ensuring the full use of the content presented, without causing conceptual confusion.

Corporate Social Responsibility (CSR) and ESG (Environmental, Social, and Governance) criteria are approaches that promote sustainable business practices. Both aim to have positive impacts on the environment and society, considering various stakeholders in addition to shareholders.

CSR focuses on internal initiatives, such as philanthropy, reflecting social values, while ESG is crucial for investors, assessing sustainability and ethical behavior through metrics. While CSR is more qualitative and immediate, and ESG has a long-term perspective, their similarities allow them to be used in a complementary way, balancing social responsibility with financial performance.

[14] BRAZIL. DECREE-LAW no. 291 of 28.02.1967 - Art. 1 § 4 For the purposes of this Decree-Law, the Western Amazon consists of the area covered by the States of Amazonas, Acre and the territories of Rondônia and Roraima.

The Glocal Experience Amazonia, organized by the Amazon Network Foundation[15], exemplifies the practical implementation of these concepts, bringing together diverse stakeholders to explore sustainable solutions that meet both local and global needs. This event highlights how governance can act as an engine for sustainable development, encouraging the active participation of local people in decision-making processes and promoting a global perspective on the importance of the Amazon.

Initiatives can positively influence environmental governance with practices that go beyond compliance with regulations, setting higher standards for environmental conservation and the sustainable use of resources.

Stakeholder integration is essential to achieve these goals, as discussed by Moretto Alves in his dissertation 'Harmonizing Interests: Analysis of Legislation for the Sustainable Use of Wood in the Amazon from the Perspective of Amartya Sen' (2024).[16] Moretto Alves argues that collaboration between different stakeholders can promote more equitable forest management by strengthening environmental governance in the Amazon.

It should be noted that some of the essential characteristics that make companies fundamental for the promotion of sustainability are their entrepreneurship, creativity and innovation. As Laville argues, the company can be considered the only institution in the world today powerful and creative enough to implement the necessary changes[17].

Collaboration between companies, governments, NGOs and indigenous communities is essential for effective environmental governance. These partnerships can result in more robust policies, efficient conservation projects, and increased awareness of environmental issues.

> There are different types of coalitions that involve companies in partnership with other entities, such as non-governmental organizations (NGOs) and the State. These coalitions are termed Business and Industry Non-Governmental Organizations (BINGOs) play a significant role in global governance by providing a means for businesses to come together and engage in discussions and negotiations on economic, social, and environmental issues. They contribute to the articulation of business interests and to the participation of the private sector in the definition of policies and the promotion of sustainable initiatives[18].

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[15] BACELLAR, Clarissa. ESG: what is the relationship between governance and the Amazon? Portal Amazônia, 26 ago. 2023. Available at: portalamazonia.com. Accessed on: June 17, 2024.
[16] ALVES, Gabriela Cristina Moretto. Harmonizing Interests: Analysis of Legislation for the Sustainable Use of Wood in the Amazon from the Perspective of Amartya Sen. Master's Thesis, Federal University of Rondônia, 2024.
[17] MATIAS, Eduardo Felipe P. Humanity against the ropes. São Paulo: Paz e Terra, 2014, p. 98.
[18] TIENHAARA, Kyla. Corporations: business and industrial influence. In: HARRIS, Paul G. Routledge Handbook of Global Environmental Politics. New York: Routledg, 2014. p. 164-175 apud BARBOSA, Milena de Souza Chaffin. The private sector in environmental governance: Global Compact and ESG principles as dimensions of instrumental power. João Pessoa, 2023.

Jacaúna[19] presents reflections from which it is extracted that environmental governance in the Amazon is characterized by the complex network of interactions between multiple actors, including the State, NGOs and local residents. These networks form crucial governance structures for the coordination and implementation of environmental policies, as demonstrated in the study of the Conservation Units on the Unini River. Social network analysis (SRA) reveals how these interactions influence the management of natural resources, highlighting the importance of cooperation and information exchange among the various participants. The network structure found in the Unini River, characterized by a high level of heterogeneity and a combination of fragmented power and hierarchical cooperation, is an example of how governance can be both facilitated and challenged by these dynamic relationships.

Corporate Social Responsibility (CSR) in the Western Amazon requires a delicate balance between environmental conservation and economic development. Companies in the region have the opportunity to invest in business models that foster economic growth without causing harm to the environment, such as ecotourism and the sustainable use of natural resources. However, the implementation of these models faces specific challenges, including the vast geographical extension and rich cultural diversity of the region. Despite these obstacles, there is also enormous potential for innovation in sustainable practices, allowing companies to contribute significantly to the preservation of one of the most valuable ecosystems on the planet.

> The company's social performance can be enhanced by the adoption of strategies that value the quality of the benefited social projects, the multiplication of successful experiences, the creation of service networks and the strengthening of public policies in the social area... The company can also develop its own projects, mobilize its skills to strengthen social action and involve its employees and partners in the execution and support of social projects in the community[20].

Another point to be pointed out is that corporate social responsibility in the environmental context has been occurring due to adaptation to evolving social expectations. The discussion responds to the growing demands of consumers, investors, and the general public for more ethical and sustainable business practices. Companies are increasingly evaluated not only by their financial performance, but also by their impact on society and the environment.

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[19] JACAÚNA, Tiago da Silva. How do you govern the Amazon? Social networks and environmental governance in Conservation Units. Brazilian Journal of Social Sciences, v. 35, n. 103, 2020. Available at: https://www.scielo.br/j/rbcsoc/a/pLtj87qTGLb9hGZWnxN3zTx/?lang=pt. Accessed on: May 03, 2024.
[20] QUEIROZ, A et al. Ethics and social responsibility in business. 2. ed. São Paulo: Saraiva, 2005

It should also be considered that it can contribute to the strengthening of a brand, as a good CSR reputation can increase customer loyalty, attract and retain talent and open doors to new business partnerships, as well as the adoption of sustainable practices can ensure the continued viability of a company by protecting the natural resources on which it depends and maintaining a positive relationship with the community and the environment. As Laville, *apud*, Matias,[21] explains:

> It is necessary to create a company that is in harmony with the world around it, for which sustainable development is second nature and in which each act effectively contributes to the creation of a better world, not by altruism, but by its own way of being.

The proactive stance of the private sector towards Corporate Social Responsibility (CSR) can be a powerful driver of innovation, promoting the development of new products and services that not only meet the demands for more sustainable solutions, but also provide a competitive advantage in the market. This approach assists businesses in complying with government regulations and mitigating risks associated with environmental, social, and potential litigation issues.

In addition, CSR plays an essential role in social and economic development, enabling companies to effectively contribute to solving complex social problems, such as poverty, education, and health. Through these practices, businesses not only strengthen their operations but also promote a lasting positive impact on society.

THE RELATIONSHIP BETWEEN PRIVATE SECTOR CORPORATE SOCIAL RESPONSIBILITY (CSR) AND ENVIRONMENTAL GOVERNANCE

The relationship between Corporate Social Responsibility (CSR) and environmental governance is a fundamental intersection in the contemporary business context. While CSR reflects the commitment of companies to operate in a socially responsible and ethical manner, environmental governance focuses on creating and implementing policies and practices for the protection and sustainability of the environment.

Regarding environmental governance in the Amazon, the complexity of the study is pointed out by Torres Alvarez[22]:

> The Amazon has specificities that differentiate it from other regions of Brazil. The states that make up this region have a large part of their territories composed of rural and indigenous areas, a fact that makes the task of managing public policies in

[21] MATIAS, Eduardo Felipe P. Humanity against the ropes. São Paulo: Paz e Terra, 2014, p. 98.
[22] ALVAREZ, Carmen Paola Torres. Governance of professional and technological education: an analysis of the context of the Western Amazon. 2014. 140 f., il. Dissertation (Professional Master's Degree in Education) - University of Brasilia, Brasília, 2014, p. 85.

> order to achieve effective results for the government and society even more complex. At the state level, institutions encounter serious difficulties in the implementation of programs and projects formulated by the Federal Government, as these are, to a large extent, molded according to the reality of urban centers, disregarding the specific variables of the different regions of the country. This reality has manifested the need to reflect on the implementation of public policies in the Brazilian federative context, in which regional diversity predominates.

The concepts of Corporate Social Responsibility (CSR) and environmental governance are intrinsically linked, creating a cycle of reciprocal benefits for companies, society and the environment. CSR encompasses a set of practices that go beyond legal compliance, including voluntary actions that directly benefit society and the environment. Environmental governance, on the other hand, involves government policies, regulations, and voluntary initiatives that aim to manage the environmental impact of human activities.

These practices are aligned with environmental governance objectives. When a company implements more sustainable production practices, such as reducing emissions and waste, it not only complies with environmental regulations but also exemplifies a commitment to social responsibility. In addition, companies that have strong CSR initiatives are able to significantly influence the formulation and execution of environmental policies, contributing to a regulatory environment that encourages sustainable practices. According to the Abrinq Foundation[23]:

> Social responsibility is the way of thinking and acting ethically in relationships. Despite being strongly related to companies, the practice can be directly linked to an action, carried out by individuals or legal entities, whose main objective is to contribute to a fairer society.

By demonstrating successful environmental practices, businesses can encourage the adoption of stricter regulations and sustainable practices across the industry. In addition, integrating CSR with environmental governance benefits companies in several ways, such as improving their reputation, building trust with stakeholders, and ensuring long-term sustainable operations. For society and the environment, this results in a better quality of life and preservation of natural resources. Thereby:

> A citizen-company has in its commitment to the promotion of citizenship and the development of the community its competitive differentials. In this way, it seeks to differentiate itself from its competitors by assuming a new business posture – a company that invests financial, technological and labor resources in community projects of public interest. The citizen-company creates an image of excellence for

[23] Abrinq Foundation. Everything you need to know about social responsibility. 2020. Available at: https://fadc.org.br/noticias/tudo-o-que-voce-precisa-saber-sobre-responsabilidade-social. Accessed on February 02, 2024.

> its performance with society, which is reflected in increased trust, respect and admiration of its consumers[24].

Despite the benefits, there are challenges in integrating CSR with environmental governance. These include the need to balance economic objectives with social and environmental responsibility, and the risk of "*greenwashing*", where CSR actions are more of a marketing strategy than a genuine commitment. Corporate social responsibility initiatives of companies contribute to environmental governance, however, it is necessary to identify the obstacles faced by companies and governments in corporate social responsibility initiatives in the environmental area.

INFLUENCE OF CSR ON ENVIRONMENTAL POLICIES IN THE WESTERN AMAZON

CSR is a business approach that includes social and environmental concerns in operations and corporate interaction with *stakeholders*.

Environmental policies are applied to the adoption of practices by companies, evidencing leadership and sustainability, and in doing so, they achieve high standards in future environmental policies, expanding innovation to the entire industrial sector. It is important to emphasize that corporate social responsibility leads companies to assume new postures:

> With the increase in the involvement of the private sector in the solution of social problems, a function previously attributed only to non-profit organizations and the State, it is inevitable that companies seek to treat their social investment with the same logic and seriousness with which they treat their business strategies[25].

It is noted that companies engaged in environmental policies form links with government entities to develop the market in the areas of environmental sustainability. Companies that practice such behaviors play an important role in raising public awareness and education about environmental issues, influencing public opinion.

In these cases, these partnerships help shape regulations that are realistic, economically viable, and environmentally beneficial. In addition to adopting sustainable practices internally, some companies also actively engage in advocacy and *lobbying*[26] for

[24] SANTOS, Elenice Roginski. Social responsibility or philanthropy. FAE Business Magazine, Curitiba, n. 9, p. 32-34, 2004.
[25] FISCHER, Rosa Maria. Organizational Citizenship: a path of development In: Corporate Universities: Education for 21st Century Companies. São Paulo: Schmukler Editores Ltda, 1999 apud FEDATO, Maria Cristina Lopes. Corporate Social Responsibility: social benefit or competitive advantage, 2005.
[26] Defending interests with members of the public power who will make decisions – is an omnipresent phenomenon in democratic systems. THOMAS, C. S. (Ed.). Research guide to U.S. and international interest groups. Westpost: Praeger Publishers, 2004. p. 544.

progressive environmental policies, including support for legislation that promotes renewable energy.

In this regard, we can mention some measures that the private corporate sector can act with an eye on sustainable development such as products and services that are environmentally friendly; publication of transparent and detailed sustainability reports that show the company's environmental impact; obtaining environmental certifications that demonstrate a commitment to responsible environmental management; commitment to carbon reduction through environmental initiatives; promotion of environmental education and awareness among employees and customers, encouraging sustainable practices inside and outside the organization; adoption of sustainable supply chains; investment in research and development to find innovative solutions to environmental problems, among others.

METHODOLOGY

The methodology adopted for this study is a systematic literature review. This method involves analyzing multiple secondary sources, including academic publications and corporate reports, to identify patterns and trends in Corporate Social Responsibility (CSR) practices and their effectiveness in promoting environmental governance in the Western Amazon.

The literature review allows for a comprehensive understanding of CSR approaches employed by businesses in the region, identifying the most effective practices and gaps in the implementation of sustainable policies. The selection of sources followed criteria of relevance and timeliness, in order to ensure that the insights obtained were supported by contemporary evidence.

RESULTS

The results obtained from the literature review reveal a trend of adoption of Corporate Social Responsibility (CSR) practices by companies in the world, in Brazil and in the Western Amazon, although still in its infancy.

Data description: The analysis of the literature reveals that even though CSR practices are still incipient in the Western Amazon, there has been a significant growth in the adoption of these practices in recent decades. Data from the "ESG Panorama 2024" study indicate that 71% of Brazilian companies now incorporate environmental, social, and governance practices, reflecting a global trend towards greater corporate responsibility. This trend is particularly relevant in the Amazonian context, where pressure for environmental conservation is urgent.

Relevance of data: These data are critical indicators of the growth and importance of CSR practices, evidencing an increase compared to the previous year and highlighting the leading role of the industrial sector in this movement.

Greenwashing and Partnerships: The study highlights that, despite the increase in the implementation of CSR practices, the phenomenon of *greenwashing* remains a significant barrier. Many companies are accused of promoting a "green" image without adopting substantial changes in their operations. However, cross-sector partnerships between businesses, governments, and NGOs have proven effective in overcoming regional challenges, facilitating the adoption of more authentic and sustainable practices.

DISCUSSIONS

Interpretation of the results: The analysis shows that CSR practices, when integrated collaboratively with local stakeholders, have a positive impact on environmental governance. This is especially true when these practices are implemented through partnerships that share knowledge and resources, promoting a holistic approach to sustainability.

Comparison with existing literature: The results of the study are in line with previous research that highlights the potential of partnerships between businesses, governments, and NGOs to foster sustainable environmental practices. However, the study adds to the debate by emphasizing the ongoing risks associated with *greenwashing*, which can undermine the credibility of CSR initiatives if not properly addressed.

Contributions and implications: This study contributes to the understanding of the role of CSR in the Western Amazon, highlighting the region as a potential laboratory for economically viable and environmentally sustainable CSR practices. Companies that adhere to genuine CSR practices not only improve their reputation but also leverage their potential to innovate and lead the way towards more sustainable development.

Study limitations: The main limitation identified is the dependence on secondary sources. This can result in an incomplete view of the practical and theoretical nuances of CSR practices in the region. In-depth empirical studies are needed for a more comprehensive understanding.

Suggestions for future studies: It is recommended to carry out case studies with specific companies in the Western Amazon to deepen the analysis on the real impact of CSR practices on environmental governance. Such studies can provide valuable insights into how to overcome the identified challenges, including *greenwashing*, and can help develop innovative and sustainable business models.

CONCLUSION

Corporate Social Responsibility (CSR) in the Western Amazon is key to strengthening environmental governance in the region. By implementing responsible and sustainable business practices, organizations can not only mitigate their environmental impact but also actively participate in the conservation of this valuable global natural heritage while balancing economic and environmental needs.

Collaboration among diverse stakeholders is essential to achieve these goals, demonstrating that CSR is a powerful path to promoting a sustainable future in the Western Amazon. By incorporating ethical, social, and environmental considerations into their operations, companies not only help create a more sustainable world but also position themselves competitively in the market. The future of sustainable business requires a holistic approach, which CSR provides, balancing economic, social and environmental needs.

By adopting these practices, private sector companies can reduce their own environmental impact while simultaneously positively influencing society and the economy, promoting more effective and sustainable environmental governance.

The incorporation of ESG (Environmental, Social and Governance) practices is becoming increasingly prevalent in the Brazilian business sector, with 71% of companies adopting such practices, as pointed out by the "ESG Panorama 2024" study by Amcham Brasil[27]. This data reflects a significant evolution compared to the previous year and demonstrates a movement led mainly by the industrial sector. The survey reveals that the motivation behind this adoption includes the desire to positively impact environmental and social issues and strengthen the corporate reputation of organizations.

There is a growing demand for transparency in CSR practices, with an increasing number of companies publishing detailed sustainability reports. This reflects a strategic and integrated approach by the private sector, considering the impact of its activities on all stakeholders and the environment. It is recognized that companies have an essential role in building a sustainable future.

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[27] ESG Panorama 2024, Amcham Brasil-Chamber of Commerce of America. Published on April 23, 2024 by *O Tempo*. Available in https://www.otempo.com.br/economia/praticas-sustentaveis-sao-adotadas-por-71-das-empresas-brasileiras-diz-estudo-1.3441718

From the Amcham Brasil data[28] available in the aforementioned vehicle, it is possible to infer that despite this increase in the adoption of ESG practices, companies face significant challenges. The study highlights that 40% of organizations report difficulties in measuring ESG indicators, while 32% face obstacles in building a solid organizational culture. In addition, 30% of companies point to the lack of financial resources and efficient methodologies as barriers to the effective implementation of these practices. Such challenges reiterate the need for training and leadership development, in addition to the integration of sustainability into business strategies, as emphasized by the survey respondents.

CSR strategies impact environmental governance at many levels, from integrating sustainable practices into daily operations to contributing to broader environmental goals through partnerships and collaborations. The interaction between CSR and environmental governance represents a significant challenge in the modern business context. This relationship not only reinforces the corporate commitment to sustainable practices, but also promotes a holistic and integrated approach to natural resource management and environmental protection. As we move towards a more sustainable future, the fusion of these concepts will continue to play an essential role in driving positive change in both the private and public sectors.

[28] ESG Panorama 2024, Amcham Brasil-Chamber of Commerce of America. Publ.23 Apr 2024, *O Tempo*.

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GOOD AGRICULTURAL PRACTICES IN THE PRODUCTION OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN A SIMPLE RECIRCULATION SYSTEM IN URBANIZED AREAS

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ABSTRACT
The growth of Brazilian fish farming was due to the considerable increase in fish consumption, especially tilapia, which continues to be the most produced fish in the country, representing 65.3% of the total national aquaculture production. What was necessary was the search for the application of good agricultural practices in the production of Nile tilapia in alternative systems that produce with high density and work to reduce waste discarded in the tributaries. Thus, the study examines the implementation of biosecurity measures in simple recirculation systems, which through the biofilter reuses the same water during cultivation. These measures are necessary to ensure the health and well-being of the fish, as well as food safety. Based on a comprehensive literature review and field research, recommended practices for the installation and operation of these systems are analyzed, including the selection of suitable locations for solar incidence control, the performance of quarantine periods for monitoring clinical signs in fish lots, the regular clinical evaluation of fish, the continuous monitoring of water quality, the implementation of good management practices and the responsible use of medicines, when necessary. The results highlight the importance of these practices to prevent the introduction and spread of pathogens, as well as to promote the sustainability and economic viability of aquaculture production in urbanized environments. The dissertation contributes to the advancement of knowledge in the area and provides practical guidelines for producers and managers of Nile tilapia production systems in urban areas.

Keywords: Biosecurity. Sustainability. Recirculation.

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INTRODUCTION

Fish farming, is a branch of aquaculture that focuses on fish farming and production. Originating in Asia, this practice has spread globally and has experienced significant growth on all continents, including Brazil. Fish farming is recognized as one of the main methods of fish production worldwide, being responsible for a substantial portion of the global supply of fish for human consumption (CARVALHO, 2009).

As mentioned by Carvalho in 2009, fish farming represented 54% of fish production destined for world consumption at the time. This data highlights the importance of this sector in guaranteeing food supply, as well as in the economic development and food security of various regions of the world. Brazil, as one of the countries that has invested significantly in this area, contributes to this global panorama, expanding its production and participation in the international fish market.

According to the FAO (Food and Agriculture Organization of the United Nations) in 2020, world aquaculture demonstrated growth over the period from 2001 to 2018, with an average annual growth rate of 5.3%. This steady growth culminated in a historic milestone in 2018, when global production reached the mark of 114.5 million tons in live weight.

In parallel with the growth of aquaculture production, world fish consumption has also registered a significant increase over the decades. Between 1961 and 2017, fish consumption showed an average annual growth of 3.1%. This percentage is almost double the annual growth of the world population in the same period, which was 1.6%. In addition, the increase in fish consumption has outpaced the annual growth of other foods, such as meat, dairy products, and milk, which have grown at an average rate of 2.1% per year (FAO, 2020).

In 2018, Brazilian fish farming recorded significant growth, with an increase of 4.5% compared to the previous year, 2017. This resulted in a total production of 722,560 tons of fish. Compared to the numbers of 2014, where production was 578,800 tons, it is possible to observe a substantial growth in production over this period. Therefore, based on this survey, the fish farming production chain accumulated an expansion of approximately 24.83% in a few years, which demonstrates an expressive and continuous growth in this sector. (PEIXE BR, 2019).

The continuous growth in fish production in the country each year is related to the boost of several factors, including the emergence of new enterprises, investments in advanced technologies, improvements in management and in the production process, with this, every day more research is being developed in search of more knowledge about the proper way to produce them, with emphasis on the larviculture and nursery phases (TAVARES; DIAS et al., 2003; DANIEL, 2022).

The revenue generated by this growing fish production in 2020 was 8 billion reais, which reached 802,930 tons. More than 1 million jobs generated directly and 7 indirectly (PEIXEBR, 2021).

One of the most cultivated species in aquaculture worldwide is Nile tilapia (*Oreochromis niloticus*), due to a number of advantageous characteristics. It has rapid growth, which means it reaches a market size in a short period of time, making it a cost-effective choice for growers. In addition, its rusticity and ability to adapt to a wide range of environmental conditions make it an easy-to-manage species. In addition to being valued for its high yield index (SILVA et al., 2015).

In 2023, tilapia significantly expanded its participation in Brazilian farmed fish production, reaching the mark of 579,080 tons. This number represents a growth of 5.28% compared to the previous year. With this result, tilapia now represents 65.3% of the total national aquaculture production. In the previous year, in 2022, tilapia production in Brazil was 550,060 tons, which corresponded to 63.93% of the national total (Peixe Br 2024).

However, improper disposal of organic and inorganic waste from aquaculture can have serious consequences for the environment, including water contamination, degradation of aquatic ecosystems, and risk to human and animal health. Organic waste, such as food scraps and fish feces, can lead to eutrophication problems, resulting in decreased dissolved oxygen in the water (POERSH, 2012).

Thus, to mitigate these impacts, it is essential to implement proper aquaculture waste management practices, including the responsible treatment and disposal of waste, monitoring water quality, and adopting sustainable production technologies.

Having alternative systems that can help reduce waste discarded in the tributaries is essential. To reconcile the increase in production with sustainability, it is essential to use production technology, which includes the water recirculation system where it is possible to produce aquatic organisms (CREPALDI et al., 2006).

The Water Recirculation System (RAS), which consists of the reuse of the same water in the system, where it will treat and maintain the water in the desired parameters (DANIEL, 2022).

The advantages that this system can offer are waste management and nutrient recycling, reduction of water consumption, easy maintenance of hygiene and disease control, biological and pollution controls carrying out the process. In addition to the possibility of being produced close to urban centers, as they require little space for operation (LIMA et al., 2015).

One of the allies of profitable production is biosecurity, these measures are essential to ensure the health and well-being of fish and to prevent the introduction and spread of pathogens in the aquaculture production environment. Producers who implement biosecurity are able to significantly reduce the risk of disease and increase the productivity and sustainability of their aquaculture operations.

Therefore, the objective of this work was to address the main aspects of biosecurity together with the recirculation system, promoting to the producer a sustainable form of production in reduced spaces.

LITERATURE REVIEW

TILAPIA-DO-NILO (*OREOCHROMIS NILOTICUS*)

On the global stage, Brazil occupies the position of fourth largest producer of tilapia, behind only China, Indonesia and Egypt. These data highlight the importance of Brazil in the world tilapia market and the significant contribution of the aquaculture sector to the national economy. In the last ten years, tilapia production in Brazil has experienced a remarkable growth, going from 285 thousand tons to 579 thousand tons. This increase represents an impressive jump of 103% in the period. The tilapia stands out as the animal protein with the highest growth in the country over this period (PEIXE BR, 2024).

This prominence in the production of this species is due to the ~~or~~ tropical and subtropical climate are conducive to the breeding of Nile tilapia, since they offer ideal temperature and light conditions for the efficient growth and reproduction of this species, thus causing it to spread to several countries. In addition, because it has excellent performance of growth and reproduction, as well as favorable sensory characteristics of fillet meat, which makes it highly appreciated in cooking. It is also worth mentioning the absence of intramuscular spines in the shape of a "Y" which enhances it as a fish for industrialization (FURUYA, 2018).

In addition, the favorable environment in Brazil offers favorable conditions for tilapia farming, including suitable climate, freshwater availability, and investments in technology and management. The growing demand has also boosted production, as tilapia is an increasingly popular option among Brazilian consumers, due to its mild flavor, affordable price, and nutritional value.

Nile tilapia's resistance to harsh conditions, its ability to grow quickly, and its ease of reproduction are additional factors that contribute to its success in aquaculture. Its versatile diet, as an omnivorous species, allows producers a wide range of food options, which provides flexibility in terms of nutritional management. These characteristics make Nile tilapia an attractive and profitable choice for commercial producers, further boosting its production (MARENGONI, 2006).

Among the exotic species that Brazil uses as a source of economy, tilapia has great competitive advantages over native ones. It is known to be a disease-resistant species. Widely used in fish farms throughout the Brazilian territory, precocious, with high productivity and good organoleptic and nutritional characteristics, such as: tasty meat, low fat content (0.9 g 100 g -1 of meat) and calories (172 kcal 100 g -1 of meat) (LIZAMA et al., 2004).

Since 2021, six out of ten farmed fish in Brazil are tilapia. Demonstrating a Brazilian growth of 12.5%, participating in 60.06%, in 2019, it represented 57% and in 2018, 54.1% of the national cultivation. With this excellent performance, the species has consolidated itself even more (PEIXEBR, 2021).

Zootechnical Indices

A careful assessment of the water resources available for cultivation is essential to determine the success of production. This involves analyzing parameters such as pH, temperature, dissolved oxygen, turbidity, nutrient levels, and the presence of chemical contaminants. Knowledge of these parameters allows producers to implement appropriate measures to maintain water quality within the ideal standards for healthy fish growth (LEIRA et.al. 2016)

Water has some variables, such as dissolved oxygen, in which values must be above 4 mg/L, lower values make the animals stressed, impairing growth (LIMA et.al., 2013).

Monitoring water quality in fish farming to ensure the well-being and healthy growth of fish is a crucial fact. Problems such as deteriorating water quality can lead to fish stress, increased susceptibility to disease, and even mortality (DANIEL, 2021).

The measurement of water parameters should be carried out regularly, preferably daily, using reliable and practical water analysis kits. Some of the important parameters that should be monitored include water turbidity, which should be monitored as it influences the growth of aquatic plants and can cause stress in the animals. In addition, the pH of the water is a critical factor as it affects the health of the fish and the effectiveness of their absorption of nutrients. Dissolved oxygen levels in the water are essential. It is also important to monitor the levels of ammonia and nitrites in the water, since high concentrations of these compounds are toxic to fish (LIMA et.al., 2013; Santos et.al 2021).

Finally, the water temperature should be monitored, as it affects the metabolism of the fish and their growth rate. Maintaining the temperature within an adequate range is essential for the success of cultivation (Santos et.al., 2021)

Keeping water quality within optimal parameters requires not only regular monitoring, but also corrective actions when necessary, such as partial water changes, proper aeration, and adjustments to filtration systems. Proper water management is essential for the success of fish farming (CAVALCANTE et.al., 2017).

The transparency of the water, is how much the sun can enter the water, should be 30 to 45 cm, which can be observed through a Secchi disk. The desired water is more or less greenish, very transparent, favors the growth of filamentous algae and aquatic plants, which can result in a lack of oxygen. If it is too dark in color, it will result in problems with the oxygen concentration. However, tilapia, smaller readings are admissible, being limited to 10-15 cm (LIMA et.al., 2013).

For the ideal pH value in tilapia production systems, it is between 6.5 and 8. Variations greater than 2 units throughout the day can harm the life of the fish. As for the alkalinity parameter, which is the amount of calcium carbonate present in the water, it must be equal to or greater than 20 mg/L (SILVA et. Al, 2018). However, tilapia can withstand pH ranges between 5 and 9 due to their rusticity and adaptation, but they will not demonstrate their greatest growth potential (BARBOSA, 2007).

The recommended for dissolved oxygen in recirculation systems is that the concentration should be above 4 mg/L, because lower values make the animals stressed, impairing the growth of the fish, but tilapia has a very low dissolved oxygen requirement, living perfectly in waters containing up to 1.2mg/L (MACÊDO, 2004).

A characteristic that must be taken into account is carbon dioxide, as it is an oxygen limiter, the gas is produced day and night by the process of respiration, during the day the gas is consumed by phytoplankton, while at night its concentration is higher and those who consume it do the reverse process in this period. The ideal level is to be below 10mg/L (DAUDA et.al., 2018).

The ammonia that is found in the tanks comes mainly from the excretion of fish. It is broken down into nitrite and then nitrate. High values are toxic to fish (LIMA et.al., 2013).

Ammonia concentration levels above 0.20 mg/L are considered harmful to fish. If the levels of ammonia and nitrite are high (above 0.2 mg/L for ammonia and above 0.5 mg/L for nitrite), this may indicate a malfunction of the biological filter, which is responsible for converting these toxic compounds into less harmful forms. Therefore, the proposed solution is to increase the surface area of the biofilter to correct this situation and maintain water quality within the appropriate standards for fish (MARTINEZ et al., 2006; QUEIROZ and BOEIRA, 2007).

The temperature should vary according to the species produced, tilapia is an oviparous fish, adapted to living in still environments, capable of tolerating a wide range of temperatures, generally preferring waters with temperatures between 26°C and 30°C (SILVA et al., 2015). It is worth noting that sudden changes in this temperature can reduce food consumption and tolerance to handling diseases (LEIRA et.al. 2016).

In addition, it is important to contain the daily record of the mortality rate, in which the accepted is up to 10%, considering the entire fish breeding cycle.

WATER RECIRCULATION SYSTEM

Fish farming causes several environmental impacts, including water contamination, through organic waste, such as food scraps and fish feces. The repercussion of these impacts was highlighted precisely because of the significant growth of this sector. The search for sustainable ways to develop fish production are points addressed by specialists, in order to aim to reduce these conflicts. For this reason, the emphasis on the recirculation system, as it reduces the release of effluents and has proven to be very profitable (ZELAYA et.al., 2001)

The recirculation system stands out for being an ecologically correct source, offering maximum use of water, through the biofilter, the system becomes independent and recycles the water by reusing it throughout the process, in some countries such as Australia, USA, Mexico and Israel it is already widely explored for being able to increase the density of storage in smaller spaces and have greater zootechnical control (HUNDLEY et al., 2013; DANIEL, 2021).

It is worth noting that the balance of ammonia levels in the recirculation system occurs through the presence of a biofilter. These are responsible for the growth and attachment of heterotrophic bacteria. These bacteria play a role in the oxidation of ammonia, converting it to nitrite and subsequent to nitrate, which becomes a less toxic substance (DANIEL, 2021).

The ability to control and maintain water quality in aquaculture systems also allows the installation of these systems in places with water scarcity or where the cost of water is high. This is especially relevant in areas where freshwater is a limited and precious resource (KUBITZA, 2006)

Aquaculture can be adapted to operate in a variety of environments and scales, from large aquaculture farms to small systems installed in the back of the house, even in urban areas. The feasibility of these systems depends on the size of the equipment used, the amount of water available, and the investment required to establish and operate the system (LIMA, et al. 2015).

Water Recirculation System Infrastructure

According to MARTINS et al., (2010, 2011) in this system, the water is continuously recirculated through different components that aim to maintain water quality and the well-being of the fish. The components mentioned include decanters, mechanical and biological filters. Decanters are responsible for separating and removing heavier solid materials from the water, such as feed scraps and fish feces, through the decanting process.

The assembly of the recirculation system for mechanical-biological filters involves several steps to ensure its proper functioning. Initially, it is essential to prepare the bottom of the system by choosing a non-corrosive substrate such as plastic, fiberglass, ceramics, or rocks. This substrate is placed at the bottom of the system, serving as a filtering medium and providing porosity for bacterial colonization. Then, a protective screen, such as a shade screen, is added over the substrate, in order to protect the fine pebble that will be inserted later. The fine pebble is then introduced over this screen, functioning as another filter medium to trap smaller particles in the water. To protect the layer of coarse sand that will follow, a suitable protective screen, such as an organza screen, is included over the fine pebble. Next, coarse sand is added over this screen to complete the mechanical filtration system (LIMA et. al., 2015).

After completing these steps, the mechanical filtration system is ready, with the substrate, fine pebble and coarse sand in their proper positions. Finally, the recirculation system is activated and the water passes through the entire filtration system, being purified and ready to be reintroduced into the fish farming environment.

Mechanical filters act to remove smaller solid particles from water, ensuring its clarity and purity. Biological filters, on the other hand, are essential for controlling water quality. They provide an environment conducive to the growth of nitrifying bacteria, such as Nitrosomonas and Nitrobacter, which cycle nitrogen. Nitrosomonas convert ammonia (from feces and food scraps) into nitrite, while Nitrobacter converts nitrite into nitrate, a less toxic form of nitrogen (MARTINS et al., 2010, 2011).

In this system, oxygen is the main limiting factor for measuring water quality. However, it can be easily controlled with the use of aeration and oxygenation (LOBÃO et.al. 2018). Because bacterial metabolism requires oxygen, it is necessary for air to be supplied to the biofilter. In this way, as the water passes through the filter, it is continuously oxygenated, while carbon dioxide is removed. In this type of system, the use of biofilm is necessary. Because the metabolism of bacteria needs oxygen. This will happen with the passage of water through the filter, in which it will be oxygenated and carbon dioxide will be removed (EDING et al, 2006).

In this way, the water recirculation system allows the maintenance of ideal environmental conditions for the fish, minimizing the accumulation of toxic waste in the water and ensuring the health and proper growth of the animals. This is an effective method to optimize water use and reduce the environmental impacts of intensive aquaculture (MARTINS et al., 2010, 2011).

However, the Peixe Br (2021) highlights some disadvantages associated with the water recirculation system in aquaculture. Among these disadvantages are the constant need for energy for the circulation of the system and aeration, the high initial investment cost for the acquisition of equipment, pumps and filters, in addition to the requirement of labor for the daily monitoring of the system.

Despite these challenges, the significant advantages and benefits of the water recirculation system are highlighted. This system has a low water demand compared to other forms of farming, which contributes to the conservation of this essential resource. In addition, it reduces the discharge of effluents into the environment, minimizing negative impacts on aquatic ecosystems. Another benefit is the possibility of installing the system in urban areas, close to commercial and market areas, due to its spatial efficiency and the ability to recycle and reuse water, which can be an advantage in terms of logistics and access to consumer markets (SCHNEIDER et al., 2010).

These advantages underscore the importance and feasibility of the water recirculation system in aquaculture, especially in contexts where the conservation of natural resources and the reduction of environmental impact are priorities. Although it presents challenges, the system offers effective solutions to address issues related to sustainability and the development of the aquaculture industry.

The high density of fish is the characteristic of many water recirculation systems, which directly influences the choice of the species to be used. The species must be tolerant of high stocking densities and frequent management (HUNDLEY et al., 2013). The main freshwater species produced in this system are tilapia, African catfish, eels and trout. As marine species, sole and sea bass (MARTINS et al., 2010).

Silva *et.al.* (2015), highlights that the popularity of Nile tilapia is due to its advantageous characteristics such as fast growth, rusticity, ease of management, high yield and excellent quality meat, these attributes make it an attractive choice for producers around the world.

BIOSECURITY

According to Sesti (2005), the term "biosecurity" derives from the English word "Biosecurity" and is intrinsically related to animal health. Within this context, a biosecurity plan is established that must contain flexible standards, risk management, and preventive veterinary medicine practices to ensure the health and well-being of animals.

According to Santos et.al (2021), biosecurity in fish farming is structured actions to contain the introduction and dissemination of pathogens in the aquaculture production environment.

When developing a biosecurity plan, it is essential to identify potential hazards, which may include pathogens such as viruses, bacteria, and parasites, among others, that are specific to the species being farmed. There is also a need to carry out a risk assessment, examining risk factors and critical control points. During this stage, it is essential to carefully analyze the possible routes of introduction and dissemination of pathogens in the population, as well as their consequences. It is also worth mentioning that these measures within a fish farming system aim to protect the health of the fish and ensure the sanitary quality of the system, thus preventing the occurrence of diseases and maintaining the sustainability of aquaculture production. (SANTOS et.al, 2021).

To reduce the negative environmental impacts caused by the production systems of fish, shrimp and other aquatic organisms, Good Management Practices (BPM) (DE QUEIROZ, 2002) are recommended.

The Good Sanitary Monitoring Practices (BPMS) protocol for the recirculation system, as described by De Queiroz et al. (2017), covers a series of procedures aimed at ensuring the health and well-being of farmed fish. This includes installing the system in locations that allow solar incidence control and carrying out a quarantine period in cultivation tanks isolated from the main recirculation system. During this period, the behavior of the fish is observed and any clinical signs of disease are monitored, even if the fish have a provenance considered reliable.

In addition, the protocol involves a detailed clinical evaluation of the fish, considering their general condition, such as behavior, mucosal color, mucus production, appearance of the gills, weight and length. Possible macroscopic alterations are observed, such as deformities in the body, skin and gill infections, and the presence of ectoparasites, among other symptoms (KUBITZA, 2006).

According to Zanolo (2021), adopting strict biosecurity measures is essential to ensure health and efficiency in aquaculture production. Among the recommended practices, the purchase of fingerlings that are free or have low sanitary pressure stands out, as the acquisition of healthy fingerlings is crucial to prevent the introduction of diseases into the cultivation system. Additionally, the adequacy of crop densities is essential, since maintaining an adequate density of fish prevents stress and the spread of disease, promoting a more balanced and sustainable environment.

Carrying out preventive diagnoses is equally important, as the early detection of possible health problems in fish allows for rapid interventions, minimizing negative impacts. In addition, cleaning and disinfection programs of structures significantly reduce the presence of pathogens, ensuring safer facilities. (VIANNA et. al., 2019).

Water quality management is another vital aspect, as controlling parameters such as dissolved oxygen, temperature, pH, and ammonia is essential for fish health. Preventive vaccination is an effective tool for protecting fish against specific diseases, and the use of good quality feed ensures a balanced diet, promoting healthy fish growth and improving their resistance to disease. (FIGUEIREDO et.al., 2020).

The entry of people into the fish farming area, as well as the handling of inputs, can represent a significant risk of disease introduction, especially when these individuals transit through other fish or animal farms that share potential infectious agents in common. Therefore, it is crucial to implement strict preventive measures to minimize the possibility of contamination. All visits must be scheduled in advance, allowing for stricter control over who enters the production areas and the implementation of appropriate security measures. It is recommended that visitors and service providers respect a minimum period of 24 hours since their last visit to other fish production areas, helping to reduce the risk of transmission of pathogens that may be inadvertently carried (BARCELLOS, 2022).

In addition to prior scheduling, it is essential that all visitors undergo disinfection procedures before entering the premises, including washing and disinfecting footwear, clothing, and hands. The use of personal protective equipment (PPE), such as boots, lab coats, and gloves, should be mandatory for everyone entering the production area. Implementing an access control system to monitor and record the entry and exit of people makes it easier to track in case of disease outbreaks. It is also essential to provide guidance and training to visitors and staff on proper biosecurity practices and the importance of these measures in disease prevention (SOUZA, 2021)

That is why the installation of sinks with water, soap and other hygiene items are essential for hand washing and equipment. Regular disinfection, whether with alcohol, iodized alcohol, or other disinfectants, helps reduce the risk of contamination. In addition, the use of appropriate clothing, such as shoe covers, caps, and masks, is essential to prevent the entry of contaminating agents into the facilities. Replacing personal clothes with sterile clothes is an even more effective measure to minimize the risk of cross-contamination

Regarding inputs, it is important to ensure that all, such as feed and medicines, are purchased from reliable suppliers who follow strict safety and hygiene standards. Inputs should be stored in appropriate places, away from production areas, to avoid cross-contamination, in addition to being stored suspended on the floor to avoid humidity. Regular inspections of inputs are necessary to detect any sign of contamination or deterioration (SANTOS et.al., 2020).

In relation to the disinfection of utensils and equipment, it is common to use liquid household bleach is 3% to 6%, with the proportion of 10 ml per liter of water is adequate for effective disinfection. Similarly, granular bleach (HTH pool chlorine) is effective and can be used at a rate of 200 mg per liter of water. After disinfection, it is important to rinse the utensils thoroughly under running water to remove any residue from the disinfectant. In addition, the use of high temperatures, above 75 ºC, is also effective in destroying microorganisms, being another option to ensure the complete hygiene of equipment and utensils in fish farming (BARCELLOS, 2022).

When available, additional tests should be performed, such as hematological and parasitological parameters, to assess the health status and stress level of the fish. These tests provide valuable information about the health of the fish, including blood cell counts, biochemical profiling, and parasitological analysis of tissue samples. Hematological parameters, such as blood cell count and hemoglobin dosage, can provide additional information about the overall health of fish, identifying potential signs of infection or inflammation (DE QUEIROZ et al., 2017).

In cases of need for veterinary treatment, it is important to use medicines responsibly and according to the guidelines of a qualified professional, in order to avoid medicine residues in fish and the environment (SANTOS et.al., 2021)

It is worth noting that the professional should not only focus on the recognition of parasites and/or pathogens, but also on the knowledge of the facilities and the quality of the water in the cultivation (MARTINS, 2004).

Inadequate water quality conditions can have significant impacts on the development and health of aquatic organisms, compromising the success of production. Water quality in fish farming is crucial to ensure the growth, reproduction, health, and survival of fish. Water serves as the environment where fish live, feed, breathe, and eliminate waste. Therefore, it is essential that the water characteristics are adequate to meet the physiological needs of the fish (LEIRA et.al. 2016).

Management measures such as aeration, population density control, partial water exchanges, regular monitoring of water quality, and responsible use of inputs are essential to ensure optimal environmental conditions in fish farms. By controlling and maintaining water quality, producers can maximize productivity, minimize disease risks, and ensure the sustainability of their aquaculture operations (LEIRA et.al. 2016; FERREIRA ET AL., 2005; ALVES DE OLIVEIRA, 2001).

For this reason, MARTINS (2004) highlights the importance of sanitary measures in fish farming. To ensure the effectiveness of sanitary measures in aquaculture, it is crucial that several factors are properly coordinated. In addition to the implementation of good management practices that includes regular cleaning of tanks, proper feeding and control of population density, which can help reduce the risk of disease and improve the health of the fish. It is crucial for aquaculture enterprise owners to be aware of the importance of sanitary management and the relevant aspects to ensure the safety of the food produced. The presence of trained professionals in the area of animal health and sanitary management is essential. Maintaining water quality in ponds is essential to prevent contamination of fish by pathogens. This involves regularly monitoring parameters such as pH, temperature, ammonia, dissolved oxygen, and the presence of chemical contaminants.

Sanitary management

Parasitic and bacterial infections represent one of the main causes of economic losses in Brazilian fish farming. Fish affected by these agents show a number of signs of abnormal behavior, including lethargy, anorexia, loss of balance, grouping at the surface of the water or water entrance, agitated breathing, excessive mucus production, erosion of the skin and/or fins, inflamed or pale gills, inflamed abdomen, bloody fluid, swollen and stiffened anus, exophthalmos, apathy, isolation from the school and, eventually, death (SCHALCH et al., 2009).

These outbreaks that can cause mortality are due to the stress resulting from management, routine transport of fish, high stocking density, poor water quality. To avoid losses, fish farming processes need attention (TAVARES-DIAS *et.al.,* 2014).

To prevent diseases from becoming limiting factors for increasing productivity and causing significant economic losses, it is essential to implement constant prophylactic management in fish farming. This involves preventive measures, such as regular monitoring of fish health, water quality control, maintaining good management and hygiene practices, and, when necessary, using appropriate therapeutic treatments. Preventive management is essential to minimize the impact of diseases on aquaculture production and ensure the economic sustainability of the activity for fish farmers (TAVARES-DIAS *et.al*., 2014).

In order to reduce the number of diseases, the use of antibiotics for the prevention and treatment of bacterial infections is common in fish farms (CABELLO et al., 2013). The use of prophylactic or therapeutic antibiotics can affect the natural bacterial population by increasing the ability to produce antibiotic-resistant bacteria or environmental resistance genes. Bacterial resistance to bacteria is considered one of the most important threats to human health and affects the effectiveness of treatment of various infections worldwide (HOSSAIN et al., 2020; WHO, 2018).

On the other hand, according to Melo (2015), vaccination practices are a laborious technique and stressful for fish, in addition to requiring qualified labor for the service. This makes it impractical to completely eliminate the use of these drugs in the sector, since according to Smith (2012) antibiotics continue to be an effective treatment for diseases in intensive fish farming.

Fish farmers resort to antibiotics, either by preventive or therapeutic methods, in order to reduce the incidence and spread of bacterial infections. Generally, antimicrobials are used in two situations: prophylactically, through treatments via immersion bath or incorporated into the feed; and therapeutically, for the treatment of bacterial infections (Ali et al., 2016). In Brazil, only two antimicrobials are approved for use in fish farming: oxytetracycline and florfenicol (National Union of Animal Health Products Industry - SINDAN, 2018).

Oxytetracycline is widely used to treat bacterial infections in fish (RIGOS; TROISI, 2005). This substance has bacteriostatic action, inhibiting protein synthesis in bacteria (RIGOS; NEMGAS; ALEXIS, 2006). Administered in doses ranging from 50 to 125 mg/kg, for a period of 7 to 10 days (MARQUES, 2018). Excessive or inappropriate use of this antimicrobial can result in adverse effects on fish organisms and the promotion of bacterial resistance (MARSHALL; LEVY, 2011).

Florfenicol, considered an antimicrobial of critical importance for the control of diseases in fish, is indicated for the treatment of *S. agalactiae*. It demonstrates a wide range of action and is often administered through feed, in doses that usually range from 10 to 20 mg/kg, for a period of 10 days (ARMSTRONG et al., 2005).

Antimicrobial resistance presents substantial challenges to animal health and welfare. The ability of resistant bacteria to spread between humans, animals and the environment transcends borders, making it a global concern in terms of public and animal health (MARTINS, 2004). The indiscriminate and inappropriate use of medicines has been identified as one of the main drivers of the emergence of resistant strains, negatively impacting not only the balance of ecosystems, but also the health and safety of the general population (DA SILVA et al., 2022).

Even so, productions are susceptible to diseases, especially of bacterial origin, which are the cause of economic losses in tilapia cultivation, especially *Streptococcus agalactiae*. This bacterium can be found in the internal organs of tilapia, such as the kidneys, liver, intestine, heart, brain, and spleen (CAI et al., 2004; LIM AND WEBSTER, 2006).

The presence of these bacteria in the internal organs can lead to the development of bacterial diseases that affect the health and well-being of tilapia, resulting in significant losses in aquaculture production. This disease can manifest itself in several ways, including systemic infections, infections of specific organs and skin lesions, among others (SILVA, 2008).

Streptococcus is a gram-positive bacterium that represents a significant concern in aquaculture, affecting a variety of hosts, including fish. This bacterium, often associated with high morbidity and mortality rates, demonstrates remarkable adaptability to different environments, also including freshwater (JOHRI et al., 2006; EVANS et al., 2002).

Among the fish species affected by *S. agalactiae*, Nile tilapia (*Oreochromis niloticus*) is particularly susceptible. These infections can lead to serious impacts on fish health, resulting in significant losses in production and aquaculture as a whole. Given the severity of infections caused by *Streptococcus agalactiae*, it is crucial to implement effective control and prevention measures, including appropriate management practices, regular health monitoring, and, when appropriate, the use of vaccines to protect fish against this pathogenic bacterium (EVANS et al., 2002; EVANS et al., 2004).

Vaccination is recognized as the most effective procedure for immunization against a variety of pathogens in aquaculture. It works by activating the acquired immune response and generating memory cells through the introduction of antigens into the fish's bodies (SECOMBES AND BELMONTE, 2016).

In aquaculture, there are three main routes of vaccine administration: oral, immersion, or intraperitoneal/intramuscular injectable (Dadar et al., 2017; Derome et al., 2016). The choice of vaccine administration route depends on several factors, including the characteristics of the target pathogen, the natural route of infection, the type of vaccine (live or inactivated), the state of immune memory and the immune system of the fish, the production cycle, the production system, management practices, nutrition, cost-effectiveness, and environmental conditions, such as water temperature (ASSEFA AND ABUNNA, 2018; DADAR ET AL., 2017).

Oral vaccination, performed by administering the vaccine in the feed, has been shown to be an effective approach in protecting against *Streptococcus agalactiae* in Nile tilapia (MELO et.al., 2015). According to Firdaus-Nawi et al. (2012), oral vaccination offers several advantages, including reduced labor costs, needle and syringe expenses, and minimizing stress on fish during the vaccination process.

However, it is important to recognize that oral vaccination can induce immunity mainly in the mucosa of the gastrointestinal tract, providing local protection (MELO et.al., 2015). Studies, such as that by Rombout et al. (1986), who investigated oral vaccination in carp (*Cyprinus carpio*), observed that this form of vaccination may result in less pronounced immunity in the circulatory or systemic system.

In addition, as mentioned by Evensen (2009), orally vaccinated fish may have a shorter protection period compared to other forms of administration, such as injection or immersion. This means that the immunity conferred by oral vaccination may be short-lived compared to other forms of vaccination.

Despite these considerations, oral vaccination is still a viable strategy to protect fish against *S. agalactiae*, especially in aquaculture systems where oral administration is more practical and cost-effective. However, it is important to regularly monitor the effectiveness of oral vaccination and consider other vaccination options, depending on the specific needs of each production system and growing conditions (MELO et.al., 2015).

The aforementioned studies, by Evans et al. (2004) and Longhi et al. (2012), indicate that the vaccine administered by immersion bath proved to be less effective in protecting against *Streptococcus agalactiae* in Nile tilapia compared to other forms of vaccination.

In the study by Evans et al. (2004), where only an immersion bath with the vaccine was used, there was no statistically significant difference in survival between the vaccinated fish and the control group. The study conducted by Longhi et al. (2012), where two immersion baths with the vaccine were applied, with an interval of 25 days between them, observed a greater protective effect compared to the control group. However, this protection was similar to that observed in the group of fish submitted to only one bath. In addition, due to the high mortality rate recorded in all fish groups (approximately 43%), the authors concluded that the immersion bath has low efficacy in protecting against *S. agalactiae* in Nile tilapia.

Injectable vaccination has been shown to be the most effective. According to Klesius et al. (2000), intraperitoneal vaccination with inactivated *Streptococcus* cells significantly reduced mortality in tilapia infected with this bacterium, preventing the appearance of symptoms such as erratic swimming and hemorrhagic exophthalmos.

Intraperitoneal vaccination using inactivated *Aeromonas hydrophila* cells in tilapia achieved significant protection in the weeks following vaccination (RUANGPAN et al., 1986).

Injectable vaccination has some significant advantages over other methods of vaccine administration. Because it is administered in small quantities, directly into the fish's body (intraperitoneal or intramuscular), and often accompanied by adjuvants, this form of vaccination can provide a longer period of protection (immunization). In addition, it allows the inoculation of antigens from different pathogens in a single vaccine, known as a multivalent vaccine (DADAR et al., 2017).

However, it is important to highlight that vaccination by injection may not be suitable for the initial phase of the life cycle of fish, such as post-larvae and fingerlings, whose immune system is still developing. This is because administering the vaccine by injection can cause stress in the fish, leading to a reduction in feeding and even tissue injury (ASSEFA AND ABUNNA, 2018; LILLEHAUG, 2014).

However, it is important to recognize that vaccination through individual injections is a laborious and stressful technique for fish. This is because it requires the removal of the fish from the water and their anesthesia before administering the vaccine. In addition, this approach may not be economically viable in large-scale crops, and is generally reserved for high-value fish, breeding and ornamental fish (MELO et.al., 2015).

In addition to vaccination and the use of antibiotics, fish farming has as an ally the use of common salt, in addition to being a low-cost option, also reducing the need for other chemotherapy drugs, providing ideal health conditions for fish and increasing the safety of the production system and consumers (CHAGAS et al., 2012; SILVA et al., 2009).

The mucus produced by fish plays a key role in protecting against salt loss and osmotic regulation of the body, as well as acting as a barrier against overhydration. The stimulation of mucus production, facilitated by the use of salt, also contributes to reducing the chances of secondary infections caused by fungi and bacteria. Therefore, the use of salt can be an effective strategy to promote the health and well-being of fish in intensive fish farms, helping to prevent health problems and minimize negative impacts on production (MELO et.al., 2015).

The use of salt is effective in controlling some ectoparasites (SCHALCH et al., 2009; SILVA et al., 2009), minimizes osmoregulatory stress during transport (KUBITZA, 2007; URBINATI; Carneiro, 2004, 2006) and during management, in addition to preventing methemoglobinemia, known as brown blood disease (FRANCIS-FLOYD, 1995). In addition, the use of common salt decreases the parasite load of *Piscinoodinium pillulare* after transport.

In recirculating systems, fish often face water with a high amount of suspended solids, which can result in the proliferation of parasites, bacteria and fungi. In addition, due to high stocking densities and continuous exposure to stressors such as variations in water quality parameters, fish can lose salts more quickly. Maintaining a constant salinity of around 20g/L helps mitigate problems with parasites and fungi, reduces irritation of the gill epithelium, and minimizes excessive loss of salts by fish (RECOLAST, 2017)

In this same system, toxic concentrations of nitrite can occur. Applying salt to water can mitigate the toxic potential of nitrite to fish. Chloride ions, when present in adequate amounts in water, bind to nitrite receptors in fish gill cells, preventing the absorption of this toxic compound (KUBITZA, 2007).

FINAL CONSIDERATIONS

In conclusion, the implementation of good agricultural practices in the production of Nile tilapia in simple recirculation systems in urbanized areas is crucial to ensure the sustainability and economic success of this activity. The emphasis on biosecurity plays a key role in this context, as it makes it possible to prevent the introduction and spread of pathogens, ensuring the health and well-being of fish, as well as food safety.

By prioritizing biosecurity, producers can minimize disease risks and increase the efficiency of the recirculation system, resulting in healthier and more productive production. This is especially relevant in urban environments, where environmental and health challenges can be more intense due to proximity to residential and industrial areas.

It is also important to ensure that suppliers are reliable for the best results, and to be aware of the signs that fish may present throughout the cultivation cycles, in order to make appropriate decisions when necessary. Seeking guidance is essential for the success of the producer in this venture.

Therefore, investing in biosecurity measures, such as proper system installation, quarantines, regular water quality monitoring, and implementing proper management practices, is essential to ensure successful production in simple recirculation systems in urban areas. These measures not only protect the health of fish but also contribute to the economic viability and long-term sustainability of aquaculture in urbanized environments.

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ITAPEMIRIM AND THE CHALLENGE OF SUSTAINABILITY: LESSONS FROM CURITIBA

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ABSTRACT

This article aims to critically analyze the characteristics of the cities of Itapemirim (ES) and Curitiba (PR), focusing on sustainability practices and smart cities. From a literature review, public policies, waste management, urban mobility and citizen participation in both municipalities were examined. While Curitiba stands out as an exemplary model of urban planning and sustainable management, Itapemirim faces significant challenges in implementing sustainable practices and mobilizing the community. The study discusses the importance of environmental education, green infrastructure and the use of smart technologies to promote a more sustainable city. The exchange of experiences between cities can provide valuable learning, allowing Itapemirim to develop urban planning that prioritizes sustainability and climate resilience. By adopting practices inspired by Curitiba, Itapemirim can transform its characteristics and challenges into opportunities for a more sustainable and inclusive future.

Keywords: Sustainability. Smart Cities. Town planning. Environmental education.

INTRODUCTION

Contemporary cities face the challenge of becoming sustainable in a context of increasing urbanization and environmental degradation. The videos presented address experiences of cities that have implemented innovative urban planning and sustainability practices, highlighting Curitiba as a reference model. Curitiba is widely recognized for its efficient public transportation system, abundant green areas, and recycling policies, all of which contribute to a superior quality of life. In contrast, Itapemirim, in Espírito Santo, has characteristics that reveal both opportunities and challenges in its urban development.

Itapemirim, with its rich natural and cultural heritage, faces issues such as the management of urban space and the infrastructure necessary to promote sustainability. Although the city has areas of scenic beauty and potential for ecotourism, its current practices in relation to urban planning and environmental management need to be critically analyzed. This article aims to discuss the sustainable characteristics present in Curitiba and compare them with the practices of Itapemirim, highlighting the positive and negative aspects that influence the quality of life of its inhabitants. In the end, we will propose recommendations so that Itapemirim can follow a firmer path towards urban sustainability, taking advantage of its potential and learning from the experience of model cities such as Curitiba.

When expanding the comparison to include Itapemirim (ES), it is important to analyze the similarities and differences in relation to Curitiba and its approaches towards sustainability and the concept of smart cities. Itapemirim, a coastal and tourist city, has characteristics that make it unique, but it also faces significant challenges that can be addressed in its quest for more sustainable development.

Sustainability in Itapemirim: Itapemirim has a rich biodiversity and a privileged natural environment, which gives it great potential for sustainable practices. The city has environmental preservation areas and an ecosystem that, if well managed, can contribute to local sustainability. However, solid waste management and urban infrastructure are areas that require attention. Disorderly growth, driven by tourism, can compromise environmental quality if there is no adequate planning.

Comparison with Curitiba: Curitiba, on the other hand, is widely recognized for its innovative public policies and its efficient public transportation system, which prioritizes sustainable urban mobility. The use of public transport and the creation of green areas are examples of how the city has integrated sustainability into its urban planning. The experience of Curitiba highlights the importance of well-structured policies, which include the participation of the population and social inclusion.

Smart Cities: In terms of smart cities, Curitiba stands out for the use of technology and innovation in its urban solutions. The city has invested in information systems that improve the management of public services and promote transparency. Data collection and citizen participation are key components for the success of initiatives aimed at improving the quality of urban life.

Itapemirim, in turn, can learn from Curitiba's experience in the implementation of technological solutions that promote the efficiency of public services and social inclusion. The use of applications for service management, such as transportation and waste collection, could facilitate interaction between the public administration and citizens, allowing for more agile and participatory management.

Both cities face challenges regarding sustainability, but how they approach these problems can be quite different. While Curitiba has an already established and recognized system, Itapemirim is still in the process of developing its sustainable practices. For Itapemirim, this means that there is an opportunity to learn from the best practices of Curitiba and other smart cities, adapting them to their local reality. The comparison between Itapemirim and Curitiba reveals the need for integrated urban planning that considers the particularities of each city, but also benefits from innovations and successful experiences. The path to sustainability is therefore a collective journey, where mutual learning and collaboration are essential to build more resilient cities adapted to the needs of their inhabitants.

Curitiba stands out globally as a reference in urban sustainability and innovation in the concept of smart cities. Over the decades, the city has implemented a series of public policies focused on urban mobility, waste management, smart use of public spaces, and social inclusion, creating an environment that balances economic development with environmental preservation. Curitiba's public transport system, for example, is one of the most admired in the world. The BRT (Bus Rapid Transit) model, implemented in the 1970s, optimized urban mobility, reducing the use of individual vehicles and consequently the emissions of polluting gases. The city also invests heavily in green areas and in the sustainable management of its parks and reserves, creating a network of public spaces that serve both leisure and environmental conservation.

In contrast, Itapemirim, in Espírito Santo, is still at an incipient stage when it comes to adopting policies and practices that foster sustainability and transformation into a smart city. While Curitiba benefits from decades of urban planning, Itapemirim faces challenges typical of medium-sized cities in less industrialized regions with less technological support. The city has great natural potential, especially in relation to ecotourism, due to its beaches and environmental preservation areas. However, the lack of adequate investments in sustainable urban infrastructure and the absence of integrated planning make it difficult to take full advantage of these resources. One of the central issues that differentiates Itapemirim from Curitiba is the level of urban planning focused on sustainability. In Curitiba, the planning is based on a long-term vision that involves both the public authorities and the private sector and civil society. The implementation of bike lanes, the priority to public transport and the projects aimed at social housing show how the city manages to align urban growth with environmental preservation. In Itapemirim, urban development is still fragmented, without a clear articulation between environmental and urban policies. The city suffers from problems related to the collection and management of solid waste, as well as a lack of infrastructure aimed at sustainable mobility, such as bike lanes and quality public transport.

On the other hand, Itapemirim has some characteristics that, if well managed, can put it on a path of sustainable growth. The city has vast potential in terms of generating renewable energies, such as solar energy, due to its geographical location and high solar incidence for much of the year. In addition, the environmental richness of the region, with its preservation areas, offers unique opportunities for the development of sustainable ecotourism policies, which can benefit both the local economy and the environment. However, for this to happen, a robust sustainable development plan would be needed, something that Curitiba has implemented continuously and strategically over the years.

In addition, the concept of smart cities — which involves the use of technology to improve urban management, increase the efficiency of services, and promote quality of life — is still little explored in Itapemirim. Curitiba, on the other hand, has been investing in technological solutions for public management, such as sensors for traffic monitoring and efficient public lighting, as well as initiatives aimed at citizen participation, allowing residents to actively participate in urban planning and sustainability decisions. Connectivity and digitalization of urban services are fundamental for the development of smarter cities, which creates challenges and opportunities for Itapemirim, which still needs to invest in technological infrastructure and platforms that promote innovation.

In summary, while Curitiba is a consolidated example of how a city can integrate sustainable practices and innovative technologies to improve the quality of life of its citizens, Itapemirim still has a long way to go to achieve this integration. The city has great natural and energy potential, but faces significant challenges in terms of urban planning, mobility, waste management, and the implementation of smart technologies. For Itapemirim to become a truly sustainable city, it will require a collective effort, involving public and private investments, policies to encourage sustainability, and a clear commitment to the preservation of its natural resources. By learning from cities like Curitiba, Itapemirim can chart its own path towards urban sustainability and smart development.

METHODOLOGY

The methodology of this article will be of a bibliographic nature, seeking to analyze and compare the sustainability characteristics and practices of smart cities in Curitiba and Itapemirim. The research will take place through the review and analysis of academic literature, technical reports, articles, and relevant publications on sustainable urbanism, ecotourism, and the management of smart cities.

First, a search will be carried out for bibliographic sources that address the concepts of urban sustainability and smart cities, including books, theses, and scientific articles. The focus will be on studies that deal specifically with the cases of Curitiba, widely recognized for its innovative urban planning practices, and Itapemirim, whose urban reality is less discussed, but equally relevant to understanding the challenges and opportunities that cities face in the search for sustainability. From the selection of sources, a qualitative analysis of the data collected will be carried out, with the objective of identifying the main characteristics that differentiate the approaches adopted by Curitiba and Itapemirim in relation to sustainability. This analysis will include the evaluation of indicators such as urban mobility, waste management, green areas, and the use of smart technologies.

In addition, official documents, such as master plans, municipal laws, and public policies related to urbanism and the environment, will be considered to understand how the municipal administrations of both cities have structured their actions in favor of sustainability. The methodology will also contemplate the critical comparison between the practices adopted in Curitiba and Itapemirim, highlighting the positive and negative aspects observed in each context. From this analysis, the article will seek to propose recommendations that can help Itapemirim in building a more sustainable future, inspired by the experiences of Curitiba.

Finally, the study will be systematized in a text that articulates the main findings of the research, highlighting the lessons learned and the possibilities of sustainable development that Itapemirim can explore, considering its unique characteristics and the socioeconomic context in which it is inserted. This approach will allow for a deeper understanding of urban dynamics in both cities, contributing to the debate on urban sustainability in Brazil.

RESULTS AND DISCUSSION

The comparative analysis between Itapemirim and Curitiba reveals significant differences in their approaches to sustainability and the development of smart cities. While Curitiba stands out for its innovative and successful practices, Itapemirim faces challenges that, if not properly addressed, can compromise its potential to become a sustainable city.

One of the main pillars of urban sustainability in Curitiba is its public transport system. The BRT (Bus Rapid Transit) model, implemented in the 1970s, transformed mobility in the city, promoting a significant reduction in the use of automobiles and, consequently, in greenhouse gas emissions. According to the Urbanization of Curitiba, "the public transport system is considered one of the most efficient in the world, integrating buses, terminals and exclusive lanes" (CURITIBA, 2021). This approach results in a more accessible and less congested city. In contrast, Itapemirim still relies on a public transport system that is limited and faces coverage and frequency issues. According to a study conducted by Oliveira et al. (2023), "the transport infrastructure in Itapemirim is insufficient to meet the growing demand, which contributes to the increase in the use of private vehicles and the consequent air pollution." Therefore, the lack of effective urban planning can negatively impact the quality of life of inhabitants, reflecting in an increase in mobility problems.

Solid waste management is another critical aspect in which Curitiba stands out. The city has implemented a selective collection and recycling system that achieves a recycling rate of approximately 70%, as reported by the Paraná Sanitation Company (SANEPAR, 2020). This initiative not only reduces the amount of waste destined for landfills but also promotes environmental awareness among citizens.

On the other hand, in Itapemirim, solid waste management is still a significant challenge. According to research by Silva et al. (2022), "less than 20% of the waste generated in the city is recycled, and the lack of an effective selective collection system results in negative impacts on the environment." The scarcity of awareness campaigns and adequate infrastructure for waste management highlights the need for urgent improvements in this sector.

Curitiba is also recognized for its extensive network of parks and green areas, which occupy approximately 53 m² per inhabitant, according to data from the Municipal Department of the Environment (2021). These areas not only provide recreation and recreation, but also contribute to biodiversity and the mitigation of the effects of urban heat islands. The city was a pioneer in integrating green areas into urban planning, creating a healthier and more pleasant environment for its citizens. In Itapemirim, although the city has beautiful beaches and natural areas, the conservation of these spaces is still precarious. According to the study by Almeida and Sousa (2023), "uncontrolled urbanization and the lack of public policies aimed at environmental preservation have led to the degradation of important natural areas." This indicates a missed opportunity for Itapemirim, which could use its natural resources to boost sustainable tourism and improve the local quality of life.

The implementation of smart technologies in Curitiba is a factor that contributes to the efficiency of urban services. The city adopts solutions such as mobility applications, traffic monitoring, and smart street lighting, which not only improve the quality of services provided, but also allow for more effective management of resources. According to the report by the National Association of Public Transport (2022), "the digitalization of public services in Curitiba has been a crucial factor in improving the user experience and optimizing operating costs."

In Itapemirim, the adoption of smart technologies is still incipient. The city lacks integrated systems that can facilitate citizen participation and improve the management of public services. According to the research of Pires et al. (2024), "the absence of digital platforms that allow communication between the public administration and citizens limits transparency and efficiency in urban management." For Itapemirim to develop as a smart city, it will be essential to invest in technology and innovation. The analysis of the characteristics of Curitiba and Itapemirim highlights the importance of effective urban planning and integrated policies to promote sustainability. In a context where urbanization is advancing rapidly, cities need to find ways to adapt to the growing needs of the population, while preserving the environment. Curitiba's experience, with its systematic and holistic approach, can offer valuable insights for Itapemirim.

One of the most relevant aspects of the discussion is the need for a multidisciplinary approach that integrates different sectors of society, including government, private initiative, and citizens. In Curitiba, community participation in decisions about urban planning has been a crucial factor for the success of the policies implemented. According to Teles et al. (2022), "the involvement of civil society in planning processes contributes to the construction of a more inclusive and sustainable city." For Itapemirim, fostering citizen participation can be an important step to ensure that public policies reflect the needs and aspirations of the local population.

In addition, environmental education plays a key role in promoting a culture of sustainability. In Curitiba, educational campaigns on recycling and environmental preservation have been essential to achieve high recycling rates and environmental awareness. According to Araújo and Lima (2023), "environmental education should be a priority in public policies, as it is through it that a more aware and engaged population is formed." Itapemirim, by investing in environmental education programs, could create a sense of shared responsibility between citizens and local authorities, promoting concrete actions in favor of sustainability. Another important point to be discussed is the resilience of cities in the face of climate change. Curitiba has demonstrated a commitment to adapting to and mitigating the effects of climate change through strategies such as the recovery of degraded areas and the promotion of green infrastructure. According to the Sustainable Cities Network report (2021), "cities that invest in green infrastructure are more resilient to extreme weather events." Itapemirim, in turn, should consider adopting similar practices to increase its resilience, especially considering its coastal location and vulnerability to weather events, such as rising sea levels and more intense storms.

The comparison between the two cities also illustrates the importance of investments in infrastructure. Curitiba, with a consolidated model of public transport and waste management, benefits from decades of strategic investments. In contrast, Itapemirim lacks the resources and adequate infrastructure to support sustainable urban growth. Fundraising, whether through public-private partnerships, government funding, or donations, can be a viable solution for Itapemirim to develop projects that prioritize sustainability.

In addition, the analysis of smart technologies, such as monitoring systems and data management, reveals a significant opportunity for Itapemirim. Implementing technologies that facilitate the collection of data on resource usage and quality of services can help the city identify areas in need of improvement and respond quickly to emerging issues. The experience of cities that already use these technologies, such as Curitiba, demonstrates that the use of data can increase the efficiency of public services and improve the citizen experience.

Finally, the research concludes that, although Curitiba has established itself as a model of urban sustainability and smart cities, there is vast potential for Itapemirim to transform itself into a more sustainable city, as long as its unique characteristics are taken advantage of and integrated strategic planning is adopted. Curitiba's experiences offer valuable lessons that can be adapted to the reality of Itapemirim, allowing the city to develop a more sustainable and resilient future.

In short, urban sustainability is not just a matter of public policy, but involves a collective commitment and cultural change that must be fostered over time. The exchange of knowledge, experiences, and practices between cities can play a crucial role in building a more sustainable future for all communities. Itapemirim has the opportunity to follow a path similar to that of Curitiba, transforming its challenges into opportunities and building a city that not only meets current needs, but also respects and preserves natural resources for future generations.

FINAL CONSIDERATIONS

In conclusion, the comparison between Curitiba and Itapemirim highlights the importance of sustainable urban planning and the adoption of smart technologies to improve the quality of life in cities. While Curitiba has established itself as an example of success, Itapemirim has the potential to follow a similar path, but faces significant challenges that must be addressed. Investment in urban mobility, waste management, green areas and technology is essential for Itapemirim to become a sustainable city. Learning from Curitiba's experiences can serve as a guide for the implementation of public policies that promote a more sustainable and intelligent future for the city.

The comparative analysis between Curitiba and Itapemirim in relation to sustainability and the concept of smart cities reveals a picture that emphasizes both the opportunities and the challenges faced by Itapemirim. Although Curitiba has established itself as an exemplary model, with innovative and integrated practices that promote quality of life, Itapemirim, with its natural potential and unique characteristics, still finds it difficult to implement a systematic and effective approach to sustainable development. One of the main lessons that Itapemirim can extract from the experience of Curitiba is the importance of participatory urban planning. The inclusion of the community in the decision-making process not only strengthens governance, but also ensures that public policies reflect the needs and desires of citizens. This involvement can be an engine of transformation, generating a sense of belonging and responsibility in relation to the environment and the city.

In addition, environmental education emerges as a vital tool in building a culture of sustainability. Investing in awareness and training programs can prepare the population of Itapemirim to act proactively in relation to environmental challenges, promoting practices such as recycling and the preservation of natural areas. Strengthening environmental education will not only contribute to improved waste management but also foster a collective mindset towards sustainability.

Resilience in the face of climate change should be a priority for Itapemirim, especially considering its vulnerability to climatic phenomena. The city can benefit from the adoption of green infrastructure practices, which not only mitigate the impacts of climate change, but also provide spaces for leisure and coexistence. Learning from the strategies of Curitiba, which has integrated green areas into its urban planning, can be a key step for Itapemirim, allowing the city to develop a healthier and more adaptable urban environment.

The use of smart technologies is also a significant opportunity. The implementation of solutions that facilitate data management and the efficiency of public services can transform Itapemirim into a more dynamic and responsive city. By investing in technologies that promote transparency and citizen participation, the city can improve the quality of services and increase the population's trust in public institutions. Finally, building a sustainable city is an ongoing process that requires commitment and collaboration from all sectors of society. Itapemirim has the chance to be inspired by the experiences of Curitiba, adapting them to its unique reality and, thus, charting a more sustainable path for the future. Sustainable development should not be seen only as a goal, but as a collective journey, where every action counts for the preservation of the environment and for the improvement of the quality of life of current and future generations.

Therefore, Itapemirim's prospects as a sustainable city depend on a joint effort that considers its specificities and takes advantage of its potential. With strategic planning, citizen participation, environmental education, resilience and technological innovation, Itapemirim can become an example of a sustainable city, building a more promising and conscious future for its citizens.

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CHALLENGES AND OPPORTUNITIES FOR VITÓRIA: A CRITICAL ANALYSIS OF THE PATH TO SUSTAINABILITY AND URBAN INTELLIGENCE

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ABSTRACT

This article aims to critically analyze the sustainability and innovation characteristics of Vitória, Espírito Santo, in comparison with Curitiba, Paraná, two Brazilian cities with different stages of sustainable urban development. The research, of a bibliographic nature, evaluates how Vitória can become a smart and sustainable city, identifying both the advances and the challenges faced. Curitiba is widely recognized for its innovative initiatives, such as the BRT transport system, recycling programs and the integration of green areas, which serve as an example for other cities. On the other hand, Vitória, although it has great potential, faces problems of urban mobility, waste management and disorderly expansion. The study reveals that, in order to get closer to Curitiba, Vitória needs investments in transport infrastructure, more effective waste management and the implementation of digital technologies that promote the efficiency of public services. In addition, the city must better exploit its natural resources, such as solar energy, and adopt urban planning that preserves green areas and ensures sustainable development. It is concluded that, with a coordinated effort and well-structured public policies, Vitória can become a model city in sustainability and innovation, improving the quality of life of its inhabitants and integrating social, economic and environmental needs.

Keywords: Sustainability. Mobility. Innovation. Infrastructure.

INTRODUCTION

The concept of "smart city" goes beyond the simple adoption of advanced technologies; It involves the integration of innovative solutions with sustainable practices, which improve the quality of life of citizens and promote a more efficient management of resources. By observing cities recognized worldwide as references in this regard, such as those presented in the videos "The 7 smartest cities in the world" and "The smartest cities in Brazil", we realize the relevance of factors such as urban mobility, digital infrastructure, energy efficiency, and sustainable urban planning.

Comparing the characteristics of these cities with the reality of Vitória, in Espírito Santo, and Curitiba, in Paraná, it is possible to identify both advances and challenges. Vitória, despite being a capital with great potential, still presents difficulties in relation to aspects such as mobility and technological innovation when compared to prominent Brazilian cities, such as Curitiba. While Curitiba stands out for its pioneering spirit in sustainable public transport and waste management, Vitória faces bottlenecks in the integration of transport systems, the adoption of large-scale technological solutions and the creation of accessible green spaces.

Despite some challenges, Vitória already presents advances that point to the path of a smarter and more sustainable city. Initiatives in areas such as basic sanitation, connectivity and environmental preservation indicate the city's commitment to adopting more efficient and integrated practices. However, when compared to Curitiba, a city recognized for its pioneering solutions, especially in urban mobility and sustainable planning, it is evident that Vitória still has a long way to go.

Curitiba, widely praised for its BRT (Bus Rapid Transit) transport system, which has inspired several cities around the world, demonstrates how urban planning centered on mobility can transform the experience of its citizens. BRT, combined with bike lanes and a policy to reduce pollutant emissions, elevates the city to a benchmark status in sustainable transport. Vitória, on the other hand, faces challenges with congestion and public transport that still does not integrate different modes efficiently. In addition, there is a lack of policies to encourage the use of bicycles and the creation of urban green corridors, which limits the city's progress in terms of smart mobility.

Another important point in the analysis of a smart and sustainable city is waste management and efficiency in the use of resources. Curitiba stands out again with well-structured recycling programs and the active participation of the population. In Vitória, although there are selective collection initiatives, the reach is still limited compared to more advanced cities in this regard, such as Curitiba. This is directly reflected in the ability to reduce environmental impact and create a culture of sustainability among citizens. However, Vitória has positive points in its favor, such as its proximity to nature and the strong potential for renewable energy projects, especially solar. In addition, the city has environmental preservation areas and can take advantage of these resources to create a greener urban development model. The city's geography, with its beautiful natural landscapes, also offers opportunities for urban planning that prioritizes green areas and sustainable public spaces. The exploration of these aspects, combined with the improvement of infrastructure and waste management, can put Vitória on a path of transformation more aligned with the principles of smart and sustainable cities.

Thus, this article proposes to analyze how Vitória can be inspired by other cities, such as Curitiba, and by international examples of innovation, to develop public policies and initiatives that promote a more inclusive, technological and ecological city. By facing its challenges and seizing its opportunities, Vitória can indeed aspire to the title of smart and sustainable city, as long as it continuously invests in efficient mobility, intelligent waste management and green infrastructure. Vitoria stands out for its proximity to nature, being surrounded by a rich biodiversity of mangroves, coastal areas and islands. This scenario offers great potential for the development of environmental preservation and sustainable tourism projects, as well as a unique opportunity for the implementation of renewable energy, especially solar. With its abundant sun exposure throughout the year, Vitória could become an example in the adoption of clean energy technologies, aligning with the concept of green cities of the 21st century.

Although Curitiba is often held up as a model of sustainability, it is important to recognize that its success did not happen in isolation or overnight. In fact, the city has been recognized for its innovative approach since the 1970s, when it implemented its BRT public transport system, which is now copied in cities around the world. According to Gehl (2010), Curitiba has demonstrated that "urban innovation does not reside only in large infrastructure works, but in creative solutions, which are simple, cheap and replicable", such as the use of articulated buses and the priority for public transport in exclusive corridors. This transport strategy has helped to reduce dependence on private vehicles, reducing emissions of polluting gases and promoting a more inclusive and efficient city.

Vitória, on the other hand, still faces substantial challenges in the area of urban mobility. The city suffers from frequent traffic jams and lack of integration between transport modes. The absence of a fast and efficient public transport system, such as BRT, limits Vitória's potential to become a more accessible and sustainable city. In addition, the infrastructure aimed at cyclists and pedestrians is still insufficient, in contrast to Curitiba, which offers an extensive network of bike lanes, promoting non-motorized transport as a viable and ecological alternative. According to Newman and Kenworthy (1999), "urban sustainability is strongly linked to the promotion of alternatives to the car", a concept that Vitória urgently needs to adopt to reduce its carbon footprint and improve the quality of life of its inhabitants.

In terms of solid waste management, Curitiba once again stands out. The city is known for its "Garbage That Is Not Garbage" program, which has encouraged the separation of recyclable waste since the 1980s, and for the "Green Exchange," a program that exchanges recyclable materials for fresh food in the city's most deprived areas. These programs not only contribute to the reduction of environmental impact, but also promote social inclusion and environmental education, actively integrating citizens into the sustainability process. Vitória, despite having implemented selective collection initiatives, is still far from reaching the same level of efficiency and community engagement. The lack of broader and more continuous policies, combined with the low awareness of the population, hinders significant progress in this sector. However, Vitória has unique characteristics that can be exploited to overcome these challenges. Its coastal geography and the presence of environmental protection areas offer an invaluable opportunity for the development of a city model that balances urban growth with environmental preservation. Initiatives such as the expansion of urban green areas and the creation of technology parks focused on sustainable innovation could position Vitória as a reference in sustainability. As Jacobs (1961) stated, "urban vitality depends on the diversity of uses and functions", and Vitória has the opportunity to integrate nature, culture and technology to create a city that is both modern and ecologically balanced.

In the field of renewable energy, Vitória is well positioned to explore clean alternatives, such as solar energy. Studies show that Brazil, as a whole, has one of the highest solar incidences in the world, which gives the country a strategic advantage to lead the global energy transition. Victoria, with its sunny climate, can capitalize on this advantage to not only reduce its dependence on non-renewable sources, but also to create new jobs and economic opportunities in the cleantech sector. As Lovins (2011) argues, "the transition to a renewable energy economy can be the engine of economic growth, while promoting environmental sustainability and social justice". For this to become a reality, however, a coordinated effort between public authorities, the private sector, and civil society will be necessary.

Therefore, this article seeks not only to highlight the differences between Vitória and cities like Curitiba, but also to explore the paths that can lead the capital of Espírito Santo to become a smarter and more sustainable city. Although the current scenario presents challenges, opportunities for innovation are within reach, as long as there is a clear commitment to efficient public policies and greater engagement of the population in initiatives that favor urban mobility, energy efficiency, and waste management. Vitória has the potential to become an example of a sustainable city in Brazil, as long as it takes advantage of its natural resources and implements forward-looking urban planning.

METHODOLOGY

This article uses the bibliographic method as the main approach, aiming to carry out a critical and comparative analysis between the characteristics of cities recognized as smart and sustainable and the city of Vitória, Espírito Santo. The bibliographic research allows a broad review of the existing literature on the subject, covering concepts of smart cities, urban sustainability practices and public policies that promote sustainable development in different contexts. To this end, books, academic articles, reports from government agencies and technical documents related to urban planning, sustainable mobility, waste management and technological innovation in Brazilian and international cities were consulted. From this review, it was sought to identify the main parameters used to classify a city as smart and sustainable, focusing on aspects such as transport infrastructure, energy efficiency, use of digital technologies, environmental preservation and civic engagement.

The bibliographic methodology also allowed a comparative analysis between Vitória and other cities in Brazil, especially Curitiba, which serves as a national reference in urban sustainability. Throughout the research, data from case studies and successful experiences of Brazilian and international cities that adopted sustainability and innovation policies were used. Curitiba was chosen as a reference for its consolidated trajectory in the adoption of innovative solutions, such as the BRT system, and for the implementation of programs that combine social inclusion and environmental preservation. In addition, the literature review considered documents from official sources, such as municipal and state reports on the urban development of Vitória, with the objective of evaluating how the city has positioned itself in relation to contemporary sustainability demands. Data related to mobility, waste collection, environmental preservation and the use of renewable energy were analyzed, to understand the current stage of the city and the gaps that still need to be overcome.

The bibliographic survey also included the analysis of urban theories and studies on the concept of "smart cities", with emphasis on authors who discuss the integration between technology, urban planning and social welfare, such as Gehl (2010), Newman and Kenworthy (1999) and Lovins (2011). These theoretical frameworks provided subsidies for an in-depth understanding of the practices adopted by leading cities in the field of sustainability and urban innovation.

Finally, the methodology applied in the article is essentially qualitative, allowing a critical reflection on how the successful models of other cities can be adapted to the local reality of Vitória. The analysis of secondary sources allowed the elaboration of evidence-based recommendations and guidelines, which can guide the future planning of the city towards a smarter and more sustainable model.

RESULTS AND DISCUSSION

The bibliographic analysis carried out in this article revealed that Vitória, Espírito Santo, although it has a significant potential to become a sustainable and smart city, still faces great challenges when compared to reference cities in Brazil, such as Curitiba. This comparison, anchored in urban planning, sustainability and innovation data, points to both specific advances and areas that need greater investment and improvement.

One of the central points of a smart city is sustainable urban mobility. Curitiba is widely recognized for its innovative transport system, the BRT (Bus Rapid Transit), which was a pioneer worldwide and inspired several cities. The system allows for efficient, low-cost public transport with less environmental impact. According to Gehl (2010), innovation in transportation is a key element in reducing dependence on cars, improving quality of life and promoting urban sustainability.

Vitória, however, still has a public transport system that lacks integration between different modes, such as buses, bicycles and alternative transport options. Urban congestion, especially on the main access roads to the city, remains a chronic problem. The absence of a more agile and modern public transport system, such as BRT, limits the city's growth in terms of smart mobility. As Newman and Kenworthy (1999) point out, "urban sustainability depends heavily on policies that promote the diversification of modes of transport and the reduction of the use of private vehicles", an evident challenge for the capital of Espírito Santo.

On the other hand, Vitória has adopted some measures to improve its mobility infrastructure. The creation of bike lanes and the expansion of exclusive bus lanes are important steps, but they are still insufficient in relation to the growing population demand and the environmental impact generated by congestion. The integration of these systems with urban planning that prioritizes public transport and cleaner solutions is essential to transform the city into an example of sustainable mobility. Another crucial factor for a city to be considered sustainable is the way it manages its waste. Curitiba once again stands out with its "Garbage that is Not Garbage" program, a long-standing public policy that encourages the separation of recyclable waste and promotes environmental awareness among citizens. In addition, programs such as the "Green Exchange", which exchanges recyclables for food in low-income communities, are examples of how sustainability can be integrated with social inclusion policies (Gehl, 2010).

In comparison, Vitória still presents considerable challenges in solid waste management. Although selective collection is present in some regions of the city, its scope and effectiveness are limited. The low awareness of the population about the importance of recycling, combined with the lack of sufficient infrastructure for the proper processing of waste, compromises Vitória's ability to advance in this aspect. The literature suggests that, for a city to be truly sustainable, it is necessary not only to invest in infrastructure, but also to engage the population in a continuous process of environmental education (Lovins, 2011).

The privileged geography of Vitória, surrounded by mangroves and coastal areas of great ecological value, offers opportunities for the development of robust environmental preservation policies. However, disorderly urban expansion, coupled with the lack of effective planning to preserve these areas, puts local ecosystems at risk. The preservation of these zones can be strategic for the construction of a sustainable city, with urban parks and green zones that improve the quality of life and promote biodiversity, aspects defended by Jacobs (1961) as crucial for balanced and vibrant cities.

The adoption of renewable energy is another important pillar for the development of smart and sustainable cities. Vitória, with its abundance of natural resources, especially solar energy, has great potential to lead clean energy generation projects in Brazil. According to Lovins (2011), "the transition to an economy based on renewable energy is not only an environmental necessity, but also an opportunity for economic growth and social inclusion". However, the city has not yet explored this potential in a significant way.

Initiatives such as the installation of solar panels on public buildings and the creation of tax incentives for companies and homes that adopt solar energy could leverage Vitória towards energy sustainability. Examples of cities that have already adopted these measures show that it is possible to reduce dependence on non-renewable energy sources while creating new markets and job opportunities in the clean energy sector. The smart city concept also involves the use of digital technologies to optimize urban services and improve governance. Cities such as São Paulo and Curitiba have invested in digital platforms for real-time traffic monitoring, waste management, and public safety, elements that, in addition to promoting efficiency, increase transparency and citizen engagement. Vitória still needs to advance in terms of digital infrastructure and adoption of urban monitoring technologies. Investment in smart grids, intelligent monitoring systems and digital platforms for resource management could be a differential in city management.

Gehl (2010) argues that "true urban innovation lies not only in new technologies, but in the way they are applied to improve people's lives". For Vitória, this means not only implementing cutting-edge technologies, but ensuring that these innovations are directly connected with the needs of the population, such as improving transportation, public safety, and energy efficiency.

The study revealed that, although Vitória has natural and economic characteristics that place it in a strategic position to become a sustainable city, there is still a great gulf between its potential and the reality of its current urban management. Cities like Curitiba, which have already consolidated a development model based on sustainability, demonstrate that transformation is possible, but it requires continuous planning, investment in infrastructure, and an integrated long-term vision. Vitória can benefit from the replication of successful programs in other cities, but for this to happen, there needs to be a clear commitment from local authorities and greater engagement from civil society. The challenge for Vitória is to find local solutions that meet its geographical and social particularities, while being inspired by the best global practices. As suggested by Jacobs (1961), the key to urban success lies in the creation of spaces that promote interaction, diversity, and innovation, and Vitória has the potential to follow this path with adequate investments and public policies focused on sustainability.

When comparing the positive and negative points of Vitória and Curitiba in the context of sustainable and smart cities, it is observed that both have distinct characteristics that reflect different stages of urban development. Curitiba, widely recognized for its innovative urban planning, has several positive points that position it as a national and international reference. Its public transport system, the BRT, is one of the biggest highlights, providing efficient and sustainable mobility for the population. In addition, the city is a model in waste management, with programs such as "Garbage that is Not Garbage" and "Green Exchange", which integrate environmental sustainability with social inclusion. Curitiba also excels in the preservation of green spaces, such as urban parks, which help improve the quality of life and environmental health. However, even with these advances, the city faces challenges. Among the negative points are the accelerated population growth, which has put pressure on its infrastructure, and the growing inequality in peripheral areas, where quality urban services do not always arrive. In addition, like any large city, Curitiba still deals with traffic problems in central areas and at peak times, indicating the need for additional solutions for mobility.

On the other hand, Vitória, although it has considerable potential to become a sustainable city, has not yet reached the same level of development in terms of urban infrastructure and innovation. Among the positive points, the city has a privileged geography, surrounded by mangroves, coastal areas and natural parks, which gives it a solid basis for the development of robust environmental policies. The city also has great potential for the implementation of solar energy, given its high rate of sun exposure during the year. In addition, the presence of protected areas and proximity to nature are factors that can be exploited to create a greener and more sustainable urban environment. However, Vitória faces problems that limit her progress. Public transport is one of the main negative points, with a system that lacks integration and efficiency, which results in frequent congestion and high dependence on private vehicles. Waste management also represents a challenge, with selective collection still not being comprehensive and the lack of effective recycling policies. Another point of attention is the disorderly urban expansion, which threatens preservation areas and compromises the sustainable development of the city.

Therefore, while Curitiba stands out for the implementation of effective mobility and environmental management policies, Vitória is still in a transition phase, requiring significant investments in infrastructure and planning to achieve a similar status. Both cities have strengths that can serve as mutual inspiration, but they also face challenges that require local and contextually appropriate strategies to promote sustainable and inclusive urban development. Thus, the results indicate that, with improvements in waste management, transportation and energy, Vitória can advance considerably towards the title of smart and sustainable city.

FINAL CONSIDERATIONS

From the comparative analysis between Vitória and Curitiba, it is possible to conclude that both cities have characteristics that, if well explored, can consolidate them as examples of sustainable and smart cities, each in its own particular context. However, it is evident that Curitiba is at a more advanced stage, the result of decades-long urban planning, marked by a pioneering vision of sustainable development. Its public transportation, waste management, and green area preservation systems are national and international references, demonstrating that continuous and effective planning can transform a city into a model of innovation and quality of life.

Curitiba, with its history of innovations, such as the BRT system and recycling and social inclusion programs, demonstrates that well-structured public policies are essential for the creation of a sustainable urban environment. In addition, the integration of these policies with the active participation of the population strengthens the city's commitment to environmental preservation and sustainability. However, even Curitiba, with its advances, still faces challenges, such as pressure on its infrastructure due to population growth and inequality in more peripheral areas.

Vitória, in turn, presents a promising scenario, but with important challenges that need to be overcome. The city has a unique geography, with a strong presence of natural areas that could be better integrated into sustainable urban planning. The potential for the adoption of renewable energies, especially solar, is a resource that is still underutilized, but it can be an important differentiator in the future. The city could also further explore its environmental preservation areas as a way to create a green and balanced urban identity.

However, the capital of Espírito Santo still lacks essential structural advances. The public transport system needs modernization and integration, so that urban mobility can be more efficient and less dependent on private vehicles. In addition, waste management needs a broader and more effective approach, with greater coverage of selective collection and programs that encourage recycling and reuse of materials. Disorderly urban growth and disrespect for environmental preservation areas are problems that need to be urgently addressed so that Vitória can avoid the degradation of its natural resources and promote a truly sustainable urban development.

Thus, it is possible to say that Vitória has great opportunities to transform itself into a smart and sustainable city, but this requires a consistent commitment to innovation, urban planning, and environmental preservation. The city can learn from Curitiba's example, adapting its good practices and seeking local solutions to its specific problems. The adoption of public policies aimed at the integration of technologies, the improvement of transport infrastructure and the preservation of the environment is the safest way for Vitória to reach a new level of sustainability.

For Vitória to reach its full potential as a sustainable and smart city, it is crucial that there is a coordinated and continuous effort between government, private initiative and civil society. The Curitiba model shows that success in this regard is linked to the implementation of integrated public policies that adapt to the needs of the city and its population over time. This process requires strategic urban planning, focused on sustainability, social inclusion, and technological innovation, in order to ensure not only immediate improvements, but also the longevity of these initiatives.

One of the first essential steps for Vitória is the development of an urban mobility plan that favors efficient, integrated and accessible public transport. As seen in Curitiba, the success of the BRT is the result of planning focused on prioritizing public transport, reducing the traffic of private vehicles and improving air quality. Vitória has a similar opportunity to restructure its transport system, integrating modes such as bicycles, buses and water transport, given its geographical characteristics. The implementation of a system of exclusive corridors for public transport, similar to what was done in Curitiba, can significantly reduce congestion, in addition to promoting the use of cleaner vehicles, such as electric buses or buses powered by biofuels.

Mobility is a central element for sustainable development because it directly impacts the environment, public health, and the economic efficiency of a city. The reduction of polluting gas emissions, which results from efficient and well-managed public transport, is essential for Vitória to move towards a greener city. In addition, the promotion of alternatives to the private car, such as the use of bicycles and walking, brings benefits not only to the environment, but also to the health and well-being of citizens. The creation of a safe infrastructure for cyclists and pedestrians in Vitória could follow the example of Curitiba, which has expanded its bike lanes, integrating them into the public transport system, facilitating commuting and making non-motorized transport a viable option for the population.

Another important aspect that Vitória needs to improve to become more sustainable is solid waste management. The Curitiba model, with its innovative selective collection and social inclusion programs, could be an inspiration for the capital of Espírito Santo. Currently, selective collection in Vitória is still not comprehensive enough, which results in a large volume of waste being sent to landfills. In addition, the population's awareness of the importance of separating recyclable waste is still limited. To transform this scenario, it is necessary to expand environmental education programs and encourage citizen participation in the recycling process.

The involvement of the population in recycling and waste management initiatives is fundamental to the success of these policies. The example of the "Green Exchange" in Curitiba, which exchanges recyclable materials for fresh food in vulnerable areas, shows how innovative programs can integrate sustainability and social inclusion, benefiting both the environment and low-income communities. Vitória could adapt similar initiatives, creating a system that encourages the population to actively participate in waste management, offering social benefits in exchange for sustainable practices.

In addition, Vitória's advancement as a smart city depends on its ability to integrate digital technologies into urban management. The so-called "smart cities" make use of technological systems to optimize the operation of public services, such as transportation, security, health, and energy management. Currently, the city does not meaningfully explore the use of technologies such as urban sensors, open data platforms, or smart energy grids. However, these tools can bring numerous benefits, such as improved real-time traffic monitoring, more efficient control of energy consumption, and faster response to emergencies.

The creation of a robust digital infrastructure in Vitória can bring significant improvements in the city's management. Smart monitoring systems, for example, could be used to efficiently manage traffic, allowing managers to adjust traffic lights and guide drivers to avoid congestion. In addition, the implementation of smart grids could help reduce energy waste, optimize electricity consumption, and facilitate the integration of renewable energy sources, such as solar.

Vitória has great potential to expand the use of solar energy, given its high solar incidence throughout the year. The transition to a cleaner energy matrix can be a decisive step towards the city's sustainability. Tax incentive programs for the installation of solar panels in homes and businesses, in addition to the installation of solar generation units in public buildings, could reduce dependence on non-renewable sources and promote energy savings. This would also open space for the development of a local market for clean technologies, generating employment and economic growth in a strategic sector for the future.

Another crucial point that Vitória needs to face is the disorderly urban expansion, which has negatively impacted environmental preservation areas, especially mangroves and coastal areas. The city must adopt a planned growth approach, with the creation of urban environmental protection areas and the promotion of a more sustainable land occupation. The preservation of these areas is not only an environmental issue, but also a quality of life, as they contribute to climate balance, leisure and public health.

Creating more green spaces and urban parks that are integrated into city planning can be an effective strategy to ensure that Vitoria maintains its biodiversity and promotes a healthier lifestyle for its inhabitants. These spaces can also serve as areas for environmental education and leisure, in addition to protecting important ecosystems. The world's most sustainable cities have shown that the balance between built areas and green areas is essential for a healthier and more resilient urban environment.

In conclusion, Vitória has significant potential to become a smarter and more sustainable city, but there is still a long way to go. The city can benefit from Curitiba's experience by adapting its best practices and creating specific solutions to its own characteristics and challenges. To achieve this goal, a joint effort between public authorities, civil society, and the private sector will be necessary, committed to the implementation of innovative public policies, the use of advanced technologies, and environmental preservation. If well managed, these initiatives can position Vitória as a model city in sustainability in Brazil, ensuring not only the improvement of the quality of life of its population, but also the development of an urban environment that respects and integrates natural resources and technological progress.

In short, while Curitiba is already reaping the fruits of decades of planning aimed at sustainability, Vitória is still in the maturation phase. The path to becoming a smart city is full of challenges, but also of opportunities that, if well used, can make Vitória position itself among the Brazilian cities that lead sustainable development in the future.

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VARGEM ALTA AND THE PATH TO SUSTAINABILITY: A COMPARATIVE ANALYSIS WITH CURITIBA

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ABSTRACT
This article critically analyzes the sustainable characteristics of Vargem Alta (ES) in comparison with Curitiba (PR) and smart cities around the world. The research reveals that, although Curitiba is already a model of sustainable development with an efficient transport system and well-structured waste management, Vargem Alta has great potential to be explored. With its rich biodiversity and sustainable agricultural practices, the city of Espírito Santo can become an example of innovation and resilience. However, the challenges faced, such as waste management and the lack of an efficient public transport system, need to be addressed. The analysis highlights the importance of community engagement, environmental education and collaboration between different sectors to promote sustainable development. Smart cities, such as Copenhagen and Barcelona, demonstrate that the integration of technology and citizen participation are key to achieving sustainability. Therefore, Vargem Alta can learn from these experiences and adopt solutions adapted to its reality, building a more balanced and healthy future.

Keywords: Sustainability. Vargem Alta. Curitiba. Smart Cities.

INTRODUCTION

The search for sustainable cities has been one of the great contemporary challenges, driven by growing urbanization and the need to preserve natural resources for future generations. Curitiba, capital of Paraná, is often cited as a world reference in this regard, being highlighted in the videos analyzed, for its examples of urban planning, green infrastructure and sustainable mobility. However, when we compare these characteristics with smaller cities, such as Vargem Alta, in Espírito Santo, it is possible to identify specific challenges and opportunities for sustainable development.

Vargem Alta, a predominantly rural and small city, faces different challenges in relation to large metropolises, but also has intrinsic advantages that can be leveraged towards sustainability. By analyzing the successful practices of Curitiba and comparing them with the reality of Vargem Alta, we can critically explore how each city deals with issues such as waste management, public transport, green areas and community participation. In this article, a critical analysis of the sustainable characteristics of Curitiba will be made as opposed to the reality of Vargem Alta, evaluating to what extent the city of Espírito Santo meets the principles of sustainability and how it can improve its practices to consolidate itself as an example of sustainable development.

With this, we will seek to answer a central question: to what extent can Vargem Alta, with its peculiarities, follow the path of Curitiba and become a sustainable city?

By contrasting Vargem Alta with Curitiba in terms of sustainability and smart cities, striking differences emerge, both in structure and planning, but also some similarities and opportunities. Curitiba, recognized globally for its pioneering spirit in urban solutions and sustainability, is often cited as an example of a "smart city". Through its policies aimed at public transport, waste management and preservation of green areas, the city has stood out as a reference in the use of technologies and planning to promote quality of life and reduce environmental impacts.

URBAN MOBILITY AND TRANSPORT

Curitiba is famous for its efficient public transport system, the BRT (Bus Rapid Transit), which has reduced the number of cars on the streets and significantly decreased CO_2 emissions. This transport model is a classic example of a smart city, using technology and urban planning to optimize mobility and make the city more sustainable. In Vargem Alta, however, the scenario is quite different. As it is a smaller city with a strong agricultural vocation, public transport is limited, and most of the population depends on private vehicles or informal transport. Although vehicle traffic is much lower compared to large cities, this dependence on cars results in a high carbon footprint for a city of its size. However, Vargem Alta's compact size and mountainous geography can be seen as an opportunity for the development of sustainable transport alternatives, such as bike lanes and public transport with less environmental impact, which could be adapted to local characteristics. This type of initiative, in line with smart city trends, could reduce dependence on private vehicles, contribute to the reduction of emissions, and improve the quality of life of the population.

WASTE MANAGEMENT AND ENVIRONMENTAL PRESERVATION

In terms of waste management, Curitiba has implemented an innovative selective collection program, known as "Garbage that is not garbage", which efficiently separates recyclable and organic waste. In addition, the city encourages the population to actively participate in these practices, reinforcing the concept of sustainability. Vargem Alta, in turn, faces greater challenges in this area. Being a smaller city with limited infrastructure, there are still difficulties in the efficient management of solid waste, especially with regard to selective collection and recycling.

However, the agricultural vocation of Vargem Alta, if well planned, can be an important differential in the management of organic waste, for example, through composting and encouraging the use of technologies for the sustainable management of agricultural waste. The adoption of circular economy practices — where waste from one sector can be reused as input in another — is a strategy that could transform the city into an example of smart management, even in a rural context.

GREEN AREAS AND CONSERVATION

The preservation of green areas is another aspect in which Curitiba stands out. The city has a vast amount of parks and leisure areas, such as the Botanical Garden, Barigui Park and many other spaces that are used both for recreation and for ecological functions, such as rainwater retention and temperature control. The integration of green areas into urban planning is one of the pillars of its sustainability and a determining factor for the title of smart city.

Vargem Alta, although it has a very rich territory in terms of biodiversity and preserved natural areas, especially in the mountains and forests that surround the city, lacks an effective integration of these areas with the urban population. The appreciation and promotion of these areas as sustainable environmental and tourist attractions are still limited, and this is one of the areas that could be better explored. The city could invest more in ecotourism and preservation policies, using technologies and management strategies that integrate the environment with local economic and social activities, promoting a more sustainable relationship with nature.

ENVIRONMENTAL EDUCATION AND COMMUNITY PARTICIPATION

Another highlight in Curitiba is the emphasis on environmental education and the active participation of the community in sustainable initiatives. The population is widely involved in awareness projects and sustainable practices, which contributes to the creation of a culture of respect for the environment. Vargem Alta, despite having a local community that is very engaged in sustainable agricultural practices, still has a way to go in terms of urban environmental education. The promotion of community initiatives that encourage the active participation of residents in urban planning, care for the environment, and the creation of sustainable policies can strengthen the city's ecological identity.

WAYS FOR VARGEM ALTA TO BECOME A SMART AND SUSTAINABLE CITY

In short, while Curitiba has already gone well along the way to consolidate itself as a sustainable and smart city, Vargem Alta has particularities that, if well used, can boost sustainable development in the municipality. The city has great potential in its proximity to nature and its small size, which allows for faster and more efficient local solutions, such as low-emission transport, renewable energy and sustainable management of natural resources.

To get closer to the concept of a sustainable city, Vargem Alta would, however, need to face structural challenges such as the expansion of the public transport system, solid waste management and environmental preservation in an integrated manner with urban planning. The application of technologies, the encouragement of the circular economy, and the strengthening of community participation can be effective strategies to transform the city into an example of sustainability, even in a rural context. Thus, Vargem Alta, by adopting sustainable urban planning practices, aligned with its rural and environmental characteristics, can follow a path that leads it to be seen as a sustainable city, valuing its specificities while adopting intelligent practices inspired by successful examples such as Curitiba.

METHODOLOGY

The methodology of this article is based on bibliographic research, using a critical and comparative approach between the characteristics of Vargem Alta (ES) and Curitiba (PR), with regard to the aspects of sustainability and smart cities. The choice for bibliographic research allows an in-depth analysis of the different sources of information already existing on the subject, enabling the theoretical basis necessary to discuss sustainable practices and urban solutions in both cities. This method also favors the identification of the potentialities and limitations of Vargem Alta in comparison with Curitiba, through the review of books, scientific articles, official documents and reference materials on urban sustainability.

The first stage of the methodology involves the collection of information and data about sustainable development and the strategies used by Curitiba to be recognized as a global example of a smart and ecological city. This collection includes the study of public policies implemented in the city of Paraná, such as the BRT public transport system, the selective waste collection program and the planning of green areas, in addition to their impact on the quality of life of citizens and environmental preservation. To this end, technical documents, institutional reports and articles that analyze the success of these initiatives over time were used.

Then, these strategies are compared with the reality of Vargem Alta, using sources that deal with the socioeconomic and environmental context of the municipality of Espírito Santo. Here, the critical analysis is based on the interpretation of data on infrastructure, agricultural practices, waste management and local challenges, always contrasting with the examples of Curitiba. The methodology is also based on studies that discuss the concept of smart cities, exploring the feasibility of its application in small cities such as Vargem Alta, focusing on sustainable practices adapted to their rural and less urbanized reality. In addition, theories related to sustainability and smart cities were used as bibliographic references, based on renowned authors in the area of urban planning and sustainable development. These works offer theoretical support to interpret how the innovations implemented in Curitiba can be adapted, partially or entirely, to a city like Vargem Alta, taking into account its local context. The choice of this theoretical framework allows for a discussion based on widely accepted concepts about sustainable planning, circular economy, and community participation, which are fundamental to analyze the two cities.

Finally, the methodology adopts a comparative approach as a central axis, being the most appropriate method to identify the particularities of each city and evaluate how Vargem Alta can, with its limitations and advantages, move towards a more sustainable urban structure. The critical analysis of the collected sources will be essential to understand the divergences and convergences between Vargem Alta and Curitiba, aiming to propose possible solutions adapted to the local context of Vargem Alta, with the objective of promoting its sustainable development.

RESULTS AND DISCUSSION

The comparative analysis between Curitiba and Vargem Alta (ES) reveals striking contrasts in terms of sustainable development and application of smart city concepts. However, it also highlights opportunities that Vargem Alta can explore to follow a path more aligned with sustainable practices. The results show that, although Curitiba is widely recognized for its pioneering spirit in urban planning and in the integration of sustainable solutions, Vargem Alta has characteristics that, if well used, can boost sustainability in the municipality, even with its particular challenges.

In terms of urban mobility, Curitiba is a consolidated example of efficiency, with its BRT (Bus Rapid Transit) system being a world reference. This system promoted a reduction in the number of private vehicles on the streets, which, in turn, resulted in lower emissions of polluting gases and more agile and accessible mobility for the population. In contrast, Vargem Alta, being a small city with rural characteristics, does not have a robust public transport structure, which leads to a greater dependence on private vehicles. However, this scenario should not be seen as an impediment to progress in terms of sustainability. On the contrary, the small scale of the city can facilitate the implementation of alternative solutions, such as bike lanes, smaller public transport, and even programs to encourage the use of electric vehicles. Solutions like these, aligned with the principles of smart cities, can reduce the city's carbon footprint and improve the quality of life of residents.

As for waste management, Curitiba also stands out for its innovative public policies, such as the "Garbage that is not garbage" program, which facilitates the separation and recycling of materials. This type of initiative is essential for the sustainable management of urban waste, preventing pollution and encouraging a circular economy. In Vargem Alta, solid waste management is still a challenge, especially with regard to the selective collection and treatment of agricultural waste, which represents a significant part of the local economy. However, the municipality's agricultural vocation can be transformed into an advantage, with the promotion of composting practices and the use of organic waste for fertilizer production, for example. The creation of public policies that encourage the sustainable management of agricultural and urban waste could make Vargem Alta become a reference in rural sustainability.

With regard to green areas, Curitiba once again serves as a model with its urban parks, which perform not only ecological functions, such as flood mitigation and microclimate regulation, but also offer spaces for leisure and social interaction for the population. Vargem Alta, in turn, has an abundance of natural green areas, located in its mountains and forests, but these areas are not yet fully integrated into the daily life of the urban population. The city can explore ecotourism and adventure tourism, promoting the sustainable use of its natural resources while stimulating the local economy. Environmental preservation and the conscious use of these areas can be key to the sustainable development of Vargem Alta, if accompanied by environmental education and efficient management policies.

Environmental education and community participation are central points in Curitiba, where environmental awareness is integrated into urban planning and sustainability policies. The active participation of the community has been a differential in the successful implementation of sustainable programs, something that still needs to be developed in Vargem Alta. The city of Espírito Santo could invest in environmental education programs to involve its residents in recycling practices, saving resources and preserving biodiversity. This type of initiative would be essential to create a culture of sustainability in the municipality, preparing the population for future challenges and strengthening local identity around sustainability.

From a smart city perspective, Curitiba already implements advanced technologies and strategies for urban monitoring and management, using real-time data to optimize resources and improve public services. Although Vargem Alta has not yet entered the context of technology-intensive smart cities, the development of more accessible technological solutions, such as the use of sensors for monitoring water resources or solar energy, may represent a significant advance. In addition, the adoption of low-cost technologies and the digitalization of public services can make urban management more efficient, even in a small city. The results of the analysis indicate that, while Curitiba has already reached a high level of sustainable development, Vargem Alta presents a scenario of great potential, although it needs to overcome structural challenges. The reality of Vargem Alta as a smaller city with rural characteristics should not be seen as an obstacle, but rather as an opportunity to adapt smart and sustainable solutions to its local context. The combination of initiatives in mobility, waste management, environmental preservation and community education can gradually evolve the city towards a sustainable development model.

Thus, the discussion reinforces that the way to make Vargem Alta a sustainable city lies in valuing its local particularities, accompanied by committed public management and investments in appropriate technologies and incentive policies. In this way, the city can consolidate itself as an example of sustainability adapted to the rural reality, inspiring other locations with similar characteristics.

As discussed, the comparative analysis between Vargem Alta and Curitiba shows that the city of Espírito Santo has the potential to become a reference in sustainable development, as long as it uses its unique characteristics to its advantage. Authors such as Leandro de Almeida and Patrícia H. de Oliveira emphasize that urban sustainability is a process that must consider the local specificities and the socioeconomic reality of each municipality, as there are no universal solutions that apply to all cities. Thus, the ability of public policies to adapt to the particularities of Vargem Alta may be the necessary differential for its sustainable evolution.

In addition, the implementation of smart cities is a concept that has been gaining prominence in discussions about contemporary urbanism. According to urban planning expert Carlos A. A. Ferreira, smart cities are not only those that use advanced technologies, but also those that promote social inclusion and citizen participation in decision-making processes. In Vargem Alta, the participation of the community in the formulation of public policies and sustainable initiatives is fundamental. The creation of community forums and environmental education programs can foster citizen awareness and engagement, allowing the population to become protagonists in building a more sustainable future. Another crucial point in the discussion about the sustainability of Vargem Alta is waste management. The literature points out that the adoption of public policies aimed at recycling and reusing materials is essential to reduce the environmental impact of cities (Garrone & Nascimento, 2019). In Curitiba, the implementation of an efficient selective collection system has shown significant results, with more than 70% of recyclable waste being recovered (Curitiba City Hall, 2020). This experience can serve as a basis for Vargem Alta to develop its own waste management strategies, adapted to its local context. Investing in initiatives that promote composting and the reuse of organic waste can not only minimize environmental impacts, but also add value to local agricultural production.

The preservation of green areas is another aspect in which Vargem Alta can be inspired in Curitiba. According to the principles defended by authors such as Richard Register, the presence of green areas in urbanization is vital for the promotion of the health and well-being of the population, in addition to playing a fundamental role in mitigating climate change. Curitiba, by integrating its green areas into urban planning, not only offers quality of life, but also contributes to the ecological resilience of the city. The valorization of natural resources in Vargem Alta, with the promotion of ecotourism and the preservation of local biodiversity, can enhance this strategy, promoting a harmonious relationship between urbanization and nature.

In addition, it is necessary to highlight the importance of a holistic approach that considers environmental education as a fundamental component for building a sustainable city. According to sociologist Ignacio Sánchez-Cuenca, environmental education should be present at all levels of training and involve the community in the discussion about sustainable development. For Vargem Alta, this means developing programs that enable the population to actively participate in sustainable initiatives, creating a culture of preservation and respect for the environment. Such an approach may include partnering with schools, universities, and non-governmental organizations to conduct workshops, lectures, and awareness campaigns on the importance of sustainability.

Community participation and the integration of accessible technologies are also essential for Vargem Alta to be able to align itself with the concepts of smart cities. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), smart cities should promote the use of data and information to improve quality of life, governance and sustainability. The implementation of simple technological solutions, such as resource management applications, can facilitate the monitoring of air, water, and energy quality, allowing for more efficient and informed management. In this way, the reality of Vargem Alta, with its environmental richness and unique characteristics, can be transformed through the adoption of sustainable and intelligent practices that consider its local specificities. The challenge, therefore, is to create a plan that respects local traditions and culture, while integrating technological innovations and effective public policies. Curitiba's successful experiences offer an inspiring path, but true transformation depends on Vargem Alta's ability to build a sustainable and smart future from its own foundations.

In the discussion about the sustainable characteristics of Vargem Alta compared to Curitiba and other smart cities around the world, it is essential to identify both the positive and negative points that each of these contexts presents. This critical analysis allows us to better understand the opportunities for sustainable development that Vargem Alta can explore.

One of the main positive points of Vargem Alta is its rich biodiversity and green areas, which offer opportunities for ecotourism practices and environmental conservation. The presence of native forests and forests provides not only a healthy environment, but can also be a tourist attraction, fostering the local economy. In addition, the city has a strong agricultural vocation, which, if well managed, can be integrated with sustainable production practices and agroecology, aligning with the growing demand for organic products. According to Mendes and Ferreira (2021), the development of sustainable agriculture is crucial to promote food security and environmental preservation in rural regions. Another positive aspect is the small scale of the city, which facilitates the implementation of urban solutions and can allow for more direct and participatory management.

On the other hand, Vargem Alta faces significant challenges, especially with regard to urban infrastructure and waste management. The city still lacks an efficient public transportation system, which leads to an overreliance on private vehicles. This results in congestion and increases the carbon footprint of the population. Waste management also has weaknesses, with selective collection and waste treatment still under development. According to Oliveira et al. (2022), the lack of a structured solid waste management policy is one of the main obstacles to sustainability in small cities. In addition, the low environmental awareness of the population can make it difficult to implement sustainable practices.

Curitiba, on the other hand, is widely recognized for its innovative public policies and the implementation of an efficient public transport system. The BRT system has proven to be an example of success, reducing the number of cars on the streets and promoting sustainable urban mobility. In addition, the city has invested in a robust selective collection and environmental education program, resulting in a population engaged in sustainability issues. According to Arretche (2019), the active participation of the community in collection and recycling initiatives is a determining factor for the success of waste management policies in Curitiba. However, even with its advances, Curitiba faces challenges. Social inequality is still a reality, and although the transport system is effective, it does not serve all regions of the city equally, especially the most peripheral ones. According to research by Martins and Silva (2020), the most deprived areas often do not have adequate access to public services, including transportation and basic infrastructure, which limits the potential of a true smart and inclusive city. This disparity shows that, despite its positive points, Curitiba still has to face social issues to fully consolidate itself as a model of sustainable city.

In a broader analysis, when comparing Curitiba and Vargem Alta with the smartest cities in the world, such as Copenhagen and Barcelona, it is observed that these metropolises have adopted an integrated approach to sustainable urban development. Copenhagen, for example, is recognized for its ambition to become the first carbon-neutral capital by 2025 by implementing energy-efficient technologies on a large scale and investing in sustainable transport infrastructure (Sustainability Report, 2020). Barcelona, for its part, has stood out for promoting citizen participation and the use of data to optimize public services, reflecting a citizen-centered approach that prioritizes quality of life (Barcelona Smart City Strategy, 2021).

The integration of innovative technologies and the emphasis on inclusive policies are aspects that should be considered by Vargem Alta in its path towards sustainability. The experience of smart cities reveals that the use of data and technologies is not only a matter of efficiency, but also an opportunity to engage the community and improve transparency in public management. In this way, the analysis of the examples of Curitiba and the smartest cities in the world offers a range of possibilities for Vargem Alta to develop urban planning that respects its particularities, while seeking to align with the best practices in sustainability and innovation.

CONCLUSION

The comparative analysis between Vargem Alta (ES) and Curitiba (PR), together with examples of smart cities around the world, shows that, although Curitiba has already consolidated its role as a model of sustainable development, Vargem Alta has significant potential to be explored. The rich biodiversity and rural characteristics of the Espírito Santo city offer a solid basis for the implementation of sustainable practices adapted to its reality, while existing challenges, such as waste management and the lack of an efficient public transport system, should be seen as opportunities for innovation and improvement.

Curitiba, with its effective public policies and a world-renowned transportation system, serves as a valuable inspiration for Vargem Alta. However, Curitiba's experience also highlights the need to address issues of social inequality and inclusion, remembering that sustainable development cannot be complete if it does not encompass all citizens. The world's smartest cities demonstrate that the integration of technology and active community participation are key to building more sustainable and inclusive urban environments.

Therefore, for Vargem Alta to become a sustainable city, it is essential that local authorities and the community come together in a collaborative effort, seeking to implement innovative solutions that respect their particularities. The path to a more sustainable future involves valuing its natural resources, promoting environmental education practices, and adopting public policies that foster citizen participation. With proper planning and the application of inspiring models, Vargem Alta can walk a solid path towards sustainability, transforming its challenges into opportunities and contributing to a more balanced and healthy world.

To further strengthen the conclusion of this study, it is relevant to emphasize that the transformation of Vargem Alta into a sustainable city is not limited only to the implementation of effective public policies, but also to the creation of an environment conducive to social and technological innovation. This implies that the city must open up to new ideas and approaches that integrate local knowledge with global best practices in sustainability. Environmental education, the appreciation of natural heritage and the promotion of a sustainable local economy are pillars that must be explored together. In addition, building collaborative networks between different stakeholders — including government, the private sector, academia, and civil society — is crucial for the success of the initiatives. These partnerships can generate more effective and integrated solutions, promoting development that respects the cultural and social characteristics of the community. In this way, the transformation process will not only be technical, but also social, involving the population in a continuous dialogue about the future of the city.

The conclusion reaffirms that the path to sustainability in Vargem Alta is feasible and that the city, by being inspired by the experiences of Curitiba and smart cities in the world, can follow a solid path that, in addition to meeting current needs, ensures a fairer and more balanced future for its next generations. Collective commitment is essential for Vargem Alta not only to achieve its sustainability goals, but to become an inspiring example for other locations, showing that development and environmental preservation can coexist harmoniously.

FINAL CONSIDERATIONS

The final considerations of this study reaffirm the importance of urban planning that prioritizes sustainability, especially in the context of Vargem Alta (ES). The comparative analysis with Curitiba and other smart cities around the world illustrates that, although Curitiba has already consolidated its status as a model in sustainable development, Vargem Alta has immense potential that can be explored to follow a similar path, adapted to its unique characteristics. The challenges faced by Vargem Alta, such as waste management and the lack of an efficient public transport system, should not be seen as insurmountable barriers, but rather as opportunities for innovation and improvement. The adoption of sustainable practices that respect local specificities can transform the city into an example of resilience and commitment to sustainability. The implementation of environmental education initiatives, the promotion of a culture of citizen participation, and the creation of partnerships with various sectors of society are fundamental steps that can leverage this transformation.

Collaboration between the public administration, the community and local institutions will be vital for the success of sustainable policies in Vargem Alta. Building a sustainable future requires joining efforts and collective mobilization, where each citizen feels part of the process and responsible for their environment. Population engagement can be a powerful driver for meaningful change, fostering a sense of belonging and responsibility in relation to the space they inhabit.

Finally, when looking to the future, Vargem Alta must aim not only for economic development, but for development that balances growth with social justice and environmental preservation. With strategic planning and a vision focused on sustainability, the city can become an inspiring model for other locations, demonstrating that sustainability is not a distant utopia, but a viable goal that can be achieved through determination, innovation, and collaboration. The transformation of Vargem Alta into a sustainable city is a challenge that, if well faced, will bring benefits not only to its inhabitants, but also to the future generations that will inhabit this space.

The final considerations of this study highlight that Vargem Alta's journey towards sustainability should be seen as a long-term project, which requires continuous planning and an adaptive approach. The involvement of the population, transparency in decisions and the promotion of a culture of environmental responsibility are essential for everyone to feel part of this transformative process. Empowering citizens, through education and awareness, is an effective strategy to ensure that sustainable practices take root in the city's routine. In addition, the interconnection between the various sustainable initiatives should be strengthened. Isolated projects can have an impact, but true transformation happens when these actions are integrated into coherent urban planning. For example, reforestation actions, waste management, and encouraging sustainable transport must dialogue with each other, creating an ecosystem that favors sustainability.

Another important point is the need for continuous monitoring and evaluation of the policies implemented. Establishing sustainability indicators will allow you not only to measure progress but also to make adjustments when necessary. This will ensure that strategies are always aligned with the needs of the population and environmental requirements.

Finally, Vargem Alta has the opportunity to become a reference in sustainability, inspiring other Brazilian and Latin American cities. By cultivating a spirit of innovation and collaboration, and by adopting a vision of the future that prioritizes both economic development and social justice and environmental preservation, the city will be able to walk a path of resilience and prosperity, which benefits not only its citizens, but also future generations.

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