

Dariane Catapan
Head Organizer

Approaches to environmental, social and corporate governance

1st Edition

São José dos Pinhais

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**Approaches to environmental, social
and corporate governance**

1st Edition

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PRESENTATION

The book **Approaches to environmental, social and corporate governance** highlights research and collaborations by qualified authors in the field of long-term sustainability.

These articles provide important insights into environmental and social theory and practice, as well as various political and business analyses interested in promoting sustainability and social responsibility.

Through these studies, the book conveys knowledge to all those interested in understanding the best practices in environmental, social and corporate governance, both for academic studies and for professionals in the field.

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CHAPTER 1

RECYCLING INORGANIC WASTE TO REDUCE THE HOUSING DEFICIT, CONTRIBUTIONS TO PUBLIC HEALTH AND SUSTAINABILITY OF THE PLANET

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ABSTRACT: Bearing in mind that one of the greatest challenges that humanity currently needs to resolve, and urgently, is how to guarantee continuous industrial development while simultaneously preserving the environment, our objective in this work is to contribute to political leaders to find an adequate compromise for sustainable development. Several basic and applied research teams have demonstrated great effort and significant progress in studies involving recycling and reuse of a valuable diversity of industrial waste since the 1980s. The reduction in the cost of raw materials will undoubtedly contribute to combating the housing deficit and consequently for improvements in the precariousness of public health. This work presents in more detail a radical experiment that aimed to evaluate the performance of mortars with 100% fully recycled sand (AR), coming from construction and demolition waste (RCD), Class A, for an analogy with 100% natural sand (AN), coming from natural deposits. RCD recycling was carried out at the construction site, which minimizes the risk of contamination, being a more sustainable and economical alternative because it reduces transport expenses and consequently carbon emissions. Therefore, logistics must be optimized for each of the raw materials, that is, a waste management plan at construction sites.

KEYWORDS: recycling of inorganic waste, housing deficit, public health, sustainability of the planet.

RESUMO: Tendo em mente que um dos maiores desafios que a humanidade precisa resolver atualmente, e com urgência, é como garantir o desenvolvimento industrial contínuo e, ao mesmo tempo, preservar o meio ambiente, nosso objetivo neste trabalho é contribuir para que os líderes políticos encontrem um compromisso adequado para o desenvolvimento sustentável. Várias equipes de pesquisa básica e aplicada têm demonstrado grande esforço e progresso significativo em estudos que envolvem a reciclagem e a reutilização de uma valiosa diversidade de resíduos industriais desde a década de 1980. A redução do custo das matérias-primas, sem dúvida, contribuirá para o combate ao déficit habitacional e, conseqüentemente, para a melhoria da precariedade da saúde pública. Este trabalho apresenta mais detalhadamente um experimento radical que teve como objetivo avaliar o desempenho de argamassas com 100% de areia totalmente reciclada (AR), proveniente de resíduos de construção e demolição (RCD), Classe A, para uma analogia com 100% de areia natural (AN), proveniente de depósitos naturais. A reciclagem do RCD foi realizada no canteiro de obras, o que minimiza o risco de contaminação, sendo uma alternativa mais sustentável e econômica, pois reduz os gastos com transporte e, conseqüentemente, as emissões de carbono. Portanto, a logística deve ser otimizada para cada uma das matérias-primas, ou seja, um plano de gerenciamento de resíduos nos canteiros de obras.

PALAVRAS-CHAVE: reciclagem de resíduos inorgânicos, déficit habitacional, saúde pública, sustentabilidade do planeta.

1. INTRODUCTION

The world is experiencing serious ecological problems due to deforestation, forest fires, excessive emissions of polluting gases, the manufacture of common Portland cement (OPC) releases up to 1 metric ton of CO₂ emissions per metric ton of material produced, and current strategies to reduce this impact are insufficient, as demand continues to rise [1], pollution of river and sea waters and the severe urban problems caused by domestic, industrial and hospital waste, from demolition rubble and civil works, among many others. We started with civil construction because although it is not the most uncomfortable garbage, from the point of view of toxicity, it is frightened by its growing volume and requires immediate measures as it is considered one of the sectors with the highest demand for natural raw materials with 20 to 50% of the total mineral resources exploited in Brazil [2]. The discussion about the reuse of solid waste in the construction industry has always been closely linked to the questions pertinent to the formation of rubble, to the manner in which it would be disposed of, and to the economic importance that this sector represents for the Brazilian economy. The issue of resource rationalization is frequently debated by all developed and developing nations, due to the growing population demand and scarcity of natural resources. This is therefore a priority action that the sector must organize in a reasonably short time. In view of this, the construction industry should provide solutions that are equal to other industrial segments with regard to sustainable policies in order to reduce losses and waste [3].

According to the Brazilian Association of Public Cleaning Companies and Special Waste of the construction industry, it is the economic activity responsible for the largest share of municipal solid waste generated, representing 62% of the total [4]. The large amount of Construction and Demolition Waste (CDW) causes, concomitantly with environmental damage, financial burden for those who generate it and for the public sector, which bears the costs of locomotion and disposal of the final waste, which, in the majority of cases, are allocated in irregular landfills characterized by the total absence of environmental control [5]. With few areas available for the disposal of construction waste, the reduction of the environmental impacts caused by this rubble, focuses on the recycling and/or reuse of this waste.

Several research teams worked to minimize production costs while protecting the use of waste as raw material in the construction industry as a sustainable proposal [6-16].

Large solid waste generators need to make Building Waste Management Plans for submission to the municipal body responsible for urban cleaning for approval and viability of the enterprise, regarding transportation and proper destination in the Class A Landfill (Figure 1). On the other hand, the municipalities have the obligation to draw up their Integrated Plans for the Management of Construction Waste that must be added to the construction of recycling plants and to technical campaigns to expand their practice in the construction sites. This minimization in production costs will directly contribute to reducing the housing deficit and consequently to public health. Regarded as a social problem, the presence of homeless people occurs in virtually every country. Lack of housing usually results from adverse socioeconomic conditions, aggravated by health problems (alcoholism, psychological disorders, etc.) of the individual. The "Homeless, homeless, homeless, or homeless" is a person who does not have fixed housing, being their residence in the public places of a city, institutional shelters of non-profit associations or social solidarity institutions, often raising the question of the reintegration of the individual into the labor market.

There is generally a lack of consistent information on the volume of recycled aggregate generated in the country [17-21]. Depending on their chemical composition, these residues can be incorporated into mortars to replace the cement and/or small aggregate demonstrated in the sequence of this work.

Thus, in this work, the reuse of solid waste from civil construction, qualified as Class A, Resolution No. 307 of 2002 of the National Council of the Environment (CONAMA) in the composition of aggregates for the use of mortars of coatings and settlements, giving it an alternative use [22]. The performance of mortars with 100% fully recycled sand (AR), from construction and demolition waste (CDW), Class A, was evaluated for an analogy with 100% natural sand (AN), from natural deposits. Thus, to relate the two types of aggregates were prepared two traces of mortar for laying and coating, 1:2:6 and 1:2:9 in mass. Initially, the compositions of all raw materials were determined, including indices of soluble chlorides and sulfates in the (AN) and (AR) and afterwards in the traces of the mortars. After the particle size characterization of the aggregates the physical indices were analyzed: specific fresh mass, specific air dry

mass, specific apparent mass, specific apparent mass saturated, apparent porosity, water absorption, mixture water and theoretical air intake [23].

The mortars produced were characterized by index of flowtable consistency, density of mass, retraction and tensile strengths in bending and compression. The results showed that the two traces of the mortar evaluated, made up of 100% of (AR), Class A, can be used as an alternative for the substitution of (AN) in the production of mortar for laying and cladding masonry, besides conferring impermeability to the masonry, susceptible to the degradations of the weather with time, the mortar cladding is also used to maintain the acoustic comfort of the environment.

It should be noted that due to the large number of variables involved in the systems, many ABNT and ASTM standards, for example, established decades ago, facilitate the development of basic and applied studies, while sometimes requiring minor modifications for case studies.

We have also included numerous research groups that have made progress with cutting-edge technologies for detailed analysis of ancient mortar and Roman concrete of millennial durability, finding evidence about their preparation methodologies, thus opening the way for the increase of the useful life of all materials including those recycled in a globalized manner. The mechanistic and kinetic perceptions that involve each step of the process about the millennial durability of mortars and ancient Roman concretes will cease to be an enigmatic problem as they are tested through time and possibly some cautiously calculated statistical predictions can be released based on successive cumulative knowledge of nanoscience, nanotechnology and reverse engineering as has been the case until then.

2. MATERIALS AND METHODS

The environment used for the experiments was the Materials Science and Technology Laboratory – LCTM of the Department of Exact and Earth Sciences – DCET Ida UNEB. At COMED – Coordination of Soil Mechanics and Buildings and CEPED/SECTI LEC (physical and mechanical tests) and at the CEPED/SECTI Laboratory (analysis of all contaminations, including sulfates and chlorides). The raw materials (cement, hydrated lime, commercial sand and recycled sand), Figures 1 and

2, were analyzed in the laboratory of Optical Emission Spectroscopy Laboratory – ICP – OES of PARANAPANEMA.

Figure 1. Site – the waste was taken from several areas of construction and demolition of a building built in the late 1960s. Vitoria, Salvador, Bahia, Brazil



Source: Self-authored

The washed sands were filled with water from the public distribution network. Then, the waste was separated to fit the classification of (RCD), Class A, being carefully sampled and benefited. These samples were weighed and crushed (Figure 1a and 1b).

Figure 2. (a) Crusher. (b) crushed waste (CDW). (c) Ball mill. (d) Concrete mixer for mortar preparation



(a)



(b)



(c)



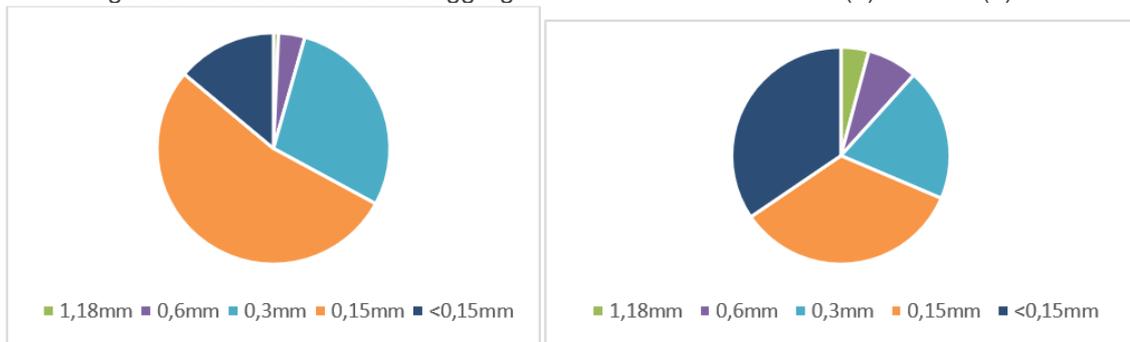
(d)

Source: Self-authored

After conventional crushing, the finest particles were submitted to a relevant function process, which consists of a ball mill (Figure 2c), where mixtures of the AR grains effectively reduce the most angular, irregular, rough and rough shapes, thus improving their workability due to the reduction of friction between the grains. When the traces of the mortar are prepared in the construction site itself, we have the concrete mixer (Figure 2d).

Figure 3 presents the characterization of the aggregate material in which a larger diameter for AR of 1.18 mm is observed while for ref sand. 63 de Menezes had a maximum 1.2 mm (1 mm = 1000 μm).

Figure 3. Characterization of aggregate material – Particle size: (a) AN and (b) AR



Source: Self-authored

The cement used in the work was the Portland CPI ABNT [24]. The chemical composition NBR 5742 (Table 1) [25]. Virgin lime and hydrated lime – Chemical analysis NBR 6473:2003 (Table 2) [26]. Hydrated lime used ABNT NBR 7175 05/2003 specifies the requirements for hydrated lime for mortars for civil construction (Table 3)[26].

Table 1. Compositions of Raw Materials

RECYCLED SAND (AR)		NATURAL SAND (AN)	
Al ₂ O ₃	4,66	Al ₂ O ₃	0,06
CaO	4,86	CaO	0,14
K ₂ O	0,70	K ₂ O	0,04
MgO	0,77	MgO	0,05
Na ₂ O	0,48	Na ₂ O	0,22
SiO ₂	79,00	SiO ₂	99,80

Source: Self-authored

Tabela 2. Requisitos químicos (em porcentagem em massa)

Acronym	Insoluble residue (RI)	Loss to fire (PF)	Magnesium oxide (MgO)	Sulfur trioxide (SO ₃)
CP I	≤ 5,0	≤ 4,5	≤ 6,5	≤ 4,5

Source: Self-authored

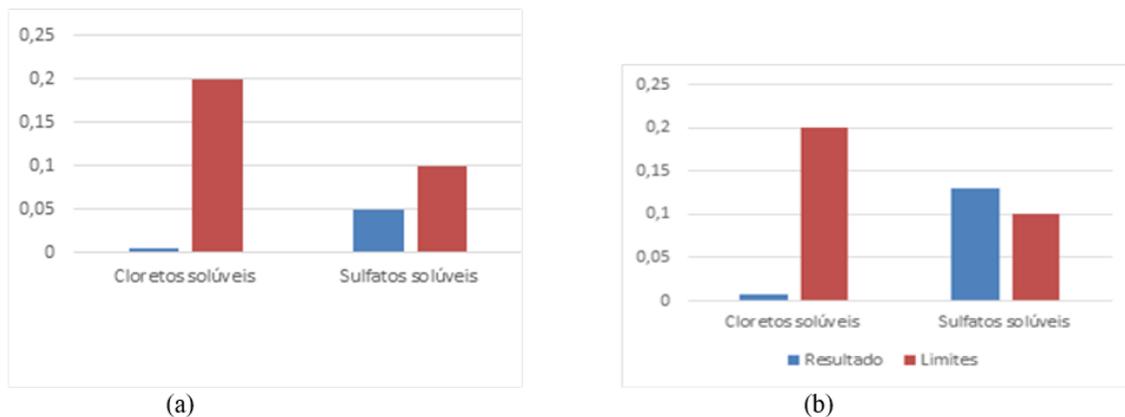
Tabela 3. Requisitos físicos mecânicos

Acronym	Class	Thickness	Handle start time	Hot expandability (mm)	Compression resistance (MP)			
		Sieve residue 75 µm			Um dia	3 dias	7 dias	28 dias
CP I	25	≤ 12,0	≤ 60	≤ cinco				

Source: Self-authored

As análises de cloretos e sulfatos foram realizadas com amostras secas a 105±5 °C, seguindo rigorosamente a ABNT NBR 9917:2009 [27], e quantificações dos cloretos e sulfatos solúveis conforme SWEWW 411OB nos Laboratórios da GETEL/SECTI [28]. Os resultados encontrados apresentaram-se em conformidade com as referidas normas, Figuras 4, 5 e 6.

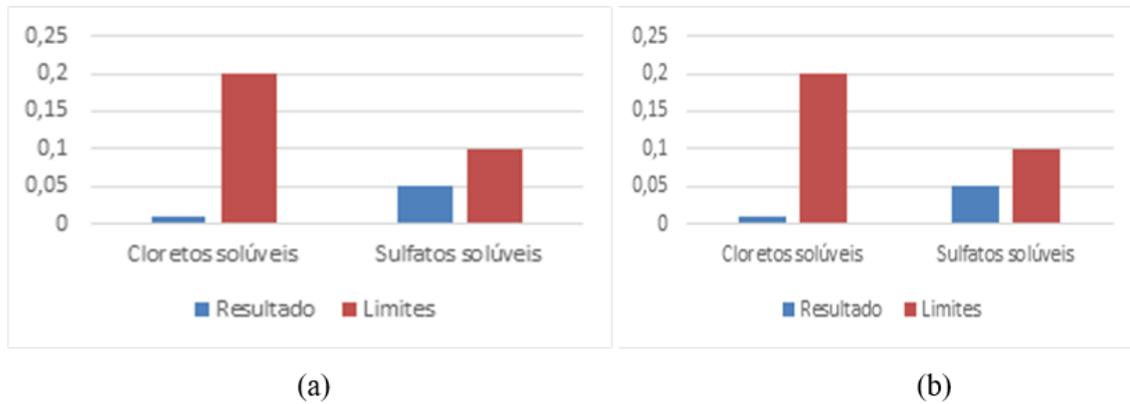
Figure 4. Chemical analysis of chlorides and sulfates in samples (a) natural sand (AN); (b) recycled sand (AR)



Source: Self-authored

In the (AR) the soluble sulfate was slightly higher than the norm, which was due to the heterogeneity of the sample, however in the 1:2:6 and 1:2:9 lines the results were satisfactory according to the same norm (ABNT NBR 9917).

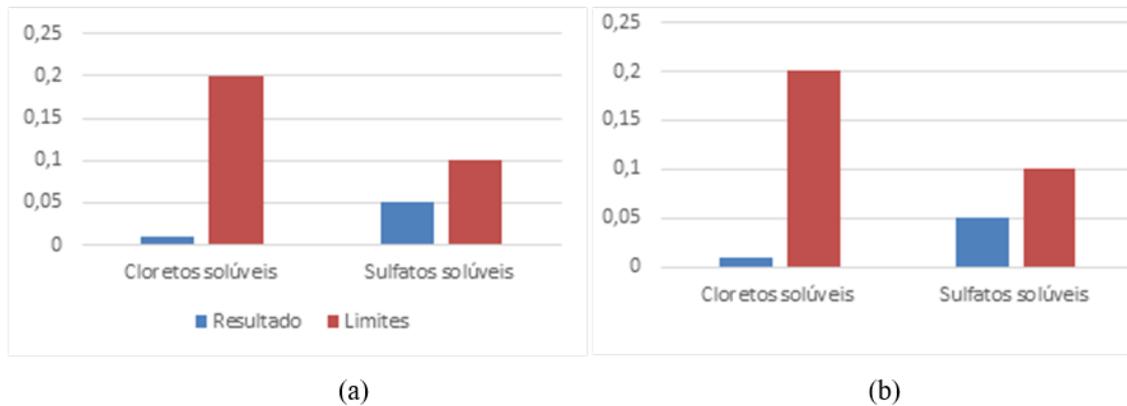
Figure 5. Presence of chlorides and sulfates, trace 1:2:6: (a) mortar consisting of (AN); (b) mortar with (AR)



Source: Self-authored

Thus, in Figure 6, the presence of chlorides in the 1:2:6 trace, both for mortar with natural sand (AN) and mortar with recycled sand (AR) was well below the tolerance limit.

Figure 6. Presence of chlorides and sulfates, trace 1:2:9: (a) mortar with natural sand (AN); (b) mortar with recycled sand (AR)



Source: Self-authored

The same is verified in the Figure for the 1:2:9 trace with natural sand (AN) and also with recycled sand (AR).

What ABNT NBR 9917 establishes, i.e. 'Maximum limits for expansion due to the alkali-aggregate reaction and chlorides and sulfates contents present in aggregates', is the same for cladding mortars, laying mortars and plain concretes, as mortars are almost always in contact with structural beams and columns [29].

Usually the armor remains long-term resistant to corrosive agents. However, there are some cases where the corrosion of the armor is quite rapid and progressive. More numerous faults have occurred in structures located on the seafloor, due to the

penetration of saline mist, which initially attacks by the coatings (mainly in the defects), penetrates the mass of the concrete, until it reaches the structure.

In the case of reinforced concrete, the preservation of an alkaline medium in the concrete is one of the fundamental requirements for the preservation of the embedded steel structures. It is assumed that the boundary for initiation of armor corrosion is located approximately 8 mm deeper than the neutralizing depth of alkalinity, measured by the use of phenolphthalein [30]. This would therefore be the limit of penetration of the ions and substances that potentialize the corrosion process during the useful life of the work. It is important to note that the occurrence of the corrosion phenomenon will depend on the binomial properties of the concrete cover and environmental aggressiveness. Marine or sulfur environments, for example, require the use of thicker and/or better-quality protective covers. In construction sites, the simplest, most practical and qualitative test can be used for chlorides, reacting to the sample with AgNO₃ solution[31]. The presence of sulfates in the sample is also quite simple and can be identified from the Barium Chloride Test for Sulfates Ions [32].

It is worth noting that no reference is made in this work on the use of sulfate-resistant Portland cement, according to ABNT NBR 5737, with the analyzes of possible mechanisms of the chemical reactions involved [33]. However, in that Standard, in section 4.2 on composition, two criteria are considered to be the most relevant: (a) cements with a CsC3A content of 8% or less and with a carbonaceous additions content of 5% or less of the mass of the total binder; and (d) 'cements with a history based on long-term test results or references to works demonstrably showing resistance to sulfates'. In addition, for Portland high initial strength cement (ABNT NBR 5737), for the specific purposes of that standard, the addition of blast furnace slag or dosing materials is allowed [33].

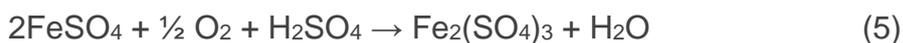
After presenting the most influential factors in the corrosive action of the HUDSON atmosphere, 1940 [34] classified the different atmospheres according to the relative corrosion of carbon steel. Corrosion and deterioration of concrete can be associated with mechanical factors (vibrations and erosion); physical (temperature variations); biological (bacteria) or chemical (chemicals with acids and salts). Among the most aggressive chemical substances are hydrochloric and sulfuric acids, which can act on mortars, cement slurry and aggregate, reaching as far as the carbon steel armature. The mechanism of chemical deterioration is associated only with the action

of chemical substances on the mortar for laying and coating, and on non-metallic components of concrete. However, with penetration, it can reach corrosion by electrochemical mechanism, this action occurs in the metal material, i.e. in the armor.

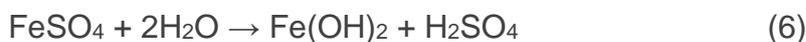
In the electrochemical mechanism, iron(II) hydroxide, Fe(OH)₂, is initially used as a corrosion product, and in an unaerated medium it is transformed into black or greenish Fe₃O₄. In the case of an aerated medium, the Fe(OH)₂ is transformed into iron(III) hydroxide, Fe(OH)₃, which is orange brown in color. Stainless steels can also undergo corrosion, as occurs with AISI 304 steel in the presence of chloride and acid medium. Chlorine quickly attacks stainless acid, as hydrochloric acid, HCl, is formed due to the reaction:

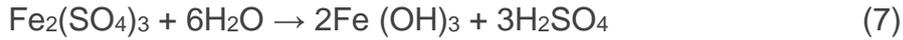


The acid rain, responsible for corrosion in metallic structures and in concrete, is due to the greater presence, generally, of oxides of sulfur, SO_x, and oxides of nitrogen, NO_x. As sulfur oxides are the most frequent pollutants and the main ones responsible for the corrosion of iron or its alloys, some authors have attempted to explain the mechanism of its corrosive action. Gentil, 2003 [35] shows the corrosive action of these oxides or acids by means of the following reactions:



FeSO₄, iron(II) sulfate or ferrous sulfate, and Fe₂(SO₄)₃, ferric sulfate or iron(III) sulfate, can react with water by hydrolysing and forming sulfuric acid again.





The sulfuric acid formed again attacks the iron, justifying the accelerated corrosive action due to this cyclic acid regeneration process. Mechanism also studied by Evans [36], Schikorr and Korr [37] presented the following possibility of attack:



Where ferrous sulfate hydrolyses:



And sulfuric acid attacks iron again:



However, FeSO_4 and $\text{Fe}(\text{OH})_3$ may still form insoluble basic iron sulfate, FeOHSO_4 , in the hydrolysis reactions.



Therefore, if the SO_4^{2-} ion is not gradually removed by leaching, by the removal of the corrosion product or due to the formation of insoluble basic iron sulfate, the process may become cyclic, as the sulfuric acid recovered in the hydrolysis reactions returns to the corrosive process forming an infinite amount of corrosion products.

NBR 6118 (ABNT, 2003) [38], prescribes in items 5, 6 and 7, respectively, the general requirements for the quality of the structure and the assessment of the conformity of the project, the guidelines for the durability of concrete structures and the design criteria for ensuring the abovementioned durability property of concrete structures and the design criteria for ensuring the said property.

It is important to emphasize that environmental influences must be foreseen and defined jointly by the author of the structural project and the owner of the work. It cites the aforementioned Standard that the environmental aggressiveness is related to the physical and chemical actions that act on concrete structures, independently of the mechanical actions, volumetric variations of thermal origin, hydraulic retraction and others foreseen in the dimensioning of these structures [39].

2.1. PRODUCTION OF MORTAR

It is verified that the lack of cladding in masonry is a constant in almost all neighborhoods of the city of Salvador, Figures 7 to 9.

Figure 7. Engomadeira neighborhood



Source: Self-authored

Figure 8. Engomadeira district



Source: Self-authored

Figure 9. Salvador. According to the Institute of Applied Economic Research (IPEA), Salvador is the Brazilian capital with the largest number of slum residents; according to the survey 'Cities in Motion: Challenges and Public Policies', which compares data from the 2000 and 2010 Census of the Brazilian Institute of Geography and Statistics (IBGE), 607 thousand people live in the so-called subnormal agglomerations in the capital of Bahia.



Source: Foto de Rômulo Faro.

In this study the mortars were produced using the mixing process described by NBR 16541 (ABNT, 2016) [40], which is used for the production of conventional mortars. This work aimed to evaluate the performance of mortars with 100% of fully recycled sand (AR), coming from (RCD), Class A, and with 100% natural sand (AN), with traces aiming at lower cement consumption for economic viability of the works and meeting the quality standards established by the ABNT. Then, four traces of mortar were analyzed for laying and coating, in a mass ratio of 1:2:6 (AN) and 1:2:9 (AR).

Since the early 1990s, large research teams from around the world have focused their attention on the use of mortar with recycled materials with various types of waste highlighting the RCD due to the large volume, but in addition to this we also have large number of mixtures containing various types of waste trying to solve regional sustainability problems that almost always result in case studies that may eventually happen, as examples for other municipalities or regions. In principle everyone is aware of the great heterogeneity of these materials, as to the nature of the raw materials, traces of cement: aggregate, several percentages of AR substitutions in NA (following from 5 to 100%), so with already debated problems as higher potential of water absorption leading to certain loss of workability, quite diversified granulometries, assuming that it would hardly be possible the same ratio a/c effective.

As only 100% of AN and 100% of AR were used in this work, obviously maintaining the same water demand used in the REF mixture (mixture without water compensation in the trace – SC) would be an impractical task. Instead of setting the consistency index at 260 ± 5 mm, according to NBR 13276 (ABNT, 2016) [41] the amount of water was experimentally defined by means of consistency tests (mixture with water compensation in the dash – CC). For the ratio of water/agglomerating traces it was considered that, given the high absorption rate of RCD, the use of the same water/agglomerating factor in traces with high amounts of residues could lead to mortars with discrepant consistency indices. To define the amount of water added to each mixture, the value needed to give each prepared mortar a spread of 240 mm (± 20 mm) was adopted, varying the water consumption according to what is necessary to meet this parameter (Figure 10).

2.2 MOLDINGS OF TEST FIELDS

The procedures adopted for making the test pieces consisted of: drying the materials in the open air; prior humidification of the aggregates. After making the cylindrical test bodies, 50x100 mm for determination of the compressive strength, hardened apparent mass density, water absorption, apparent porosity, according to ABNT NBR 13280 [42].

Figure 10. Test of flowtable consistency (mm) (a) and (b).



Source: Self-authored

Also, 40x40x160 mm prismatic test bodies were formed, according to ABNT NBR 13279:2005 [43] (Figures 11 a and b), to determine the capillary coefficient ABNT

NBR 15279[44] and the determination of tensile strength in bending and compression, ABNT NBR 13279[45]. With the mortars produced were coated panels of 80x100 cm and thickness of 2 cm, for tests of potential tensile strength adhesion, ABNT NBR 15258 [46]. For water retention by and observations of the emergence of fissures, according to ABNT NBR 13277 [47]. 24 hours were allowed for the specimens to be unmolded and submerged in buckets with water from the public distribution network.

Figure 11. Molded test bodies: (a) stroke 1:2:6; (b) stroke 1:2:9. Both with mortars 100% (NA) and 100% (AR)



Source: Self-authored

3. RESULTS

Figure 11 shows the molded test bodies: (a) dash 1:2:6; (b) dash 1:2:9. Both with mortars 100% AN and 100% AR. With the mortars in the fresh state, the density of mass, the incorporated air content and the water retention through the modified Büchner funnel were determined. The dry and saturated apparent specific masses (Table 4), as well as the absorption of water and apparent porosity were performed with prismatic test bodies strictly following ABNT NBR 13280 standards [48]. Fresh specific mass followed the test method of ABNT NBR 13278 [49].

It was found that there was a reduction in the specific masses of the mortars of those constituted with AN and AR, however both in the apparent saturated specific masses and in the apparent porosities if theoretical incorporated air these differences were relatively small between the two mortars in both the 1:2:6 and 1:2:9 lines and evidently considering the heterogeneity of the samples.

Figure 12. The adhesion test was performed according to NBR 15258, ABNT 2005 methodology [50]



Source: Self-authored

Table 4. Fresh specific mass, air dry specific mass, apparent real specific mass, saturated apparent specific mass, apparent porosity, and water absorption.

SAMPLES	*SPECIFIC FRESH MASS (kg/m ³)		SPECIFIC AIR-DRY MASS (kg/m ³)		APPARENT ACTUAL SPECIFIC MASS (kg/m ³)		SATURATED SPECIFIC APPARENT MASS (kg/m ³)		APPARENT POROSITY (%)		WATER ABSORPTION (%)	
	Traços		Traços		Traços		Traços		Traços		Traços	
	1:2:6	1:2:9	1:2:6	1:2:9	1:2:6	1:2:9	1:2:6	1:2:9	1:2:6	1:2:9	1:2:6	1:2:9
Natural	2.029	2.024	1.738	1.785	1.789	1.758	2.016	2.012	22,6	25,6	12,15	14,58
RCD	1903	1.927	1.606	1.684	1.655	1.582	1.949	1.933	25,6	24,6	14,86	21,81

Source: Self-authored

Table 5. Physical indices for potential tensile strength adhesion, flowtable consistency, mixing water and theoretical incorporated air

SAMPLES	POTENTIAL TENSILE STRENGTH (MPa)		FLOWTABLE CONSISTENCY (mm)		MIXTURE WATER (ml)		THEORETICAL EMBEDDED AIR (%)	
	Dashes		Dashes		Dashes		Dashes	
	1:2:6	1:2:9	1:2:6	1:2:9	1:2:6	1:2:9	1:2:6	1:2:9
Natural (AN)	0,29	0,3	253	239	280	227	1,8	4,03
RCD (AR)	0,31	0,4	255	240	360	250	1,5	4,13

Source: Self-authored

3.1 MECHANICAL STRENGTH TESTS

Figure 13. Compression test: positioning



Source: Self-authored

Table 6. Tests of resistance to axial compression and tensile strength at bending.

SAMPLES	AXIAL COMPRESSION RESISTANCE (MPa)		TENSILE STRENGTH AT BENDING (MPa)	
	Dashes		Dashes	
	1:2:6	1:2:9	1:2:6	1:2:9
Natural	0,29	4.1	0,40	0,38
RCD	0,31	4.5	0,44	0,39

Source: Self-authored

4. DISCUSSIONS

In Figure 3, referring to the characterization of the aggregated material, the AN shows a predominance in the particle size of 0.15 mm, followed by 0.3 mm and < 0.15 mm. In the air, it is noted that the majority of particles are < 0.15 mm, followed by 0.15 mm, 0.3 mm, 0.6 mm. Particles of more than 1,18 mm and finer than 75 µm were not detected and in order to avoid the inevitable risk of their recycling becoming impossible, the sands used and the traces of the mortars were discussed in detail, stating that the concentrations of chlorides and sulfates are within the standards established by ABNT NBR 9917:2009 [51].

Some generalized influences in relation to AR use have been analyzed since 1999 by Mesbah and Buyle-Bodin [52] as: the greater contraction of AR mortar generated greater porosity of the aggregates that influence the water migration mechanism. In this work the difference was not relevant. In the 1:2:6 trait, 22.6% were obtained for NA and 25.6% for RA. This fact is verified in our Table 4.

According to Silva, J.F, *et al* [53] in an experimental study of the physical properties of mortars produced with recycled aggregates of red ceramic waste using a trace, in volume, of 1,00:6,00, with the mass-dosed materials, for the definition of the amount of water added to each mixture, adopted the necessary value to give each prepared mortar a spreading similar to this work of 240mm (± 20mm), according to ABNT, and there is the possibility that a lower value of the consistency index has a better adhesion to blocks with lower porosity. Therefore, regarding this criterion, the four traces of the mortars presented in Table 4 of this paper can be used with degrees of confidence according to these standards.

According to Corinaldesi *et al.* in 2002 [54], mortar with recycled sand has excellent adhesion with blocks, attributable to the high quality of the interfacial area. The presence of recycled material reduces the elasticity limit value and remains low

for a long period of time, as shown by the rheological tests carried out by Moriconi *et al* (2003) [55]. This fact is seen in Table 5 of this study with the potential tensile strength values presenting better values with RCD with AR than for the same traits (1:2:6 and 1:2:9) with AN. In this way, the mortar can show better penetration into the surface of the block, evidently ensuring physical entanglement and consequently better adhesion. Also in Table 5 (Figure 10), the results for flowtable consistency with AR mortars showed values slightly higher than those with AN mortars.

Miranda and Selmo in 2006 [56] reported that in the control of the cracks likely caused by RCD AR, the capillary tension can be reduced by means of a design that controls, first of all, the finest materials in the mortar, the size of the distribution and the water/cement ratio whose methodology used was reported and justified also previously. One can perceive that there is an intrinsic relationship between all the variables of the system. In this work presented here, the existence of cracks or any other type of surface defect was not verified. Thus, continuing the discussion, Corinaldesi and Moriconi (2009) [57] evaluated the resistance of the bonding of mortar prepared with brick blocks, for resistance to compression and shearing. The results indicated that the bond and fracture resistance was slightly higher for AR mortars. According to the authors, this increase in binding force was justified by the higher quality of the interfacial zone and the possibility of the influence of mortars that have high CaO content both from the RA and from the hydraulic lime components of the 1:2:6 and 1:2:9 lines can be accepted. And in the absorption of water. In Table 6, axial compression resistance and tensile resistance at flexion (Figure 13) are represented for the same trait, the results obtained with AR were better than those of AN. The traces with cement, lime and aggregate as well as the amount of CaO from construction residues (Table 1) generally raise the index of Pozzolanic activity with significant increases in the resistance to simple compression of mortars over time. The literature shows that the best results for compression resistance are for absorption values below 7% (Table 4). Only for samples of 100%, similar to the example of this work the water absorption shows values greater than 7%. However, looking at the results of the other studies this absorption value of 7% is not uncommon in AR, especially if it results from a ceramic masonry. With regard to the tensile strength at bending, values $\geq 0,5$ are considered acceptable and even half of the mortars tested do not reach this reference.

Amorim *et al.* [58] have carried out very important work on recycling building waste for low-cost mortar production. Alternative mortars were prepared, in the 1:3 trace and, as agglomerator, pozzolanic lime, in compositions 30-70%, 40-60% and 50-50% of lime and pozzolana. The materials studied were two hydrated lime samples and four pozzolanic material samples. Carbomyl lime can be classified as calcium and Megaó as dolomitic. The samples of Pozzolanic material were: Debris 1, a civil construction sample, from the demolition of a residential house built 60 years ago and consisting mineralogically of quartz and calcite; Debris 2, a sample from the demolition of a church built 248 years ago made up of portlandite, quartz; Mixture, a sample of ceramic residue composed of 50% of bored bricks and 50% of tiles, used in constructions and acquired commercially, composed of quartz, hematite and mullite, and the sample of artificial pozzolana, obtained by heat treatment, around 700 °C from kaolinitic clay of sedimentary origin composed of quartz, kaolinite and mullite. Normal sand obtained by sieving according to Standard NBR – 7214 (ABNT, 1982) [59] and with the following chemical compositions was used: The samples Trunk 1, Trunk 2, Mixture and Pozzolana, presented the sum of the percentages of Si₂O, Fe₂O₃ and Al₂O₃, of 87.07%, 92.88% and 96.73%, respectively, whose values exceed the minimum value of 70% [60-61]. The percentage of MgO also meets the required maximum 5% value; thus, these samples meet the chemical specifications required by ASTM for a sample to be considered pozzolanic material.

Comparing the results of Simple Compression Resistance (SCR) obtained for the mortars studied for 28 days of curing, with the specification of ABNT (RJ), NBR-13281 [62] these can be classified as Type I mortars, because they meet the resistance limit between 0,1MPa and 4,0MPa. Samples from this paper are also framed in Type I with values of 0.31MP and 4.5 MPa for the residue mortars 1:2:6 and 1:2:9 respectively (Table 6).

It is observed in the graphs presented for the Simple Compression Resistance (SCR) as a function of the curing time of the mortars studied by L.V. AMORIM and col. [58], i.e. those of Envelope 1, Envelope 2, the Mixture and the Posolana, that the latter always presented the highest values, then the Mixture, Envelope 1 and Envelope 2, for the 3 compositions of lime and posolana (A) 30-70%, (B) 40-60% and (C)50-50%. However, after 28 days the slope of the curve of the Posolana mortar is greatly reduced becoming practically parallel to the axis of the abscissas, i.e. the (RCS) becomes

practically constant with values of 4.5MPa and 3.5MPa for the composition of lime and posolana (B) 40-60% and (C) 50-50% respectively. While the inclination of the other samples mixture and the Trunks 1 and 2 increase significantly with the curing time up to 60 days, it can probably be extrapolated for a certain time depending on the mechanism and kinetics of each step involved in the process. It should be noted that the sample of the Ceramic Waste Mixture that presented the best results is composed of 50% of hollowed bricks and 50% of tiles, used in construction and acquired commercially corresponds mineralogically to quartz, hematite and mullite. In the study on Recycling of Civil Construction Waste for Mortar Production of Menezes and col. [63], the RC-03 sample, which had the lowest Pozzolanic activity index of less than 2 MPa, was attributed to the small amount of material originating from the remains of ceramic blocks and tiles. In the same study by Menezes [63], three civil construction residues, identified by RC-01, RC-02 and RC-03, were used in the preparation of mortars, sawdust from RG granite, calcium hydrated lime, CH-I [26-a] and sand with a maximum diameter of 1,2 mm (normalization [26-b]) and fineness module of 0,36 % (normalization [26-c]).

The four mortars were prepared with a 1:3 mark (one part lime and three part sand), similar to that of Amorim and col. [58], using a water/binding factor of 0,48. The residues were incorporated with contents of 25, 35 and 50%. All residues have levels of SiO₂, Al₂O₃ and Fe₂O₃, exceeding the minimum value of 70% required in normalization and that the loss to fire, less than 10%, also meets the requirements. As regards the MgO and alkali levels in Na₂O, which are established by normalization as maximum 3 and 1,5%. The residues also have low levels of alkali and alkaline earth oxides and present as crystalline phases, quartz, mica, feldspar and calcium carbonate, the residues have a high fraction of particles with dimensions of less than 45 µm, the substitution of the agglomerant by the residue in the production of mortars can be successfully carried out at levels of up to 50% and the residues with pozzolanic activity provide increases themselves.

Table 7. Simple Compression Resistance (SCR) tests with 1:3 lines (one part lime and three part sand)

SAMPLES	SIMPLE COMPRESSION RESISTANCE (MPa) 28 days of cure 50% waste	SIMPLE COMPRESSION RESISTANCE (MPa) 60 days of cure 50% waste
RG	4,5	6,0
RC-01	18	21
RC-02	7	12
RC-03	5,5	6
Convencional	4,5	5

Source: Menezes *et al.* [63]

Interestingly, between 28 and 60 days of maturation the inclinations of the Conventional sample and RC-3 become small almost parallel to the axis of the abscissas, that of the RG (granite sample) similar to that of the RC-01 sample, and the RC-02 shows the largest inclination of the 5 samples. The value obtained by the RC-01 sample for 28 and 60 days of maturing were the largest presented until then in the references of this work.

The 4,5 MPa Simple Compression Resistance (SCR) presented by the conventional sample [63], 1:3 stroke (one part lime and three part sand), was equivalent to that of Amorim E Col. [58] and this work for the 1:2:9 trace with 100% recycled sand and 4.5 MPa (Table 6) with sands with a maximum diameter of 1.2 mm. It seems that these mortars are the least costly since both the agglomerating agent and the sand can be replaced by waste.

The incorporation of granite residues (RG) and RC-03 in place of lime does not lead to improvements in the mechanical performance of the mortar produced. Studies had already indicated that the RG residue does not have pozzolanic activity, as mentioned by Menezes and col. [63] however, other work [64] has shown that granite residues when used in concrete and mortar produce refining in the pore structure, filling the pores and reducing the space available for water, lodge between grains of the aggregate, contributing to a densification of the transition zone (matrix-aggregate) and the agglomerating matrix. Thus, it is believed that the RG residue acted in a similar way to the RC-03 residue in the mortar produced, as a filler. According to T. C. F. Guimarães *et al.* [65] Here in Bahia we have large reserves of granite and consequently with excellent employment for its waste as well as our ceramic pole factories that use or will use our red clays [65].

In 2015 E. Garcia *et al.* [66] deepened their knowledge about the cemented properties of CVR, focusing on the pozzolanic properties of eight samples collected in

ceramics representative of four of the main poles of São Paulo, and their relations with the compositions of the raw materials used and with the burning temperature. The ceramic residues, after controlled grinding, have been shown to be suitable for use as a pozzolanic additive for Portland cement. The samples tested had an average consumption of 500 mg Ca(OH)₂/gram of sample in the Chappelle Assay, exceeding the minimum standard value by 14.7%. The highest reactivity observed is in the range of burning temperature between 700 °C and 800 °C. This interval of greater reactivity corresponds to the levels of burning customary practiced in the red ceramic companies, which corroborates the potential for making use of their residues as a mineral addition, making the RCV can constitute a new source of Pozzolanic material for the cement sector in the country. And, reinforcing the work of GARCIA1 and col. [66] we have the research conducted in 2021 by the team of T. C. F. Guimarães *et al.* [65], with the study of the physical and mechanical properties with the chemical composition of red clays of the State of Bahia [65].

As regards the values of specific areas, determined by the Blaine Permeameter method, pozzolanic material samples and lime samples [58], Pozzolana was the sample with the largest specific area, followed by Mixture, Rubble 2 and Rubble 1 samples. The Carbomil lime presented a specific area of 1,222 m² g⁻¹, while the Megaó lime presented a greater specific area compared with the previous one, of 1,738 m² g⁻¹e, due to its greater contact surface is probably the most reactive. However, although the specific area of a lime is one of the most important factors among its physical properties as a building material, it cannot be taken as the sole criterion of selection and quality. For example, the result presented by the mineralogical characterization was adopted the Carbomil lime as a single sample for the development of the other stages of this study, due to the MgO content, which, in Megaó lime, is present in high quantity, resulting in a slower hydration, occurring simultaneously with carbonation. Thus, the hydration stage can take place in a delayed way, after application, causing an increase in volume, which compromises the mortar, through the emergence of fissures and breakdowns, Guimarães and Cincotto, 1985 [67]. If magnesium is immersed in a vitreous matrix in the residue it will not interfere in the application of the residues for mortar production, however, if it can hydrate and form expandable phases, it may compromise the use of the residues for this purpose, already discussed [65-66].

In 2021, A. C. A. Jantsch *et al.* [68], they discussed the importance of the durability and useful life of buildings, aiming, besides safety, to the search for sustainability and rationalization of construction processes. Study of the evaluation of the behavior of coatings in stabilized mortars submitted to surface treatment with crystallizing additives contributes to the reduction of water absorption and to the increase of mechanical resistance and possible suitability of the material to the normative requirements when necessary.

There is the inclusion of a diversity of other types of waste that generate more complex, in the majority of cases immediate, inevitably targeting very challenging problems involving public health, as well as the growing scarcity of natural resources. Some universities located in these regions have constantly contributed to the entire scientific community [69-75].

In one study, Almeida Camargo *et al.* [76], they manufactured many mortars by adding a mixture of industrial waste as a substitute for the finely used aggregate in construction materials (sand). The purpose of this work was to improve the productivity and lightness of an industrial mortar for sink sheet. An ideal mixture containing about 30% by volume of textile exhaustion was obtained, and this provided the best compromise between adhesion, lightness and ordinary mechanical strength (1.0 MPa minimum).

The direct method of determining the lime content fixed by pozzolanic activity optimizes the interaction of the mineral addition with calcium hydroxide by performing the test in solution under agitation, as the reaction is accelerated by the high temperature (90 ± 5 °C). Thus, there is potentialization of the Pozzolanic activity and the consequent consumption of lime becomes an indication of the potential, maximum reactive of the mineral addition. The NBR 15.895 standard for determining the Pozzolanic Activity Index (PPI) with lime, as established by NBR 5.751[77], is not suitable for the hierarchization of high reactivity Pozzolanic mineral additions, given the probability of lime exhaustion during the test period. The exhaustion of portlandite ceases the pozzolanic activity and consequently the reactive potential of the mineral addition is underestimated, despite meeting the criterion established in NBR 12.653 [78] for classification as pozzolana. The particle volume ratio indicated in NBR 5.751 should be modified when characterizing high reactivity mineral additions to reduce the mineral/portlandite addition ratio in order to keep residual lime content available at the end of the test. The availability of portlandite at the end of the test is indispensable for

other intervening factors to be addressed in anticipation of further improvements in the IAP evaluation methodology with lime, such as the influence of the specific area of mineral additions, reaction kinetics depending on the mineralogical composition of the characterized material and the use of a dispersing additive to keep the water/binder ratio of mortars constant [79].

However, Medina [80], when assessing the lime binding capacity of a sample of metakaolin, with a specific BET area of 32,7 m² g⁻¹ and average particle diameter of 9,05 μm, obtained the consumption of 999 mg Ca(OH)₂/gram. And the fixed lime content was lower than that determined in the sample from another study, although this had a smaller specific BET area (23.26 m² g⁻¹) and a larger average particle diameter (15.92 μm). Such behavior indicates that the ability to fix lime does not depend solely and exclusively on the physical characteristics of Pozzolana, i.e. the chemical composition and the content and composition of the amorphous fraction are also relevant for Pozzolanic activity.

Rodríguez and col. [81], they used recycled mixed aggregates (RMA) in the preparation of non-structural pre-molded concrete. For this, different percentages of natural aggregate were replaced by RMA in non-structural elements (25, 50.75 and 100%). The levels of cement, water and dosages commonly used by companies were not changed with the introduction of RMA. They carried out specific tests of resistance to compression and bending, water absorption, dimensional tolerances, resistance to abrasion and to slipping. The stability of the properties tested confirmed the possibility of using this waste on an industrial scale meeting the standard requirements. They also noted that the acquisition of resistance is slower with the addition of AMR. for most substitution percentages being significantly higher after 360 days than after 28 days. The authors admitted to being due to a self-healing effect that could be produced by absorbing water that commonly undergoes recycled aggregates. And the team of Luiz A., [82] evaluated the "recyclability" of ground glass waste, collected in the municipal service of the interior of Portugal, and some red clay ceramic waste as a replacement of mortar cement and concrete. A basic experimental study of the physical and mechanical properties of mortars containing red clay and glass waste recycled as Pozzolano material provided the following results and conclusions: Among the types of red clay ceramic waste studied here, only tile residue powders have Pozzolanic reactivity potential. That is, they concluded that the temperature of the brick furnace,

lower than that used in industrial roofing, does not confer pozzolanic properties on this kind of Portuguese industrial waste. The determination of the oxide composition of the selected glass and samples of waste indicates that, according to NP EN 450 [83], the glass meets the basic chemical requirements for a pozzolane. However, it does not meet the additional alkaline content requirement due to the high percentage of Na₂O in the glass. Despite this situation, finely ground glass powders, exceeding 250 m² k⁻¹g⁻¹ of Blaine's specific surface, had very high Pozzolanic activity. This means that fineness provides potential activity. In terms of the amount of cement replacement, 30% of the cement can be replaced by frosted glass waste of 45-75 μ m range in mortar or concrete without any harmful effects caused by the alkali-silica reaction induced expansiveness. The results presented in this article show that there is great potential for the use of glass waste in mortar and concrete as a partial replacement of expensive materials, such as active silica, fly, ash and cement.

According to Ahmed Al Shouny [84], sustainable concrete selection plays a significant role in achieving sustainability principles in green buildings. This article aimed to develop a sustainable concrete selection decision making model (SCSDMM) to support the selection of the best sustainable concrete material. The research included the identification and use of six criteria as a basis for comparing nine sustainable concrete mixtures available in Saudi Arabia and Egypt as case studies for applying the model. The SCSDMM used concepts of fuzzy logic to assess the weights of the criteria and the AHP technique to support decision makers dealing with sustainable concrete to select appropriate alternatives based on the effect of many criteria. In relation to the results obtained in this study, the specific conclusions can be summarized as follows:

- compression resistance and low water absorption were the most important criteria, followed by low environmental impact, while tensile strength and the importance of the availability of recycled materials were ranked as the lowest;
- the availability of recycled materials and cost savings in Egypt were more important than in Saudi Arabia. On the contrary, low water absorption and low environmental impact in Saudi Arabia were more important than in Egypt;
- RNP and FRNA were desirable for use in KSA, while CRCA was not recommended. In Egypt, SF and FRCA could be used preferably, while GGFS

was not approved. On the other hand, FRCA, CRCA and SF were supported to be used more in Egypt than in Saudi Arabia;

- as for the sensitivity analysis, there were no imperative variations in the model results due to the change in the weights of the criteria. Although there have been reasonable changes in the relative weights of the alternatives, the final decision remains unchanged, reflecting the insensitivity of the model.

Ancient Roman concretes are known to have survived millennia, and excellent studies have been carried out [85-87]. However, mechanistic perceptions about its durability remain an enigma. The resulting extended life span, combined with a reduction in the need for extensive repairs, could therefore reduce the environmental impact and improve the economic life of the modern cement construction cycle. Here, Linda M. Seymour and col. [88] studied mechanistic insights into the durability of ancient Roman concrete, using a multiscale correlative chemical and elemental mapping approach to investigate relic lime clasts, an ubiquitous and illustrious mineral component associated with ancient Roman mortar. Together, these analyzes provide new insights into mortar preparation methodologies and provide evidence that the Romans employed hot mixing, using quicklime in conjunction with, or instead of, slaked lime, to create an environment where limestone clasts of large surface area are retained within the matrix mortar. Inspired by these discoveries, it was proposed that these macroscopic inclusions could serve as sources of reactive calcium for long-term pores and cracking filling or post-Pozzolanic reactivity within cemented constructions. The subsequent development and testing of modern cement mixtures containing lime clast demonstrate its self-healing potential, thus paving the way for the development of more durable materials, resilient and sustainable concrete formulations.

Stressing that the mechanistic and kinetic perceptions involving each step of the process about the millennial durability of mortars and ancient Roman concretes will cease to be an enigmatic problem when tested over time. It should be noted that regardless of the application, strict specifications for the raw materials were detailed by the ancient scholars Vitruvius and Pliny, especially for limestone, which should be pure white, so as not to have impurities [89]. Previous studies on Roman architectural mortars determined that calcined lime in these samples often contained < 5% by weight of oxides in addition to CaO [90].

In the south of Bahia, in the municipalities of Mascote, Itamaraju, Belmonte, Nova Viçosa, Mucuri, Santa Luzia, Prado, Alcobaça, Camaçã and Canavieiras, there are several semiplastic clays of the primary or formational kaolin type, in mines or deposits, with the expectation of medium to large size reserves, with mineralogy estimated with a majority in %weight of kaolinite, among quartz, micas and others, and whose chemical composition $\leq 5\%$ in weight of oxides besides CaO. As well as plastic clays of the formational type or floodplain, usually in deposits followed by deposits [91].

5. CONCLUSIONS

In this work, the use of recycled sand (AR) from construction and demolition waste (CDW) was evaluated for the production of mortar for laying and coating. From the experimental results and discussions, the following conclusions can be drawn:

- first, analyzes of contaminants in raw materials such as chlorides, soluble sulfates and carbonates are unavoidable because they can prevent any re-use of waste;
- the particle sizes between the AN and AR since work have not been very differentiated. The AN shows a predominance in particle size of 0,15 mm followed by 0,3 mm and $< 0,15$ mm. In the air it is noted that the majority of particles are < 0.15 mm, followed by 0.15 mm, 0.3 mm, 0.6 mm. No particle sizes greater than 1,18 mm or finer than $< 75 \mu\text{m}$ called powder were detected;
- the continued use of the ball mill immediately after crushing significantly reduced the effects on recycled aggregates as to the more irregular, angular shape, porous surface with rough and rough texture, and the improvement of the texture as regards the presence of mortar adhering to the grains;
- the results of the tests of potential resistance to adhesion attraction as well as those of flowtable consistency were better for AR mortars than for those made with AN;
- for the same trace (1:2:6 and 1:2:9) the results of the axial compressive strength and tensile strength at bending tests obtained with the AR were better than those of AN;

- on the average of the axial compressive strength and tensile strength tests on bending for mortars with 1:2:6 lines were higher than in the 1:2:9 line, but the second one has greater economic viability;
- no cracks were detected, possibly due to the size of our thinnest materials smaller than 0.15 mm. Usually the use of the fine fraction (75 μm) of mixed AR in mortars, although it does not affect the mechanical properties, contributes to a greater emergence of cracks, and it is indicated that the content of these fines should be limited by 25%;
- as we are dealing with studies referring to new materials for possible substitutions of the traditional acquaintances already tested for a long time, we now have, besides the growing scarcity of natural resources, the urgent need for the recovery of various types of waste for the recovery of regions that cause direct damage to public health. These are the biggest challenges for the universities closest to each municipality with degraded areas;
- studies aimed at future standardization of the ABNT should be carried out in parallel by research teams, with more similar materials possible, including only RCD that evidently have smaller numbers of variables, and preferably using mixtures cements /aggregates with between 1,00:3,00 and 1,00:4,00 that guarantee in advance good physical and mechanical results mainly those of resistance to axial compression and tensile resistance in flexion. Smaller AR substitutions by AN is probably also a safer path for ABNT standardization. Of course users will have greater credibility and will be a lever for sustainability;
- the results showed that the two traces of the evaluated mortars made up of 100% of (AR), Class A, can be used as an alternative for the substitution of (AN) in the production of mortars for laying and coating masonry;
- the Simple Compression Resistance (SCR) 4.5 MPa presented by the conventional sample of Menezes and col. [63], stroke 1:3 (one part lime and three-part sand), was equivalent to that of Amorim and col. [61] and this work for the 1:2:9 trace with 100% recycled sand and 4.5 MPa (Table 6) with sands with a maximum diameter of 1.2 mm. Possibly these mortars are the most cost-effective because both the binder and the sand can be replaced by waste;
- it seems that the mortars with the highest amount of CaO from the waste with the recycled sands (AR) of this work, as well as other substitutions of the fine

aggregate or the agglomerant by residues in the traditional mortars, show higher indices of Pozzolanic activity. It has been found by several authors that these reactions are slow, and increase significantly with time as shown through graphs of the dependence of Simple Compression Resistance (SCR) over time;

- alternative mortars have a satisfactory mechanical performance, and waste recycling is very promising, capable of producing low-cost building elements, in addition to preserving the environment, improving the quality of life of the general population and consequently public health;
- despite the numerous variables included in the processes cited, few generalizations can be completed. Thus:
- despite the similarity of the mineralogical characteristics of some residues studied, it appears that the content of reactive material can vary significantly according to each type of waste;
- amorphous materials or materials with a high degree of crystalline disorder are difficult to identify and quantify through traditional mineralogical analysis techniques, and the need for technological study to be developed in parallel with mineralogical analysis in order to accurately assess the Pozzolanic character of the waste from construction;
- the particle size ratio indicated in NBR 5.751 should be changed in the characterizations of high reactivity mineral additions to reduce the mineral addition/portlandite ratio to keep residual lime content available at the end of the test;
- in the IAP evaluation methodology with lime, cautious researchers have recently verified the need to introduce some criteria such as: (i) the influence of the specific area of mineral additions, (ii) the reaction kinetics depending on the mineralogical composition of the characterized material, (iii) the use of dispersing additive to maintain the water/mortar binders ratio constant, (iv) the ability to fix lime does not depend solely and exclusively on the physical characteristics of pozzolana, but mainly on the chemical composition and the content and constitution of the amorphous fraction relevant to Pozzolanic activity;
- not all residues have dosing activities, but can be used as a filler, avoiding cracks and resulting in further improvements in mortars as verified by several authors cited here;

- finally, the residues from all countries must be carefully analyzed, and those that, in the majority of them have dose-related activities, can be recycled easily with the collaboration of other teams that have undoubtedly already carried out equivalent studies, either in total or partial substitution of the agglomerates and/or fine aggregates, possibly with adjustments in the composition of the raw materials, of the granulometries, in the manufacturing process, etc., in an attempt to follow the pre-established STANDARDS for each of the countries;
- emphasizing that the mechanistic and kinetic perceptions involving each stage of the process about the millennial durability of mortars and ancient Roman concretes will only cease to be an enigmatic problem when tested over time. And for every increase in the useful life of a material we will always have a commemoration of our efforts;
- the collaboration of federal or government political leaders, as well as private initiatives, is fundamental for globalized sustainability.

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CHAPTER 2

URBAN BIRDFAUNA IN DIORAMA, STATE OF GOIÁS

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ABSTRACT: Urban birds in Diorama, state of Goiás. The urban avifauna of the north-western mesoregion of Goiás is currently poorly known. Therefore, this study analysed the specific composition, richness, trophic niche and influence of the tree density variable on the birds of Diorama, at nine point counts in the municipal urban network. The data was obtained from visits between March and September 2023 (N=6), between 7:30am and 9:30am, totalling 12h. 61 species from 25 families were recorded, with Psittacidae (8 species), Columbidae, Tyrannidae and Thraupidae (all with 6) being the families with the greatest richness. The Black-throated Saltator *Saltatricula atricollis* (Vieillot, 1817), a species endemic to the Cerrado, was recorded at a point at the entrance to the urban network. The estimated richness Jackknife₁=77.67 showed that 78.5 per cent of the expected species were recorded, a marginally satisfactory result, perhaps due to the few visits made to obtain the data. The distribution of species in trophic niche categories showed a predominance of invertivores and omnivores, as expected for urban birds. Bird richness and tree density were positive and significant ($r_s=0.700$, $p<0.05$), and it is likely that afforestation influences bird richness. We recommend maintaining cultivated plants in order to conserve bird richness in the municipal urban network. Future studies will certainly reveal new aspects about birds in these anthropogenic environments in and around north-west Goiás.

KEYWORDS: Aragarça's microregion, community ecology, specific composition, afforestation.

RESUMO: Aves urbanas em Diorama, estado de Goiás. A avifauna urbana da mesorregião noroeste de Goiás é pouco conhecida atualmente. Portanto, este estudo analisou a composição específica, a riqueza, o nicho trófico e a influência da variável densidade de árvores sobre as aves de Diorama, em nove contagens pontuais na malha urbana municipal. Os dados foram obtidos em visitas entre março e setembro de 2023 (N=6), entre 7h30 e 9h30, totalizando 12h. Foram registradas 61 espécies de 25 famílias, sendo Psittacidae (8 espécies), Columbidae, Tyrannidae e Thraupidae

(todas com 6) as famílias com maior riqueza. O Saltador-de-garganta-preta *Saltatricula atricollis* (Vieillot, 1817), uma espécie endêmica do Cerrado, foi registrado em um ponto na entrada da rede urbana. A riqueza estimada Jackknife1=77,67 mostrou que 78,5% das espécies esperadas foram registradas, um resultado marginalmente satisfatório, talvez devido às poucas visitas feitas para obter os dados. A distribuição das espécies nas categorias de nicho trófico mostrou uma predominância de invertebrados e onívoros, como esperado para aves urbanas. A riqueza de aves e a densidade de árvores foram positivas e significativas ($r_s=0,700$, $p<0,05$), e é provável que a arborização influencie a riqueza de aves. Recomendamos a manutenção de plantas cultivadas para conservar a riqueza de aves na rede urbana municipal. Estudos futuros certamente revelarão novos aspectos sobre as aves nesses ambientes antropogênicos no noroeste de Goiás e arredores.

PALAVRAS-CHAVE: microrregião de Aragarça, ecologia de comunidades, composição específica, arborização.

1. INTRODUCTION

Understanding the effects on biodiversity in urban areas is essential for establishing effective conservation measures, despite each city possessing a unique and complex system of occupation (Marzluff; Bowman; Donnelly, 2001; Marzluff, 2017). In this context, birds are frequently examined in urban ecological research, as they are excellent indicators of the city-ecosystem tension (Macgregor-Fors; Escobar-Ibáñez, 2017). The conservation of urban birds also supports the preservation of biodiversity, promoting well-being for inhabitants and, typically, the conservation of biological resources (Platt; Lill, 2006; Fontana; Burger; Magnusson, 2011).

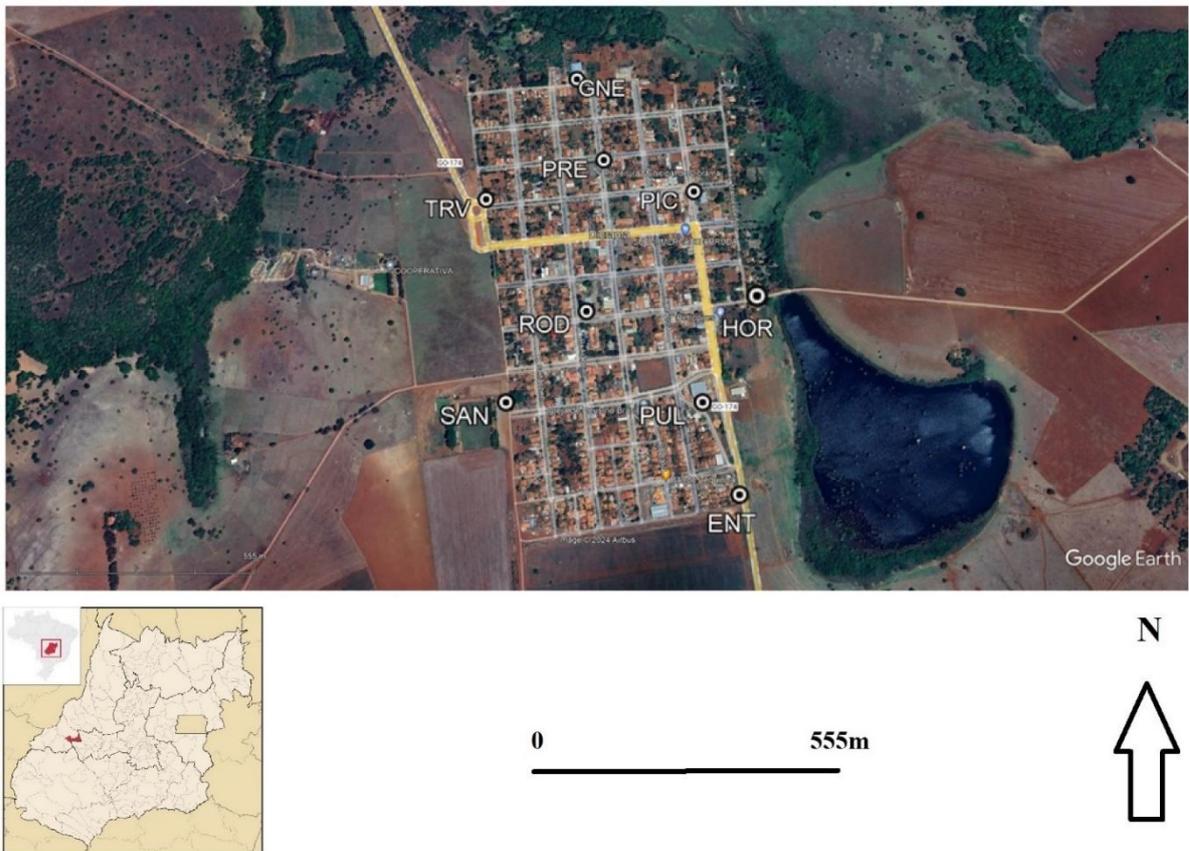
In Brazil, significant studies on birds have been conducted in various urban areas (Fontana; Burger; Magnusson, 2011; Reis; Lopes-Ibórra; Pinheiro, 2012; Alexandrino *et al.*, 2013; Sacco *et al.* 2015; Moura; Moura; Machado, 2018; Ferreira *et al.*, 2020; Navega-Gonçalves; Trevisan, 2021; Valadão *et al.*, 2022). These studies generally assessed species composition and assembly structure and proposed conservation measures for each studied avifauna.

However, to date, only one study has analyzed urban birds in the northwestern mesoregion of Goiás (Cardoso *et al.*, 2022). Thus, this work evaluated species composition, richness, trophic niche, as well as the relationship between tree density and avifaunal richness in Diorama, a municipality in northwestern Goiás, across nine different points distributed throughout the municipal urban grid.

2. MATERIAL AND METHODS

Study Area. This work was conducted in the urban grid of Diorama (Figure 1). The municipality is located in the Northwestern Mesoregion of Goiás and the Aragarças Microrregion, with an estimated population of 2,062 inhabitants (IBGE, 2022), situated 258 km from the capital, Goiânia (<https://br.distanciacidades.net/distancia-de-goiania-a-diorama>), and bordered by the cities of Montes Claros de Goiás, Iporá, Jaupací, and Arenópolis (Prefeitura de Diorama, 2024).

Figure 1. Geographic location of the municipal urban grid of Diorama, state of Goiás, Brazil, highlighting the nine counting points. ENT: entrance on the side of the GO-174 highway; PUL: Uesdar de Jesus Lima square; SAN: SANEAGO water treatment plant; HOR: horticulture; ROD: municipal bus station; PIC: catholic church square; TRV: GO-174 interchange; PRE: city hall; GNE: sports gym.



Source: Abreu (2023) and Google Earth Pro (2024).

The urbanized environment of the municipality is bordered by the “Rio dos Bois” to the north, along with an eastern tributary stream that supplies a large artificial water reservoir (dam) on private property (Figure 1). The municipal urban grid is also surrounded by pastures of *Urochloa* sp. grass, temporary crops of *Glycine max* L. Merryll (soybean) and *Zea mays* L. (corn), as well as remnants of native riparian forests and cerrado *sensu stricto* (description of the physiognomies of Cerrado according to Oliveira-Filho; Ratter, 2002).

The urban grid of Diorama features numerous residences, squares, and open spaces with fruit-bearing plants, including various species of palms (Arecaceae), mango trees (*Mangifera indica* L.), cashew trees (*Anacardium* spp.), and tangerines (*Citrus reticulata* Blanco). There are also many ornamental plants of the species *Moquilea tomentosa* (Benth.) Fritsch (Figure 2).

Figure 2. Detail of the “Rodoviária (ROD)” counting point. Mango tree *Mangifera indica* L. in bloom at “Colégio Dona Eva”, plus guariroba palms *Syagrus oleracea* (Mart.) Becc. 1916 in the square and surroundings.



Author: D. Blamires, 06-17-2023.

Nine counting points were established in the area (Figure 1). Tree density (TD) was estimated on a categorical scale within a 50m radius of each point (Fontana; Burger; Magnusson, 2011): 1 (4-8 individuals), 2 (9-14 individuals), 3 (15-20 individuals), and 4 (>20 individuals), with trees defined as any plants taller than 2m (Table 1).

Table 1. Tree density (DA) and species richness (S) categories for each counting point in the urban area of Diorama, Goiás state. See text for further details.

Points	Abbreviation of points	DA	S
Municipal bus station	ROD	3	25
Horticulture	HOR	4	37
SANEAGO Station	SAN	3	28
Plaza Uesdar Lima	PUL	1	23
Square of the Catholic Church	PIC	2	25
Trevo GO-174	TRV	3	27
City Hall	PRE	2	28
Sports Gym	GNE	4	29
GO-174 Input	ENT	1	27

Source: Authors, 2024

Methods. Data were collected through six visits from March to September 2023 (N=6), between 7:30 AM and 9:30 AM, totaling 12 hours of activity. Each visit was preceded by a draw to determine the starting point and the direction of sampling (Aleixo; Vielliard, 1995). The method employed for avifaunal inventory was point count

(Bibby *et al.*, 2000), with a ten-minute stay (10 min) at each counting point to record all species seen or heard, within a detection radius of 50m from the researchers. The time spent traveling between points ranged from 5 to 10 minutes.

Individuals were documented whenever possible using a SONY Cyber-shot DSC-H400 digital camera (20.1 Megapixels, 63x optical zoom) and a Sony ICD-SX712 digital recorder. The documentation was deposited in the collections of Wikiaves (<http://www.wikiaves.com.br/>) and Xeno-Canto (<http://www.xeno-canto.org/>). The taxonomic sequence, as well as the scientific and common names used in this study, follows the Brazilian Committee for Ornithological Records (Pacheco *et al.*, 2021).

Only the data obtained using the point count method were considered for analysis. To check if the sampling significantly represented the studied bird assembly, an estimate of richness was calculated for the total data using the non-parametric Jackknife1 index (1000 randomizations), employing the EstimateS 9.1.0 program (Colwell, 2013).

All species were categorized based on trophic niche, according to the AVONET listing (Tobias *et al.*, 2022): omnivore (O), aquatic herbivore (HA), frugivore (F), granivore (G), invertivore (I), nectarivore (N), and scavenger (S).

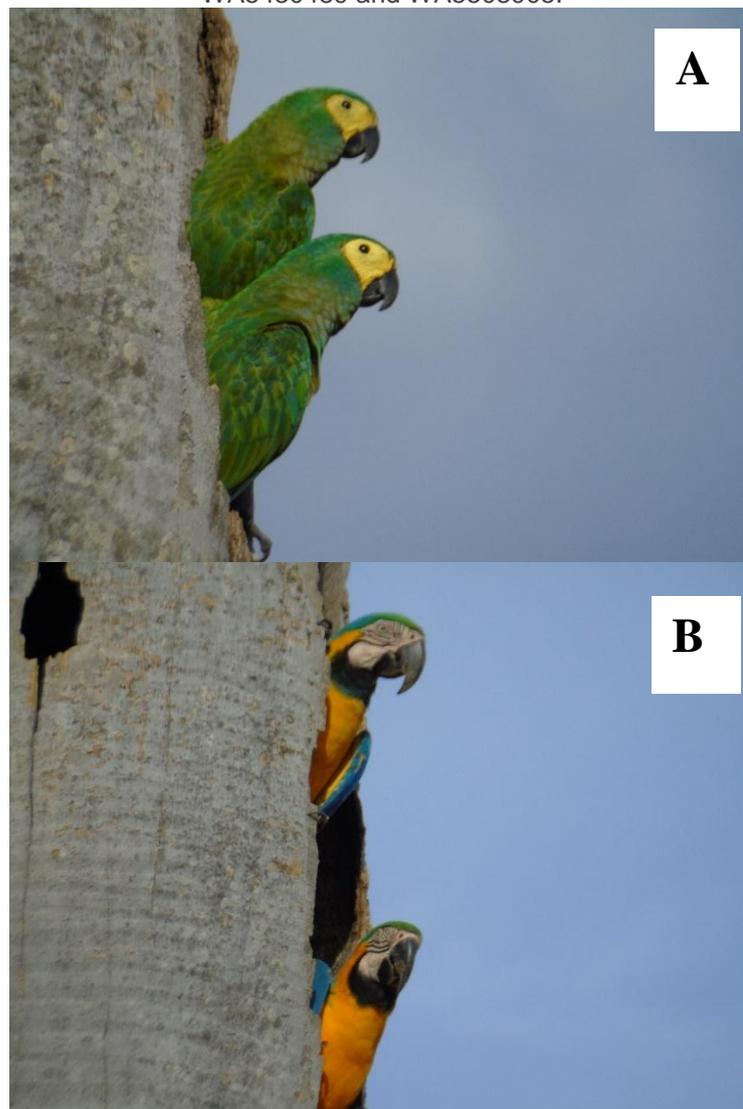
The non-parametric Spearman correlation (r_s) was used to check whether the environmental variable tree density influenced avifaunal richness across the points, with the Bonferroni test applied to reduce the inflation of Type I error probability (ZAR, 1999). This calculation was performed using the PAST 3.23 program (Hammer; Harper; Ryan, 2019), with results considered significant for $\alpha < 0.05$.

3. RESULTS AND DISCUSSION

A total of 61 species, belonging to 12 orders and 25 families (APPENDIX), was recorded across the nine study points in the municipal urban grid. In the neighboring municipality of Arenópolis, also located in the Aragarças Microrregion, 63 species from 26 families were recorded in a similar avifaunal inventory, which involved 12 visits to obtain the data (Cardoso *et al.*, 2022), representing double the number recorded in this study (see "Materials and Methods"). Thus, this work demonstrated a comparatively rich avifauna in the urban zone of Diorama, despite the fewer number of visits to the studied area.

The families with the highest avifaunal richness were Psittacidae (8 species), followed by Columbidae, Tyrannidae, and Thraupidae (all with 6 species). The higher richness of Psittacidae is likely due to many residences with backyards and fruit-bearing plants (see study area), including palms, where these species seek food and shelter, respectively (Sick, 1997; Gwynne *et al.*, 2010; Sigrist, 2014). This study highlights the documented record of pairs of the *maracanã-do-buriti* (*Orthopsittaca manilatus*, Boddaert, 1783) and the *arara-canindé* (*Ara ararauna*, Linnaeus, 1758) excavating nests in *Roystonea oleracea* (Jacq.) O. F. Cook in the area of the point “Praça da Igreja Católica (PIC)” (Figure 3).

Figure 3. Pairs of Psittacidae birds digging burrows in imperial palms *Roystonea oleracea* (Jacq.) O. F. Cook at the “Praça da Igreja Católica (PIC)” counting point. A: Buriti macaw *Orthopsittaca manilatus* (Boddaert, 1783); B: blue-and-yellow macaw *Ara ararauna* (Linnaeus, 1758). Wikiaves records WA5430489 and WA5508905.



Source: Authors, 2024

The high representativeness of the families Columbidae, Thraupidae, and Tyrannidae was also an expected outcome, as their species are common in both natural and anthropogenic environments throughout the country (SICK, 1997; Gwynne *et al.*, 2010; Sigrist, 2014). It is worth highlighting the documented record of the *batuqueiro* (*Saltatricula atricollis*, Vieillot, 1817), a species considered endemic to the *Cerrado* according to Braz; Hass (2014). The vocalization of one individual was recorded (WA5517667, XC820905) at the entrance of the urban grid (point ENT, see more details in “Study Area”). According to Myers (1990), the greater the richness and endemism in an area, the higher its conservation priority. In this sense, the record of an endemic species in the urban grid of Diorama may justify conservation measures in the municipality.

The richness according to the Jackknife1 estimator was equal to 77.67, and thus, considering that the recorded richness is 61 species, approximately 78.5% of the total expected bird species was documented in this study. This is a marginally satisfactory proportion, perhaps due to the fewer number of visits for data collection (N=6, see Materials and Methods). The distribution of species across trophic niche categories is shown in Table 2, with a predominance of invertivores and omnivores, respectively.

Table 2. Species grouped by trophic niche categories according to AVONET (TOBIAS *et al.*, 2022) and respective proportions, for the total data in the urban area of Diorama, state of Goiás.

TROPHIC NICHES	SPECIES (%)
Invertivore	21(34,4)
Omnivore	20(32,7)
Granivore	09(4,7)
Frugivore	08(13,1)
Herbivore-Aquatic	01(1,7)
Nectarivore	01(1,7)
Detritivore	01(1,7)
TOTAL	61

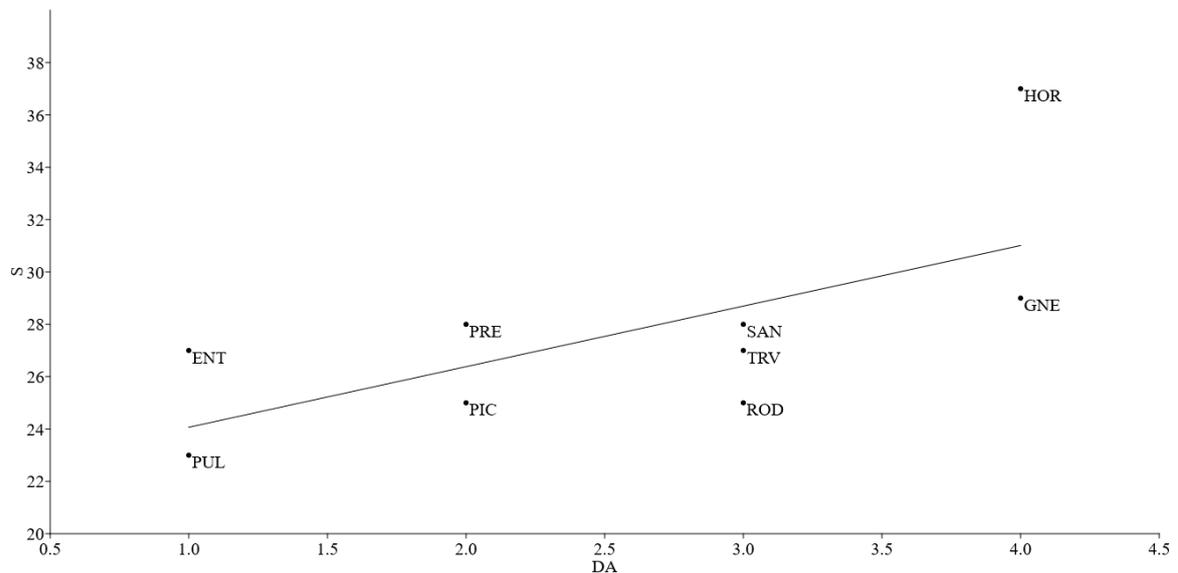
Source: Authors, 2024

In Brazil, studies in other cities have also demonstrated the predominance of insectivorous and omnivorous species (Cruz; Piratelli, 2011; Moura; Moura; Machado, 2018; Navega-Gonçalves; Trevisan, 2021). Urbanization typically favors insectivorous species that forage in the air and on the ground (Allen; O’Connor, 2000; Chace; Walsh, 2006). In urban environments, generalist diet species such as omnivores, as well as less specialized insectivores that feed in flight, also prevail, and are not necessarily harmed (Argel-de-Oliveira, 1995). In Goiás, similar results were obtained in the urban grid of

Quirinópolis, in the southwest of the state (Claro; Rossi; Lopes, 2020), and Iporá, in the central mesoregion (Oliveira; Blamires, 2013; Albado; Silva; Blamires, 2019). In Arenópolis, the neighboring city to Diorama in northwestern Goiás, the predominance of insectivores and omnivores was also observed (Cardoso *et al.*, 2022).

A significant relationship was found between avifaunal richness and tree density ($r_s=0.700$, $p<0.05$). Thus, it is likely that tree cover influences the richness of the studied birds, with more species found at counting points with higher tree density (Figure 4).

Figure 4. Relationship between tree richness (S) and tree density (DA) of the nine counting points in the urban area of Diorama, state of Goiás. ENT: entrance on the side of the GO-174 highway; PUL: Uesdar de Jesus Lima square; SAN: SANEAGO water treatment plant; HOR: horticulture; ROD: municipal bus station; PIC: catholic church square; TRV: GO-174 interchange; PRE: city hall; GNE: sports gym.



Source: Authors, 2024

Tree cover is one of the most important factors for the arrival and potential permanence of species in urban environments (Blair; Launer, 1997). Thus, more tree-rich urban areas provide more resources, such as shelter and food (Melles; Glenn; Martin, 2003; Toledo; Donatelli; Batista, 2012). In Brazil, Fontana; Burger; Magnusson (2011) found greater richness at points with higher tree density in the urban grid of Porto Alegre. Sacco *et al.* (2015), in a study on functional attributes in the urban zone of Pelotas, southern Brazil, identified tree cover as one of the important variables for avifaunal composition. In Goiás, two studies demonstrated a positive and significant relationship between vegetation and bird richness in the urban grid of Iporá (Albado;

Silva; Blamires, 2019; Valadão *et al.*, 2022). Claro; Rossi; Lopes (2020) identified various vegetation characteristics as essential for maintaining a bird community with high richness and diversity in urban squares of Quirinópolis, in southwestern Goiás.

4. FINAL CONSIDERATIONS

Despite being preliminary, this work demonstrated that the studied area has a comparatively rich avifauna, with predominantly generalist feeding habits, and one species endemic to the Cerrado. The significant relationship between tree density and avifaunal richness suggests that tree cover is likely important for the studied species. We recommend the management and care of cultivated plants to conserve bird richness in the municipal urban grid. Another study with more visits for data collection would certainly be important to enhance knowledge about the urban avifauna in Diorama. Future studies in the surrounding municipalities will likely reveal new aspects of avifaunas in these anthropogenic environments.

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APÊNDICE

Table 3. Avifauna na malha urbana municipal em Diorama, estado de Goiás. Nomes científicos, populares e sequência taxonômica seguem Pacheco *et al.* (2021). **PC**: pontos de contagem (ENT= entrada às margens da rodovia GO-174, PUL= praça Uesdar de Jesus Lima, SAN= estação de tratamento hídrico SANEAGO, HOR= horticultura, ROD= rodoviária municipal, PIC= praça da igreja católica, TRV= trevo GO-174, PRE= prefeitura municipal, GNE= ginásio de esportes). **T**: categorias de nicho trófico segundo AVONET (TOBIAS *et al.*, 2022) (O=onívoro, HA= herbívoro-aquático, F= frugívoro, G= granívoro, I= invertívoro, N= nectarívoro, S= detritívoro). **WA**: registro fotográfico (f) ou sonoro (s) na página Wikiaves. **XC**: registro sonoro na página Xeno-Canto.

ESPÉCIES	NOMES POPULARES	PC	T	WA	XC
ANSERIFORMES					
ANATIDAE					
<i>Dendrocygna viduata</i> (Linnaeus, 1766)	irerê	HOR	H A		
<i>Cairina moschata</i> (Linnaeus, 1758)	pato-do-mato	HOR	O		
COLUMBIFORMES					
COLUMBIDAE					
<i>Columba livia</i> Gmelin, 1789	pombo-doméstico	PUL, GNE	G	5312215f, 5441728f	
<i>Patagioenas picazuro</i> (Temminck, 1813)	pomba-asa-branca	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	O		
<i>Patagioenas cayennensis</i> (Bonnaterre, 1792)	pomba-galega	SAN, ENT, HOR, ROD, PIC, PRE, TRV	F	5300375f, 5300376f	
<i>Leptotila verreauxi</i> Bonaparte, 1855	juriti-pupu	HOR, GNE	G	5441756f, 5441759f	
<i>Columbina talpacoti</i> (Temminck, 1811)	rolinha-roxa	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	G	5300362f, 5317980f	
<i>Columbina squammata</i> (Lesson, 1831)	rolinha-fogo-apagou	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	G	5317968f, 5430502f	
CUCULIFORMES					
CUCULIDAE					
<i>Guira guira</i> (Gmelin, 1788)	anu-branco	ENT, PIC, TRV	I	5441766f, 5441768f	
<i>Crotophaga ani</i> Linnaeus, 1758	anu-preto	PUL, ENT, HOR, PRE, GNE, TRV	O	5312206f, 5575964f	
<i>Piaya cayana</i> (Linnaeus, 1766)	alma-de-gato	ROD	I	5575989f	
APODIFORMES					
TROCHILIDAE					
<i>Chlorostilbon lucidus</i> (Shaw, 1812)	besourinho-de-bico-vermelho	SAN, PRE, GNE	N	5441788f, 5441794f	
CHARADRIIFORMES					
CHARADRIIDAE					
<i>Vanellus chilensis</i> (Molina, 1782)	quero-quero	PUL, ENT, HOR, GNE	O		
PELECANIFORMES					
ARDEIDAE					
<i>Syrigma sibilatrix</i> (Temminck, 1824)	maria-faceira	SAN	O		
THRESKIORNITHIDAE					

ESPÉCIES	NOMES POPULARES	PC	T	WA	XC
<i>Theristicus caudatus</i> (Boddaert, 1783)	curicaca	PUL, SAN, HOR, ROD, PIC, PRE, TRV	O	5362670f, 5575949f	
CATHARTIFORMES					
CATHARTIDAE					
<i>Coragyps atratus</i> (Bechstein, 1793)	urubu-preto	PUL, SAN, ENT, HOR	S	5362672f, 5441745f	
GALBULIFORMES					
GALBULIDAE					
<i>Galbula ruficauda</i> Cuvier, 1816	ariramba-de- cauda-ruiva	HOR	I		
PICIFORMES					
RAMPHASTIDAE					
<i>Ramphastos toco</i> Statius Muller, 1776	tucanuçu	SAN, HOR, ROD, PRE, GNE, TRV	F	5317971f, 5430495f	
<i>Pteroglossus castanotis</i> Gould, 1834	araçari-castanho	SAN	F	5441817s	813740
PICIDAE					
<i>Melanerpes candidus</i> (Otto, 1796)	pica-pau-branco	PIC	F	5441777f, 5441779f	
<i>Campephilus melanoleucos</i> (Gmelin, 1788)	pica-pau-de- topete-vermelho	PIC	I		
<i>Colaptes melanochloros</i> (Gmelin, 1788)	pica-pau-verde- barrado	ROD	I		
FALCONIFORMES					
FALCONIDAE					
<i>Milvago chimachima</i> (Vieillot, 1816)	carrapateiro	HOR	O		
<i>Falco sparverius</i> Linnaeus, 1758	quiriquiri	PUL, SAN	O	5508898f	
PSITTACIFORMES					
PSITTACIDAE					
<i>Brotogeris chiriri</i> (Vieillot, 1818)	periquito-de- encontro-amarelo	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	O	5320576s , 5517679s	790519 , 820908
<i>Pionus menstruus</i> (Linnaeus, 1766)	maitaca-de- cabeça-azul	HOR, GNE, TRV	O	5517647s , 5575981f	820903 , 828124
<i>Amazona aestiva</i> (Linnaeus, 1758)	papagaio- verdadeiro	HOR	F		
<i>Eupsittula aurea</i> (Gmelin, 1788)	periquito-rei	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	O	5317970f, 5317982f	
<i>Orthopsittaca manilatus</i> (Boddaert, 1783)	maracanã-do- buriti	HOR, PIC	F	5430486f, 5430487f	
<i>Ara ararauna</i> (Linnaeus, 1758)	arara-canindé	SAN, PIC	O	5430477f, 5430479f	
<i>Diopsittaca nobilis</i> (Linnaeus, 1758)	maracanã- pequena	SAN, ENT, HOR, ROD, PIC, PRE, GNE	O	5317986f, 5317988f	790520
<i>Psittacara leucophthalmus</i> (Statius Muller, 1776)	periquitão	ENT, PRE, GNE, TRV	O	5578241s	
PASSERIFORMES					
THAMNOPHILIDAE					
<i>Thamnophilus doliatus</i> (Linnaeus, 1764)	choca-barrada	ENT, HOR, PRE, TRV	I	5517657s	

ESPÉCIES	NOMES POPULARES	PC	T	WA	XC
<i>Taraba major</i> (Vieillot, 1816)	choró-boi	GNE	I		
FURNARIIDAE					
<i>Furnarius rufus</i> (Gmelin, 1788)	joão-de-barro	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	I	5317989f, 5317991f	
TYRANNIDAE					
<i>Camptostoma obsoletum</i> (Temminck, 1824)	risadinha	ENT	I		
<i>Myiarchus tyrannulus</i> (Statius Muller, 1776)	maria-cavaleira-de-rabo-enferrujado	PUL, SAN, ROD, PRE, GNE	I		
<i>Pitangus sulphuratus</i> (Linnaeus, 1766)	bem-te-vi	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	O	5312219f, 5441784f	
<i>Machetornis rixosa</i> (Vieillot, 1819)	suiriri-cavaleiro	SAN, ENT, HOR,	I	5441772f, 5441774f	
<i>Megarynchus pitangua</i> (Linnaeus, 1766)	neinei	HOR, GNE	I		
<i>Tyrannus melancholicus</i> Vieillot, 1819	suiriri	SAN	I	5300348f, 5362662f	
HIRUNDINIDAE					
<i>Stelgidopteryx ruficollis</i> (Vieillot, 1817)	andorinha-serradora	HOR	I		
<i>Progne tapera</i> (Linnaeus, 1766)	andorinha-do-campo	ENT, PRE, GNE, TRV	I	5300335f, 5300345f	
<i>Progne chalybea</i> (Gmelin, 1789)	andorinha-grande	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	I	5317993f	
TROGLODYTIDAE					
<i>Cantorchilus leucotis</i> (Lafresnaye, 1845)	garrinchão-de-barriga-vermelha	HOR	I		
DONACOBIIIDAE					
<i>Donacobius atricapilla</i> (Linnaeus, 1766)	japacanim	HOR	I		
TURDIDAE					
<i>Turdus leucomelas</i> Vieillot, 1818	sabiá-barranco	SAN, ROD, PRE, GNE, TRV	F	5575987f	
MIMIDAE					
<i>Mimus saturninus</i> (Lichtenstein, 1823)	sabiá-do-campo	PUL, SAN, ROD, PIC, PRE	O	5300349f, 5300350f	
PASSERIDAE					
<i>Passer domesticus</i> (Linnaeus, 1758)	pardal	PUL, ENT, HOR, ROD, PIC, PRE, GNE, TRV	G	5300351f, 5300357f	
FRINGILLIDAE					
<i>Euphonia chlorotica</i> (Linnaeus, 1766)	fim-fim	PUL, HOR, ROD, PIC, PRE, GNE, TRV	F	5441827s	813742
ICTERIDAE					
<i>Leistes superciliaris</i> (Bonaparte, 1850)	polícia-inglesa-do-sul	SAN, ENT, TRV	I		
<i>Cacicus cela</i> (Linnaeus, 1758)	xexéu	PRE, TRV	O		
<i>Icterus pyrrhopterus</i> (Vieillot, 1819)	encontro	ROD	I		

ESPÉCIES	NOMES POPULARES	PC	T	WA	XC
<i>Molothrus bonariensis</i> (Gmelin, 1789)	chupim	PUL, SAN, ENT, HOR, ROD, PRE, GNE, TRV	I	5441741f, 5508895f	
<i>Gnorimopsar chopi</i> (Vieillot, 1819)	pássaro-preto	PUL, SAN, ENT, HOR, PIC, PRE, GNE, TRV	O	5441751f, 5508899f	828122
THRAUPIDAE					
<i>Saltatricula atricollis</i> (Vieillot, 1817)*	batuqueiro	ENT	G	5517667s	820905
<i>Volatinia jacarina</i> (Linnaeus, 1766)	tiziu	PUL, ENT, HOR, PIC, TRV	G		
<i>Sporophila nigricollis</i> (Vieillot, 1823)	baiano	SAN, ENT, HOR, ROD, PIC, PRE	G	5300358f, 5362659f	
<i>Sicalis flaveola</i> (Linnaeus, 1766)	canário-da-terra	PUL, SAN, ENT, HOR, ROD, PIC, PRE, GNE, TRV	G	5300346f, 5300360f	
<i>Thraupis sayaca</i> (Linnaeus, 1766)	sanhaço-cinzento	ROD, PIC, GNE	O		
<i>Thraupis palmarum</i> (Wied, 1821)	sanhaço-do-coqueiro	PUL, HOR, ROD, PIC, PRE, GNE, TRV	O	5320593s , 5362658f	

*. Espécie endêmica do Cerrado segundo Braz; Hass (2014).

Fonte: Autores

CHAPTER 3

ULTRASONIC CONTROL OF AQUATIC MACROPHYTES IN RESERVOIRS: AN INTEGRATED REVIEW

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ABSTRACT: The excessive proliferation of cyanobacteria and aquatic macrophytes in water reservoirs has been a concern for governments, energy companies managing hydroelectric and thermal power plants, and local populations. These aquatic organisms, when overabundant, negatively impact the management of water for public supply and energy generation, obstructing intake systems and damaging water treatment stations. Ultrasound emerges as a potential technique for controlling these organisms. The aim of this study was to perform an integrative review by selecting articles published between 2020 and 2024, focusing on the efficacy and ecological implications of ultrasonic control on these aquatic populations. The methodology involved searching scientific databases, selecting 14 articles out of a total of 42, based on their relevance to the theme of ultrasonic control and its practical applicability. The results indicate that ultrasonic frequencies of 20 kHz collapsed gas vacuoles in these aquatic organisms within 40 seconds of exposure, demonstrating the potential application of this technique in controlling these organisms, although it is necessary to adjust the intensity according to the specific environmental conditions of the reservoir and the biology of the target organisms. However, exposure to ultrasound can release toxins, affect non-target organisms, and alter the aquatic community structure, resulting in negative impacts such as hypoxia and fish death. It highlights the need to adopt an adaptive model to adjust ultrasound parameters and integrate them with other management practices. The study emphasizes the importance of conducting laboratory-scale tests and continuous monitoring to optimize efficacy and minimize environmental risks. Future development of more efficient and less invasive ultrasonic transducers is also recommended, as well as interdisciplinary collaboration to promote more sustainable reservoir management.

KEYWORDS: ultrasonic waves, acoustic cavitation, floating macrophytes, cyanobacteria, sustainability.

RESUMO: A proliferação excessiva de cianobactérias e macrófitas aquáticas em reservatórios de água tem sido uma preocupação para governos, empresas de energia que administram usinas hidrelétricas e termelétricas e populações locais. Esses organismos aquáticos, quando superabundantes, afetam negativamente o gerenciamento da água para abastecimento público e geração de energia, obstruindo os sistemas de captação e danificando as estações de tratamento de água. O ultrassom surge como uma técnica em potencial para o controle desses organismos. O objetivo deste estudo foi realizar uma revisão integrativa, selecionando artigos publicados entre 2020 e 2024, com foco na eficácia e nas implicações ecológicas do controle ultrassônico sobre essas populações aquáticas. A metodologia envolveu a busca em bancos de dados científicos, selecionando 14 artigos de um total de 42, com base em sua relevância para o tema do controle ultrassônico e sua aplicabilidade prática. Os resultados indicam que frequências ultrassônicas de 20 kHz colapsaram vacúolos de gás nesses organismos aquáticos em 40 segundos de exposição, demonstrando o potencial de aplicação dessa técnica no controle desses organismos, embora seja necessário ajustar a intensidade de acordo com as condições ambientais específicas do reservatório e a biologia dos organismos-alvo. No entanto, a exposição ao ultrassom pode liberar toxinas, afetar organismos não-alvo e alterar a estrutura da comunidade aquática, resultando em impactos negativos, como hipóxia e morte de peixes. Ele destaca a necessidade de adotar um modelo adaptativo para ajustar os parâmetros do ultrassom e integrá-los a outras práticas de gerenciamento. O estudo enfatiza a importância da realização de testes em escala laboratorial e do monitoramento contínuo para otimizar a eficácia e minimizar os riscos ambientais. Recomenda-se também o desenvolvimento futuro de transdutores ultrassônicos mais eficientes e menos invasivos, bem como a colaboração interdisciplinar para promover um gerenciamento mais sustentável dos reservatórios.

PALAVRAS-CHAVE: ondas ultrassônicas, cavitação acústica, macrófitas flutuantes, cianobactérias, sustentabilidade.

1. INTRODUCTION

Reservoirs, semi-artificial bodies of water located between rivers and lakes, play critical roles for ecosystems and human activities. They are essential for water storage, irrigation, flood control, potable water supply, energy generation, recreation, and biodiversity conservation (Xu *et al.*, 2024; Ye *et al.*, 2017). Moreover, these aquatic environments are sensitive indicators of ecosystem changes, reflecting watershed quality through the dynamics of phytoplankton and zooplankton communities (Tao *et al.*, 2024). However, human intervention and the exploitation of natural resources have exacerbated nutrient loads in these reservoirs, fostering excessive proliferation of cyanobacteria and aquatic plants (macrophytes), as they act as indicators of water pollution due to their sensitivity to changes in the chemical composition of the aquatic environment. They absorb nutrients and chemicals from the water, which makes them capable of reflecting the level of pollution and the presence of nutrients like nitrogen and phosphorus (Córdova *et al.*, 2024; X. Li *et al.*, 2023; Sayanthan *et al.*, 2024).

Macrophytes can indicate the eutrophic state of a water body, based on their rapid growth in response to increased nutrient levels from sources such as agricultural fertilizers, and domestic and industrial effluents. Additionally, the composition of macrophyte communities can provide information about the presence of specific pollutants, salinity, and pH conditions. Thus, macrophytes are valuable indicators for environmental monitoring and assessing the health of aquatic ecosystems (Huisman *et al.*, 2018; Rocha *et al.*, 2018; Sompura *et al.*, 2024; Yang; Liu, 2023).

Although aquatic macrophytes are essential for ecology due to their roles in photosynthesis, nutrient cycling, and as habitats for various species, they become problematic when their proliferation is uncontrolled (Zhang *et al.*, 2024). This unchecked growth is often attributed to human interventions, including agricultural practices and improper waste disposal, leading to serious environmental issues such as decreased oxygen availability in the water and compromised water quality. Excessive growth of these plants can also have adverse economic and ecological impacts, interfering with activities such as hydropower production (de Paula *et al.*, 2024), chemical consumption for water treatment (Baydum *et al.*, 2018), recreational activities, and flood management (Bai *et al.*, 2020).

In light of this situation, there is a need to explore environmentally sustainable and efficient control methods. While conventional physical, chemical, and biological methods of controlling macrophyte proliferation are widely used, they have significant limitations, including negative impacts on aquatic biodiversity and high operational costs (Hussner *et al.*, 2017). In this context, ultrasonic control, which uses high-frequency sound waves (20 kHz and higher), emerges as a promising alternative. This method offers the advantage of being less invasive and potentially more sustainable, minimizing impacts on the aquatic ecosystem, especially due to the short application time required (Akinnowo, 2023; Alahuhta *et al.*, 2018; Bermarija *et al.*, 2022; Karouach *et al.*, 2022; L. Li *et al.*, 2023; Misteli *et al.*, 2023; Moura Júnior *et al.*, 2018; Sobral; Santos, 2023; Souza *et al.*, 2020; Wang *et al.*, 2023; Wu; Wu, 2007; Zhao *et al.*, 2012).

This study aims to evaluate the efficacy and ecological implications of ultrasonic control of cyanobacteria and aquatic macrophytes in reservoirs, using an integrative review methodology. The research was conducted through a systematic search in the Web of Science and PubMed databases, accessible via the CAPES periodicals portal, covering publications from 2020 to 2024. A total of 14 articles were meticulously selected from 42 available, based on stringent criteria such as: articles in English, peer-reviewed, and directly relevant to the use of the ultrasound in controlling cyanobacteria and macrophytes. The integrative review will not only identify and understand the potential of the ultrasound as an effective strategy but also develop environmentally responsible and efficient control approaches. This effort is aimed at improving water quality in reservoirs, preserving aquatic biodiversity, and promoting the sustainability of water resources, fostering more integrated and sustainable management practices that combine ultrasound with other control strategies for optimized management of aquatic ecosystems in reservoirs.

2. METHODOLOGY

This study adopted an integrative literature review methodology to evaluate the efficacy and ecological implications of using ultrasonic control on cyanobacteria and aquatic macrophytes in reservoirs. The integrative review allows for the systematic inclusion of both experimental and non-experimental studies, providing a comprehensive understanding of the subject under investigation, synthesizing existing knowledge, and identifying gaps for future research (Botelho *et al.*, 2011; Camargo Júnior *et al.*, 2023).

The guiding question for this review was: "What is the efficacy of ultrasonic control in managing cyanobacteria and aquatic macrophytes in reservoirs, and what are its ecological implications?"

The research was conducted using relevant scientific databases, including PubMed and Web of Science. The search terms used were: "ultrasound", "ultrasonic control", "cyanobacteria", "aquatic macrophytes", "management of aquatic reservoirs". Article selection was based on stringent criteria such as: articles published in English between 2020 and 2024; peer-reviewed; and directly relevant to the use of ultrasound in controlling cyanobacteria and macrophytes.

Studies that addressed the use of ultrasonic control in aquatic environments, specifically for managing cyanobacteria and macrophytes, were included. Articles that did not directly deal with ultrasonic control or that were literature reviews without primary data were excluded.

Data were extracted from each selected article, including author(s), year of publication, study objectives, methodology, main results, and conclusions. This information was used to synthesize relevant findings related to the efficacy and ecological implications of ultrasonic control.

The quality of the included studies was assessed based on specific criteria for experimental and observational studies, considering the study design, clarity of result presentation, and the relevance of findings to the practice of controlling cyanobacteria and macrophytes.

The results of the studies were qualitatively analyzed to identify trends, commonalities, and discrepancies in the findings. This analysis highlighted the efficacy of ultrasonic control and its potential implications for the sustainability of aquatic ecosystems.

This methodology enabled a comprehensive and detailed assessment of the use of ultrasound in controlling cyanobacteria and aquatic macrophytes, contributing to the scientific knowledge base and informing environmental management practices.

3. LITERATURE REVIEW

3.1 ECOLOGY OF FLOATING MACROPHYTES

Aquatic macrophytes are plants that live in aquatic environments such as lakes, rivers, swamps, and estuaries. They can be found floating freely, submerged, or rooted

at the bottom of water bodies. They play important ecological roles by providing oxygen through photosynthesis, serving as habitat for other species, and assisting in water purification by absorbing nutrients and heavy metals (Couto *et al.*, 2022).

Aquatic macrophytes are vital components of aquatic ecosystems, crucial in nutrient cycling and promoting primary productivity, helping to maintain ecological balance by absorbing and recycling nutrients. Moreover, they significantly contribute to aquatic biodiversity, serving as habitat and refuge for a wide range of organisms, including birds, fish, and insects. They also play a crucial role in protecting stream banks from erosion and adding essential organic matter to the water, thus enhancing the overall quality of the aquatic ecosystem (Alahuhta *et al.*, 2017; Rocha *et al.*, 2018).

However, despite their numerous ecological benefits, macrophytes can become problematic under certain conditions, especially when influenced by human activities. Overgrowth of macrophytes can lead to environmental problems such as reduced diversity of aquatic flora and fauna, disease proliferation, diminished water quality, and negative impacts on recreational activities, navigation, and energy generation. Therefore, careful management of these organisms is essential to ensure their benefits are maximized while potential adverse impacts are mitigated, highlighting the complexity of their role in aquatic ecosystems (Calvo *et al.*, 2019; dos Santos *et al.*, 2020; Gentilin-Avanci *et al.*, 2021).

There is a variety of macrophytes that adapt to different aquatic environments, from saltwater in marine ecosystems to freshwater environments in lakes, ponds, and rivers. A study conducted in Lake Manzala in Egypt recorded eleven species of aquatic macrophytes, including *Potamogeton pectinatus*, *Eichhornia crassipes*, *Pistia stratiotes*, *Phragmites australis*, *Typha domingensis*, and *Echinochloa stanina* (Esiukova *et al.*, 2021; Haroon, 2022).

The Electric Company of Minas Gerais (CEMIG) also conducted a survey of macrophyte species occurring in Brazilian hydroelectric reservoirs, which is presented in Table 1.

Table 1. Species of macrophytes found in Brazilian hydroelectric reservoirs

Família	Nome científico	Nome comum	Hábito	Habitat	Características	Distribuição
ARACEAE	<i>Pistia stratiotes</i> L.	Alface-d'água	Free-floating herb; annual or perennial	Calm or slow-moving water, often fully covered on the surface and located in wind-protected areas.	Spongy leaves, up to 30 cm, sensitive to cold, reproduces by seeds or stolons, used for fodder and ornamentation, but can invade and become weedy in wet areas.	Pantropical
COMMELINACEAE	<i>Commelina diffusa</i> Burm.f.	Trapoeraba	Amphibious and emergent herb	Prefers moist regions along drainage canal margins.	Weed in fertile and semi-shaded soil, reproduces by seeds or stems, used in animal feed.	Frequent throughout the country
CYPERACEAE	<i>Eleocharis mínima</i> Kunth	Tiririca	Aquatic plant that can be submerged, emergent, or amphibious, with a perennial or annual life cycle, depending on water level.	Rivers and lakes	Varies in size; reaches 15-25 cm submerged, and 5-10 cm in wet areas. Serves as food for aquatic and terrestrial animals, and is used as aquarium ornament.	Tropical America
CYPERACEAE	<i>Rhynchospora corymbosa</i> (L.) Britton	Capim-navalha	Amphibious or emergent herb; perennial	Wetland zones, common in marshes.	Tufted plant with triangular stem, cutting leaves, rough corymb inflorescence, reproduces by seeds or division. Food for capybaras and invader in wet areas.	Pantropical
LYTHRACEAE	<i>Cuphea melvilla</i> Lindl	Sete-sangrias	Perennial, sparsely branched plant that can be amphibious or emergent.	Riverbanks, moist and shaded habitats.	Ornamental plant with rough leaves and red flowers 2.5 to 3 cm.	Tropical, all of Brazil
ONAGRACEAE	<i>Ludwigia leptocarpa</i> (Nutt.) H.Hara	Cruz-de-malta	Aquatic herbaceous or subshrub plant, perennial or annual, can be emergent or amphibious.	Aquatic or moist, sunny environments, including fields, riverbanks, and floating islands of aquatic plants.	Plant that appears after floods, with invasive potential. Reproduces by seeds and stem rooting, used as animal forage.	From the southwestern USA to Argentina; also in Africa
ONAGRACEAE	<i>Ludwigia octovalvis</i> (Jacq.) P.H.Raven	Cruz-de-malta	Aquatic herbaceous or subshrub plant, perennial or annual, can be emergent or amphibious.	Lakes and rivers	Up to 120 cm, with solitary yellow flowers, spongy roots, and reddish young branches. Grows in moist or flooded soils, reproduces by seeds, thrives in disturbed environments.	Pantropical
ONAGRACEAE	<i>Ludwigia peploides</i> (Kunth) P.H. Raven	Cruz-de-malta	Perennial aquatic plant that can be amphibious, submerged, emergent, or fixed floating.	Develops in mud, on the water surface, or on floating islands formed by other macrophytes.	Ornamental plant with variable appearance, leaves change shape and size depending on the environment. Reproduces by seeds, rhizomes, or rooting at nodes, and grows rapidly in disturbed environments.	Pantropical
POACEAE	<i>Urochloa arrecta</i> (Hack. Ex T.Durand & Schinz) Morrone & Zuloaga	Braquiária-do-brejo	Amphibious, emergent perennial herb.	Lakes, rivers, and reservoirs	An invasive stoloniferous species from Africa, introduced to Brazil as fodder. It has robust, purplish stems, spreads quickly in moist areas and along watercourses, and can reach up to 120 centimeters in height, currently causing problems in aquatic communities and in hydropower production.	Pantropical

Família	Nome científico	Nome comum	Hábito	Habitat	Características	Distribuição
PONTEDERIACEAE	<i>Eichhornia azurea</i> (Sw.) Kunth	Aguapé	Emergent, fixed-floating perennial herb.	Lakes, rivers, and floodplain fields	Rhizomatous plant that can grow up to 8 meters. Serves as habitat for insects and fish, and forage for capybaras. Propagates by seeds and rhizomes, showing vigorous growth. Differs from <i>Eichhornia crassipes</i> by having fringed petal margins.	Tropical and subtropical America
PONTEDERIACEAE	<i>Eichhornia crassipes</i> (Mart.) Solms	Aguapé	Free-floating or fixed-floating perennial herb in shallower waters.	All water bodies	Native to the Amazon, it reproduces easily vegetatively, by rhizomes or fragments, and its seeds can survive submerged for about 15 years. Feared in disturbed locations due to its rapid proliferation and associated problems.	Native to tropical South America and introduced on all continents
POLYGONACEAE	<i>Polygonum ferrugineum</i> Wedd	Erva-de-bicho	Amphibious emergent or floating perennial herb.	Found along riverbanks and in areas with little shade, often growing on floating islands formed by other macrophyte species.	Described plant can reach 2.5 meters in height, being the largest in its genus. It is a pioneer species that propagates by seeds, seedlings, or pieces that root at nodes, and colonizes moist riverbanks in sedimentation areas.	Tropical America
POLYGONACEAE	<i>Polygonum punctatum</i> Elliott	Erva-de-bicho	Amphibious, emergent; perennial	Abundant along pond edges, marshes, and floodplains.	Plant has lance-shaped leaves and stems that vary from light green to reddish. Propagates through seeds, fragmentation, or rooting of nodes when they touch the ground.	Throughout Brazil
RUBIACEAE	<i>Diodia saponariifolia</i> (Cham. E Schltl.) K. Schum	Poaia-do-brejo	Amphibious; perennial	Typical of waterlogged terrains, found along riverbanks and ponds.	A creeping, unbranched species with cylindrical stems 50 to 100 centimeters long. Propagates by seeds and dominates areas with its rooted stems.	Occurs in Bahia and the South, Southeast, and Central-West regions
SALVINIACEAE	<i>Salvinia auriculata</i> Aubl	Orelha-de-onça	Free-floating herb; annual or perennial	Found in still water springs and slow-moving channels, usually in areas protected from wind.	Propagates vegetatively through offshoots or spores, forming infestations in disturbed environments, covering aquatic surfaces, blocking sunlight, and impacting aquatic ecosystems. Provides forage and habitat for capybaras, insects, birds, snails, and fish.	North and Northeast regions

Source: Brasil (2021).

Regarding their biology, macrophytes can reproduce sexually through seed production and asexually through rhizomes, stolons, or fragmentation. Macrophytes have special adaptations in their tissues, such as aerenchyma, which allows them to float and facilitates gas exchange in aquatic environments. Aerenchyma is a type of plant tissue that features enlarged intercellular spaces, enabling efficient gas diffusion within the plant, such as oxygen. This is particularly important for plants growing in environments where oxygen may be limiting, like aquatic habitats (Björn *et al.*, 2022).

Macrophytes are aquatic plants that grow in or near water, visible to the naked eye. They play crucial roles in aquatic ecosystems and are used as indicators of water quality in many parts of the world. The classification of aquatic macrophytes according to their biological form is presented in Table 2.

Table 2. Classification of aquatic macrophytes according to their biological form

Classification	Description
Amphibious	Capable of living both in waterlogged areas and out of water, often changing morphology from aquatic to terrestrial as water levels drop.
Emergent	Rooted in sediment, with parts submerged and others emergent.
Fixed Floating	Rooted in sediment with floating leaves.
Free Floating	Not rooted in sediment, can be carried by water currents, wind, or even animals.
Fixed Submerged	Rooted in sediment, with stems and leaves submerged, generally with flowers emerging above the water.
Free Submerged	Not rooted in the bottom, entirely submerged, generally only flowers emerge.
Epiphyte	Occurring on other aquatic plants.

Source: Björn *et al.* (2022); USA (2021); Ma *et al.* (2021).

3.2 DESCRIPTION OF FLOATING MACROPHYTES AND THEIR ECOLOGICAL ROLE

Floating macrophytes play essential ecological functions in aquatic environments. They serve as habitat and food sources for various organisms, such as fish, insects, and microorganisms, providing shelter and nutrition. As significant primary producers, macrophytes perform photosynthesis, converting solar energy into chemical energy, vital for the ecosystem. They also contribute substantially to water quality regulation by filtering pollutants and excess nutrients, which helps maintain the health of the aquatic ecosystem. The roots of macrophytes also play a crucial role in sediment stabilization, preventing erosion. These plants are key actors in the nutrient

cycle, facilitating the recycling and balance of nutrients in the aquatic environment (Lesiv *et al.*, 2020; Revéret *et al.*, 2023).

3.3 NEGATIVE IMPACTS OF EXCESSIVE PROLIFERATION

The excessive proliferation of floating macrophytes can cause serious social, economic, and environmental impacts. Environmentally, in ecosystems where these species are overly abundant, reduced light penetration can hinder the photosynthesis of submerged plants and affect food chains. Additionally, the decomposition of large amounts of macrophytes can lead to oxygen depletion in the water, resulting in fish kills and other impacts on aquatic life. This alteration also directly affects biodiversity and aquatic habitats, impacting ecosystem structure and function (Kumar *et al.*, 2022; Poveda, 2022; Wu *et al.*, 2021).

Economically, the overgrowth of floating macrophytes incurs substantial costs, ranging from direct expenses for mechanical removal and management to losses in hydropower generation due to turbine and channel blockages. This phenomenon adversely affects crucial economic activities such as tourism and fishing, reducing the attractiveness and accessibility of water bodies. Furthermore, water quality degradation leads to additional costs for Water Treatment Plants (WTPs), increasing expenses for affected municipalities and regions. Mechanical removal of macrophytes can cost millions annually, depending on the frequency and extent of infestations, with indirect costs significantly impacting the local economy (Misteli *et al.*, 2023; Tasker *et al.*, 2022; C. Yang *et al.*, 2023).

Socially, the excessive proliferation of floating macrophytes affects the lives of riverside communities that depend on the health of aquatic ecosystems for their livelihood, whether through fishing, agriculture, or tourism. Moreover, the excessive presence of these plants can limit access to water resources, complicate water transport, and increase public health risks as stagnant waters can become breeding grounds for vector-borne diseases like malaria (Akowanou *et al.*, 2023).

3.4 CONVENTIONAL MACROPHYTE CONTROL TECHNIQUES

The physicochemical conditions and nutrient availability in reservoirs are crucial for the survival and development of aquatic macrophytes. High densities of these plants often signal environmental imbalances, such as sewage pollution and the absence of riparian forests. To control excessive macrophyte growth, a specific analysis of each reservoir is essential, considering its dynamics, history, biota, and unique characteristics, to understand how the plants interact with the system (Lu *et al.*, 2018; Manolaki *et al.*, 2020).

In a review study by Karouach *et al.* (2022), existing approaches to control and manage the proliferation of water hyacinth (*Eichhornia crassipes*) were evaluated, highlighting globally tested control programs. The advantages and disadvantages of the main proposed control methods, including biological, chemical, and physical, were analyzed. The authors suggest that short to medium-term physical control effectively manages plant proliferation, complementing biological control. Moreover, they emphasize that integrated control, combining biological and physical methods, is a more sustainable and economical approach.

While removing macrophytes is necessary to mitigate their negative impacts, the removal techniques, such as mechanical extraction, can disturb aquatic ecosystems and affect local biodiversity. Frequent removal can be costly and labor-intensive, requiring careful management to prevent additional damage to the ecosystem. In some cases, macrophyte removal may have a temporary impact, with vegetation quickly returning if nutrient and water conditions remain favorable (Thiemer *et al.*, 2021).

To control excessive growth of macrophytes, it's crucial to implement integrated management strategies. These include controlling nutrients at the source, such as improving wastewater treatment systems and managing sustainable agricultural practices to reduce nutrient runoff. Additionally, biological methods, like introducing specific herbivorous species, and physical techniques, such as barriers or selective cutting, can be applied to maintain ecological balance and reduce the adverse impacts of macrophytes (Poveda, 2022; Thiemer *et al.*, 2023).

Conventional methods for controlling macrophytes, such as mechanical, chemical, and biological control, each have their pros and cons and are crucial for

managing aquatic ecosystems. Mechanical control, despite its immediate efficacy, can negatively impact aquatic biodiversity, affecting organisms such as phytoplankton, zooplankton, and macroinvertebrates. Chemical control, while effective, poses risks of toxicity and environmental contamination. Biological control, considered more sustainable, requires careful management to avoid ecological imbalances (Cerveira Junior *et al.*, 2023; Misteli *et al.*, 2023; Thiemer *et al.*, 2021).

Studies analyzing conventional macrophyte control methods have led to Table 3, which shows that while mechanical and chemical methods offer quicker, direct action, they pose significant sustainability and environmental impact challenges. Conversely, biological control, although potentially more sustainable and with less environmental impact, requires careful evaluation to prevent ecological imbalances. Integrating these methods may provide a more efficient and ecologically responsible solution for managing aquatic macrophytes (Diniz *et al.*, 2005).

Table 3. Comparative Analysis of Conventional Macrophyte Control Methods

Control Method	Efficacy	Sustainability	Cost	Environmental Impact
Mechanical	High for immediate removal	Low due to habitat disturbance and need for frequent interventions	High, due to specialized equipment and labor	Potentially high, can disturb aquatic ecosystems
Chemical	High for quick control	Low, risk of toxicity and resistance	Variable, depending on the herbicide	High, risk of contamination and impact on non-target species
Biological	Variable, dependent on the efficacy of the organism	High, more natural and less invasive methods	Initially high, but lower in the long term	Lower, but risk of ecological imbalance if poorly managed

Source: Karouach *et al.* (2022)

3.5 FUNDAMENTALS OF ULTRASONIC CONTROL

Ultrasonic waves are sound waves with frequencies above the audible limit for humans, that is, above 20,000 Hz (20 kHz). These waves have applications in various fields, from medical diagnostics to industrial cleaning and pest control in aquatic environments. When ultrasonic waves pass through a liquid, such as water in reservoirs, they can induce the phenomenon of acoustic cavitation. This phenomenon occurs when US waves create gas or vapor bubbles in the liquid. These bubbles can grow and collapse rapidly, generating local shock waves and high temperatures.

Acoustic cavitation can lead to a series of changes in the cells of aquatic plants. One of the main consequences is microscopic flow, which can alter the internal structure of the cell (Fetyan; Salem Attia, 2020; Li *et al.*, 2014; Rajasekhar *et al.*, 2012; Romyantsev *et al.*, 2021).

The shock waves and mechanical forces generated by the collapse of the bubbles can damage the cell walls of the plants. This damage can be minor, such as small cracks, or severe, leading to the total rupture of the cell wall. Besides the mechanical effects, the energy from the US can be converted into heat, causing thermal effects on the cells. This can alter or damage heat-sensitive cellular components. These combined effects can lead to cell death and tissue damage in aquatic plants. In cases of intense or prolonged exposure to US, generalized plant tissue death may occur, affecting their survival capacity (Dehghani *et al.*, 2023; Kurokawa *et al.*, 2016; B. Ma *et al.*, 2005; Wang *et al.*, 2021).

3.6 ECOLOGICAL IMPLICATIONS OF ULTRASOUND USE

Ultrasound (US) has been used to control the proliferation of aquatic plants and cyanobacteria in reservoirs and other aquatic environments. While effective in reducing invasive or harmful biomass by damaging the cell walls and tissues of these organisms, it is crucial to assess the intensity and duration of US exposure to protect the aquatic ecosystem, especially non-target organisms (Klemenčič; Klemenčič, 2021; Robles *et al.*, 2022).

3.6.1 Effects of Ultrasonic Control on Non-Target Organisms

Understanding how US affects these organisms is vital to ensure the safety and sustainability of its application. Different species show varying resiliencies to the mechanical effects of acoustic cavitation, which can rupture cell membranes and tissues, implying the need for careful adjustments in the application of ultrasound (Lira *et al.*, 2017; Moftakhari *et al.*, 2022). While some species of fish and invertebrates show minimal or no change, other aquatic life forms, such as certain algae and zooplankton, may experience effects ranging from sublethal to lethal (Anabtawi *et al.*, 2024; Jančula *et al.*, 2014; Lürling; Tolman, 2014).

3.6.2 Long-term implications of ultrasound in aquatic ecosystems

Ultrasound shows promising results in controlling algal blooms and macrophyte growth, rapidly reducing biomass. However, its long-term impacts are complex and require a detailed understanding to ensure sustainable applications, especially due to potential effects on aquatic biodiversity (Joyce *et al.*, 2010; Sutherland *et al.*, 2015).

Studies suggest that ultrasound can damage external and internal structures of aquatic organisms, altering their susceptibility to predators and diseases, potentially affecting food chains and the reproduction of key species like zooplankton, algae, and macrophytes, impacting aquatic community structure (Knobloch *et al.*, 2021; Park *et al.*, 2017).

Sonication may release nutrients from lysed cells, such as nitrogen and phosphorus, promoting the growth of microorganisms and potentially intensifying algal blooms after an initial decrease. These effects complicate effective water resource management and require careful strategies (Ghernaout; Elboughdiri, 2020).

Understanding and mitigating the long-term impacts of ultrasound necessitates prolonged studies including detailed ecosystem monitoring. Collaboration across scientific and technical specialties is crucial to develop practices that maximize benefits and minimize environmental risks (Humbert; Quiblier, 2019).

3.6.3 Impacts of ultrasonic control on toxin release

When cyanobacteria are exposed to ultrasonic radiation, they can release toxins such as microcystins, posing risks to both aquatic life and human health. This is particularly concerning in reservoirs used for water supply and recreation. To mitigate these risks, it is essential to carefully control the application of ultrasonic treatments, monitor water quality continuously, and adapt ultrasound parameters to minimize cyanobacterial stress and toxin release. Further research may enhance the safety and efficacy of ultrasonic methods in managing water environments. (Ghernaout; Elboughdiri, 2020; Peng *et al.*, 2023b; Thodhal Yoganandham; Pei, 2023).

3.6.4 Impacts of ultrasound on cyanobacterial cell structure and ecological consequences

The fragmentation of cyanobacterial cell walls by ultrasound releases substrates that can accelerate microbial biomass, reducing dissolved oxygen and negatively impacting aquatic fauna, potentially causing problems like hypoxia and fish deaths (Wu *et al.*, 2012; Zhan *et al.*, 2021). Contrary to the idea that ultrasonic fragmentation of cyanobacterial cell walls can release toxic substrates and exacerbate hypoxia, research indicates that selecting appropriate ultrasound parameters can avoid complete cellular lysis and consequently the massive release of harmful organic substances. This suggests a potential pathway for environmentally sustainable management of cyanobacterial blooms, using ultrasound to subtly modulate cell viability without causing broad harmful effects to the aquatic ecosystem (Grigoryeva *et al.*, 2018).

3.6.5 Monitoring and management

Therefore, it can be argued that with precise adjustments and continuous monitoring, the use of ultrasound can be a viable strategy for controlling cyanobacteria populations in an environmentally responsible manner. Implementing rigorous monitoring strategies after ultrasound application is essential. Continuous monitoring of water quality and toxin levels will help ensure that the benefits of control are not undermined by negative environmental impacts (Ali *et al.*, 2020; Burch *et al.*, 2021; Grigoryeva *et al.*, 2018; Rellán *et al.*, 2007).

3.7 PRACTICAL APPLICATIONS OF ULTRASOUND

Ultrasound techniques are used in various fields, such as chemical engineering for dispersing nanoparticles, accelerating chemical reactions, extracting bioactive compounds, and emulsification; in environmental engineering for applications like wastewater treatment, water disinfection, soil remediation, and controlling cyanobacteria and algae, in industrial cleaning, and in separation and extraction processes (Assunção *et al.*, 2022; Cai *et al.*, 2014; Fetyan; Salem Attia, 2020; Kist *et al.*, 2020; Kitamura *et al.*, 2023; Long *et al.*, 2021; Pacheco-Álvarez *et al.*, 2022); in

medicine for diagnostics and treatment; in the food industry for processing and preservation (Dolas *et al.*, 2019; Gallo *et al.*, 2018; Song *et al.*, 2021; Zhu *et al.*, 2023). Ultrasound is also applied in the pharmaceutical industry and in nanotechnology for material synthesis. These applications are noted for their efficiency, time and chemical use reduction, and versatility (Lüring; Tolman, 2014; Yücepete *et al.*, 2019).

These techniques face significant challenges in transitioning from laboratory to industrial settings, notably in terms of measurement precision and reliability. The Ultrasound Laboratory at National Institute of Metrology, Standardization and Industrial Quality (INMETRO) illustrates the complexity of this transition, highlighting the importance of US metrology, transducer and sensor calibration, and metrological characterization of the ultrasonic field. These measures are essential to ensure accuracy in industrial environments, where quality and efficiency standards are stringent (Brasil, 2020; Wang *et al.*, 2022).

Additionally, the energy transition towards more sustainable and energy-efficient processes poses additional challenges, such as integrating renewable sources, modernizing infrastructure, professional training, cultural changes, and political resistance. To meet sustainability goals, companies are adopting strategies like energy reuse, applying the principles of reduce, reuse, and recycle, and efficient asset monitoring. These approaches contribute to both operational efficiency and reducing environmental impact, maintaining the relevance of ultrasonic techniques in engineering research and development (Lampis *et al.*, 2021).

Most modern ultrasonic devices rely on piezoelectric material transducers, which react to small changes in size when an electrical potential is applied. These crystals convert electrical energy into mechanical vibration (sound) at high frequencies, producing ultrasonic sound at sufficiently high alternating potentials. Ultrasonic sound is a form of mechanical energy transmitted by pressure waves in media such as gases, liquids, or solids, with frequencies above the upper limit of human hearing, intensities above 20 kHz (Gallo *et al.*, 2018; Lira *et al.*, 2017).

3.8 CASE STUDIES

The studies by Wu *et al.* (2011) and Rajasekhar *et al.* (2012) investigated the use of ultrasound (US) as an effective and environmentally friendly method for

controlling cyanobacterial blooms, particularly the species *Microcystis aeruginosa*. It was found that sonication, the application of ultrasonic waves, is effective in controlling these blooms, with efficacy dependent on variables such as frequency, intensity, and exposure time. The results demonstrated that US can effectively inactivate algal cells and has the potential to degrade toxins, offering a promising treatment in pilot scale and field tests. This method, less polluting and feasible for large-scale application, works through the generation of cavitation bubbles that destroy cyanobacterial cells (Purdi *et al.*, 2023).

The study by Li *et al.* (2021) explores the use of ultrasound (US) to control cyanobacterial blooms, focusing on the intracellular structural changes in *Microcystis*. The research assessed the efficiency of cell removal and used transmission electron microscopy (TEM) to visualize structural changes, supplemented by polarized light measurements. It was found that polarization parameters accurately reflect intracellular changes under different sonication durations, correlating with removal efficiency data and TEM images. The study suggests that polarized light is a promising tool to determine the optimal sonication time for effective control of cyanobacterial blooms in the field.

Another study by Xu *et al.* (2023) also examines the impact of low-frequency ultrasonic treatment on *Microcystis aeruginosa* blooms, showing that while sonication effectively removes algae, it also intensifies the release of organic matter and microcystins. This process accelerates algal decomposition, creates anaerobic conditions, and increases methane production, suggesting that using ultrasound to control algal blooms might increase water toxicity and greenhouse gas emissions.

Peng *et al.* (2023a) studied how ultrasonic irradiation of extracellular organic matter from algae influences the formation of disinfection byproducts such as trichloromethane and haloacetic acids. The findings indicate that ultrasonic irradiation alters the molecular structure of this matter, increasing the formation of these byproducts due to the activity of free radicals, with significant implications for the safety of treated water.

Another study by Rummyantsev *et al.* (2022) explores the effectiveness of low-intensity ultrasound in controlling toxicogenic cyanobacteria like *Synechocystis sp.* in freshwater bodies. The studies show that ultrasonic irradiation causes stress in these cyanobacteria, leading them to thicken their cell walls and produce toxins—a process

that consumes a lot of energy and eventually leads to cell death. This method proves promising as an environmentally safe solution to mitigate toxic blooms in water bodies, contributing to the safety of drinking water and environmental protection.

The study by Shi *et al.* (2023) examines the removal of algae/cyanobacteria and changes in extracellular microcystins during three algae/cyanobacteria inactivation processes using real eutrophic water, evaluating methods like ultrasound (US), copper sulfate, and a biotic algicide (*Bacillus subtilis*). Ultrasound was effective in removing algae/cyanobacteria, but both ultrasound and copper sulfate treatments increased extracellular microcystins. In contrast, the biotic algicide reduced microcystins under certain dosing and reaction time conditions.

In another study, Zhang *et al.* (2021) address effective removal of cyanobacteria and associated toxins, such as microcystins, using a combination of protozoan grazing and ultrasound treatment. The method disaggregated *Microcystis* colonies, making them more accessible for ingestion by protozoans like *Ochromonas*, achieving about 80% removal under optimized conditions. This approach not only enhances algae removal efficiency but also minimizes impacts on non-target organisms and contributes to more sustainable management of harmful algal blooms.

Tzanakis *et al.* (2017) explore the principles and applications of ultrasound focusing on acoustic cavitation in different liquids. Using a 1 kW, 20 kHz piezoelectric transducer, they induced ultrasonic oscillations in deionized water, ethanol, and glycerin, contained in a glass tank. The study focused on the effects of liquid properties on cavitation, including cavitation cloud formation and acoustic emissions, analyzed using a cavitometer. This research is crucial for understanding acoustic cavitation and its implications in various mediums, enhancing knowledge of ultrasound's basic principles and practical applications.

Fetyan and Salem Attia (2020) discuss how ultrasonic waves serve as a novel water treatment technique, acting as an advanced oxidation method to eliminate various contaminants by fundamentally destroying hard-to-degrade organisms and bacterial cells. In another study, Zhang and Xie (2022) examined the bactericidal effects of electrolyzed water and ultrasound on bacteria, finding that their combination could accelerate cell death and minimize early damage to bacteria, offering a more eco-friendly and energy-efficient sterilization technology.

Dehghani *et al.* (2023) explore the use of sonochemical reactors in water and wastewater purification, highlighting their effectiveness against microbiological hazards that pose environmental and health risks. The review discusses acoustic cavitation reactors, which use ultrasonic energy, and hydrodynamic cavitation reactors, both efficient in deactivating microorganisms, and covers the environmental benefits, energy efficiency, economic aspects, challenges, and potential future research directions of these techniques.

In a study by Wu and Wu (2007), the control of water chestnut (a type of macrophyte) using ultrasound (US) was investigated. This plant is considered an invasive aquatic species. Different frequencies and amplitudes of US, applied directly to the plants via submerged transducers, showed that 20 kHz ultrasound was particularly effective, causing substantial damage to the plant's cells and tissues, resulting in a high mortality rate. Direct application to the stem was more efficient than to the petiole. The study suggests that US is a viable and environmentally safe alternative for managing water chestnut, though further research is needed on impacts on other aquatic species and the implementation of multi-transducer US devices for large-scale use.

In research by Sobral e Santos (2023) a survey was conducted in April 2023 in national and international patent databases—National Institute of Industrial Property (INPI), World Intellectual Property Organization (WIPO), European Patent Office (EPO), and the Lens database—using the terms "macrophytes" AND "ultrasound". Seventy patents were found, of which 12 were selected for critical analysis focusing on the use of US for macrophyte control. These patents vary in methods and devices for applying US in aquatic environments. The authors highlight the potential of US for sustainable control of macrophytes in reservoirs, suggesting the need for more research and the development of new patents in this area.

Research was conducted on the control of aquatic organisms from the perspective of applied methods, efficacy, feasibility, and limitations of US application, and a table of this information was constructed, which can be seen in Table 4.

Table 4. Studies on the control of aquatic organisms through the application of ultrasound (US)

Study	Method	Efficacy	Viability	Limitations	Reference
A review of the use of sonication to control cyanobacterial blooms	Review of studies that applied sonication with variable frequencies and intensities to inhibit cyanobacteria, focusing on the disruption of gas vacuoles and inhibition of photosynthesis.	Ultrasound proved effective in controlling cyanobacteria, impacting cellular structure, inhibiting photosynthesis, and damaging gas vacuoles. Efficacy depends on factors such as frequency, intensity, and duration of exposure.	The method is considered environmentally friendly compared to other strategies such as the use of algicides.	Sonication can cause the release of toxins such as microcystins from cyanobacterial cells, and selecting appropriate ultrasonic parameters is crucial to avoid this.	(Rajasekhar <i>et al.</i> , 2012)
Control of Algal Growth in Reservoirs with Ultrasound	Use of ultrasound at frequencies of 20 kHz and 862 kHz to reduce algal growth, with varying efficacies based on the type of algae.	Greater susceptibility of filamentous cyanobacteria to high-frequency ultrasound. Efficacy varies according to the type of algae.	The study suggests that sonication may not be economically viable as a sole solution for algal blooms due to high energy consumption.	Some species, like <i>Microcystis aeruginosa</i> , showed resistance to ultrasound at all tested frequencies.	(Purcell, 2009)
Effect of sonication frequency on the disruption of algae	Investigation of cellular disruption in different algae species using ultrasound frequencies from 0.02 to 4.3 MHz, relating the optimal frequency to the mechanical properties of the cells.	Reduction in the number of algae was dependent on the ultrasound frequency, and different algae species had different optimal frequencies for disruption.	The study suggests that physical effects of ultrasound, such as cavitation, are responsible for disrupting algae.	The need to select the correct frequency for each type of algae can be a challenge in practical application.	(Kurokawa <i>et al.</i> , 2016)
Effect of ultrasonic frequency and power on algae suspensions	Study of the impact of ultrasound on <i>Microcystis aeruginosa</i> at frequencies from 20 kHz to 1.146 MHz to determine the most effective settings for algae reduction.	The reduction in the number of algae depends on both the frequency and intensity of the ultrasound. Some frequencies were more efficient than others.	The efficiency of ultrasound for algae control is influenced by energy consumption, suggesting that optimal parameter settings are crucial.	The efficacy varied considerably among different frequencies and intensities, indicating the need for careful calibration.	(Joyce <i>et al.</i> , 2010)

Source: Authors

This table provides a comprehensive overview of various research studies examining the effectiveness of ultrasound technology in controlling aquatic organisms, specifically algae and cyanobacteria, under different conditions. Each study focuses on different aspects of ultrasound application, including frequency, intensity, and environmental impact.

3.9 COMPARISON BETWEEN ULTRASONIC AND CONVENTIONAL TECHNIQUES

Comparing ultrasonic and conventional techniques for controlling aquatic organisms such as cyanobacteria and algae involves assessing various aspects such as efficacy, sustainability, cost-effectiveness, and environmental impacts. Table 5 provides a visual comparison based on these criteria.

Table 5. Comparison between ultrasonic and conventional techniques for controlling aquatic organisms

Criteria	Ultrasonic Techniques	Conventional Techniques
Efficacy	<ul style="list-style-type: none"> - Effective in disrupting and inhibiting cyanobacteria and algae; - Specific to certain types, may require adjustments. 	<ul style="list-style-type: none"> - Generally effective, but may not be specific. - May require multiple applications.
Sustainability	<ul style="list-style-type: none"> - Environmentally friendly, does not release chemicals. - Low disturbance to the aquatic ecosystem. 	<ul style="list-style-type: none"> - Depending on the technique, may use harmful chemicals. - Can affect aquatic biodiversity.
Cost-effectiveness	<ul style="list-style-type: none"> - Higher initial cost for installation and calibration. - Low operational costs in the long term. 	<ul style="list-style-type: none"> - Variable costs, depending on the method. - Maintenance and reapplication can be costly.
Environmental Impacts	<ul style="list-style-type: none"> - Minimalist, mainly due to the absence of chemicals. - May affect species sensitive to ultrasound. 	<ul style="list-style-type: none"> - Potential for chemical pollution. - Risks of ecological imbalance.

Source: Getchell *et al.* (2022); Klemenčič; Klemenčič (2021); Mullick; Neogi (2017); Svendsen *et al.* (2018); Tan *et al.* (2021); Wu; Mason (2017)

This table summarizes the key differences in efficacy, sustainability, cost-effectiveness, and environmental impacts between ultrasonic and conventional techniques for controlling aquatic organisms like cyanobacteria and algae. Ultrasonic techniques are more sustainable and have lower environmental impacts due to the absence of chemicals, making them particularly advantageous in sensitive environments. Conventional techniques, while often effective, can pose greater environmental risks, especially with the use of chemicals. In terms of cost-

effectiveness, ultrasonic techniques may be more expensive initially but offer long-term savings due to reduced maintenance and reapplication needs. The choice between techniques should consider the specific context, including the target organism type, ecosystem sensitivity, and available resources.

3.10 GAPS IN THE LITERATURE AND FUTURE RESEARCH DIRECTIONS

Current studies on the control of aquatic organisms, including cyanobacteria, algae, and macrophytes, reveal significant gaps, particularly in the specificity of techniques for different species and in understanding long-term impacts on the aquatic ecosystem. Many studies focus on immediate effects without assessing the recovery of non-target organisms or the development of resistance. Furthermore, there is a lack of comprehensive comparative studies that evaluate the efficacy, cost-effectiveness, and environmental impacts of various control methods, including physical, chemical, biological, and ultrasonic approaches (Huisman *et al.*, 2018; Rocha *et al.*, 2018).

For future research directions, it is essential to explore integrated methods that combine different control techniques, assessing their detailed environmental impacts and developing new technologies for more selective and sustainable control. It is important to study the adaptation and resistance of aquatic organisms to control methods and to consider the socioeconomic aspects, especially for communities dependent on aquatic resources. Developing long-term monitoring and evaluation protocols is also crucial to understand the effectiveness and impacts of control methods (Huisman *et al.*, 2018; Rocha *et al.*, 2018; Zanchett; Oliveira-Filho, 2013).

4. CONCLUSION

Based on the review of studies on the use of ultrasound (US) for controlling cyanobacteria and macrophytes, it is concluded that frequencies above 20 kHz and, in some cases, higher than 1 MHz are effective in disintegrating cyanobacteria. For macrophytes, the frequency of 20 kHz also showed high efficacy. The recommended exposure time to ultrasonic radiation varies depending on the type of organism and environmental conditions, but studies indicate that exposures of 40 seconds can collapse gas vacuoles that provide buoyancy to these aquatic organisms. Adjustments

in intensity and exposure duration are necessary according to specific environmental conditions and the biology of the target organisms to optimize efficacy and avoid significant negative impacts on the aquatic ecosystem. However, most of the studies analyzed were conducted on a laboratory scale.

The observed environmental impacts include the release of toxins, such as microcystins, which can harm both aquatic life and human health. Cellular fragmentation caused by US can lead to hypoxia and fish deaths due to reduced dissolved oxygen, and potentially exacerbate existing ecological problems. These effects underline the need for careful control and continuous monitoring during the application of US to mitigate environmental risks.

The application of US also affects non-target organisms, with different species showing varying degrees of resilience to the effects of acoustic cavitation. While some species may not be significantly affected, others may suffer sublethal or lethal effects, which can impact biodiversity and the dynamics of the aquatic ecosystem. These findings underscore the importance of developing US parameters that minimize damage to non-target organisms.

The long-term effects of using US include possible changes in the aquatic community structure and the susceptibility of organisms to predators and diseases. Additionally, the release of nutrients from lysed cells can promote new algal blooms, complicating effective water resource management. Long-term studies and continuous monitoring are essential to fully understand and mitigate these impacts.

Finally, it is recommended that research continues to develop more efficient and less invasive transducers, as well as interdisciplinary collaboration for testing and applications of this control method on a laboratory scale and on a large scale, such as in reservoirs, in order to optimize the use of US. The integration of adaptive and sustainable control strategies can significantly contribute to efficient and ecological reservoir management, promoting the preservation of biodiversity and the sustainability of water resources.

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CHAPTER 4

ESG NA PRODUÇÃO DE ETANOL

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ABSTRACT: The objective of this research was to verify in the literature whether the production of sugarcane and ethanol is associated with good environmental, social and governance (ESG) practices. Searches were performed in the ScienceDirect and Spell databases. The papers on sugarcane and ethanol do not expressly mention the relationship between production and ESG, but what can be inferred is that the relationship was reported in another way, such as concern with the environmental impacts of the crop, reduction of greenhouse gas emissions, better alternatives for handling fertilizers, etc. Research on ESG practices found that the authors focused more on the relationship of companies with potential investors and evaluating practices, through indexes, as indicators of good management, for example in preventing the risk of bankruptcy.

KEYWORDS: sugarcane, ethanol, environmental, social, governance.

RESUMO: O objetivo desta pesquisa foi verificar na literatura se a produção de cana-de-açúcar e etanol está associada a boas práticas ambientais, sociais e de governança (ESG). As buscas foram realizadas nas bases de dados ScienceDirect e Spell. Os artigos sobre cana-de-açúcar e etanol não mencionam expressamente a relação entre produção e ESG, mas o que se pode inferir é que a relação foi relatada de outra forma, como a preocupação com os impactos ambientais da cultura, a redução das emissões de gases de efeito estufa, melhores alternativas para o

manuseio de fertilizantes etc. A pesquisa sobre práticas de ESG constatou que os autores se concentraram mais no relacionamento das empresas com potenciais investidores e na avaliação de práticas, por meio de índices, como indicadores de boa gestão, por exemplo, na prevenção do risco de falência.

PALAVRAS-CHAVE: cana-de-açúcar, etanol, ambiental, social, governança.

1. INTRODUCTION

The development of renewable energy is one of the primary global interests in promoting sustainability and environmental quality (Lima *et al.*, 2020). Consequently, clean and renewable alternatives have been sought to provide new materials and energy, thereby reducing reliance on fossil fuels derived from oil. In this context, sugarcane has become an important raw material as a solution to this demand (Vandenberghe *et al.*, 2022).

In Brazil, the sugar-energy sector is active, relevant, and plays a significant role in the economy (Aliano Filho; Melo; Pato, 2021; Branco *et al.*, 2019; Gonçalves *et al.*, 2021). The National Supply Company (CONAB, 2022) projected the production of 596.1 million tons in the 2022/23 sugarcane harvest, an increase of 1.9% compared to the previous harvest.

In addition to sugar production, sugarcane can also be processed into ethanol (Aliano Filho; Melo; Pato, 2021). Ethanol is an efficient and renewable biofuel that promotes the diversification of the energy matrix, reduces pollutants, and decreases greenhouse gas (GHG) emissions, playing a vital role in the energy sector (Coelho *et al.*, 2006; Goldemberg; Coelho; Guardabassi, 2008; Santos *et al.*, 2020; Souza *et al.*, 2021).

Given the need to reduce GHG emissions, fossil fuel consumption, and increase the use of renewable energy sources (Scheiterle *et al.*, 2018), a growing awareness of environmental, social, and governance (ESG) issues has been observed worldwide. Over the past twenty years, these issues have revealed their influence not only on profitability but also on the financial viability of various companies (Billio *et al.*, 2021).

In this context, ESG activities and practices have emerged for companies to express their commitment to environmental, social, and governance issues, unifying many of the demands of stakeholders (Santos; Pereira, 2022). Within this perspective, the objective of this research was to verify in the literature whether the production of sugarcane and ethanol is associated with good ESG practices.

This article, in addition to this introduction, presents in section two the theoretical framework, in section three the research method employed, in section four the results, and in section five the conclusions.

2. THEORETICAL FRAMEWORK

2.1 SUGARCANE ETHANOL

Global interest in renewable energies as a basis for meeting socioeconomic needs has been expanding, particularly since the early 21st century, due to the worldwide energy supply, rising oil prices, and the effects of climate change. Consequently, the importance of biofuels in the energy industry has increased (Castaneda-Ayarza; Godoi, 2021; Lazaro; Giatti; Oliveira, 2021).

Brazil is the world's largest producer of sugarcane and one of the largest producers of ethanol, and to meet the growing demand for renewable energy, estimates indicate that ethanol production will need to nearly double in Brazil by 2030 (Andrade Junior *et al.*, 2019; Sanches *et al.*, 2021). Additionally, Brazil is a pioneer in the large-scale production and consumption of fuel ethanol (Castaneda-Ayarza; Godoi, 2021), thereby contributing to the development of new models for renewable energy production (Souza *et al.*, 2019).

The sugarcane supply chain involves cultivation, harvesting, transportation to mills, and processing at the mills (Aliano Filho; Melo; Pato, 2021). This industry is the main supplier of renewable energy in Brazil through ethanol production and electricity generation from burning bagasse and cane straw (Branco *et al.*, 2019; Souza *et al.*, 2021). Ethanol is a renewable fuel produced by fermenting the extract of sugarcane and molasses, has a lower carbon footprint, is biodegradable, and offers greater energy-environmental efficiency (renewable energy) compared to oil (Lima *et al.*, 2020). In this sense, ethanol from sugarcane helps reduce GHG emissions and can replace fossil fuels (Coelho *et al.*, 2006).

Although promising as a gasoline substitute, ethanol derived from sugarcane has its raw material constituting about 40% to 70% of production costs, and first-generation (1G) ethanol production competes directly with land use for food crop cultivation (Pacheco; Silva, 2019).

Thus, advancements in second-generation (2G) biofuels produced from lignocellulosic biomass, such as crop residues, woody crops, or energy grasses, are gaining traction. Lignocellulosic biomasses (rice straw, corn cobs, wheat straw, sugarcane bagasse, cotton stalks) are among the best alternatives due to their

abundance, renewability, and relative cost-effectiveness. The production of 2G bioethanol will reduce environmental impacts, provided that the assessment takes a long-term perspective, including all stages of conversion and bioresource regeneration (Sharma; Larroche; Dussap, 2020).

Oliveira *et al.* (2019) warned that biofuels are essential for meeting society's energy needs in the coming decades, but the sustainability of large-scale land-use conversions to supply agricultural raw materials for biofuel production remains uncertain. Another issue raised by Sousa *et al.* (2016) regarding the use of biofuels is that the average consumer is still unwilling to pay more for a biofuel that mitigates pollutant emissions.

2.2 ENVIRONMENTAL, SOCIAL AND GOVERNANCE

Environmental, Social, and Governance (ESG) activities and practices refer to the investment of resources in routines, processes, practices, or activities aimed at the continuous improvement of a company's performance in ESG concerns. These routines, processes, practices, or activities are implemented to minimize potential negative impacts on the environment, society, and corporate governance (Whitelock, 2015).

Within this context, the author adopts the definition of ESG as a set of activities or processes associated with an organization's relationship with its ecological surroundings, its coexistence and interaction with human organisms and other populations, and its internal corporate system of controls and procedures (such as processes, customs, policies, laws, rules, and regulations) to direct, manage, and oversee all business operations in order to meet the interests of shareholders and other stakeholders (Whitelock, 2015).

Each of the three pillars that guide ESG has relevant topics within its concept, resulting in a body of themes that drive responsible actions from organizations in agribusiness, particularly in sugarcane ethanol culture towards the 2030 Agenda. For the environmental pillar, an analysis is made regarding environmental aspects and natural resources, carbon emissions, climate change, pollution, and waste management. For the social pillar, the analysis focuses on stakeholders—meaning people and the community as a whole—covering health, safety, diversity, training and development of employees, consumer responsibility, and social projects. As for

governance, the analysis evaluates how the corporation is governed and managed, and how it acts with transparency, equity, and ethics in business strategies, considering shareholder rights, remuneration policies, and board decisions (Neves; Martinez, 2020).

The concept of ESG emerged for companies to express their commitment to environmental, social, and governance issues, unifying many stakeholder demands. In addition to investigating environmental impacts, its model of social participation and governance has become increasingly important for investors. As an emerging topic in academia and industry, there is still a quest for a comprehensive materiality matrix, central ESG parameters, and the use of a matrix to compare companies in quantitative performance rankings, reducing the reliance on qualitative reports with negative screening published by specialists. Few studies suggest evaluating ESG performance for certain sectors of the economy; however, there seems to be a persistent difficulty in finding an optimal solution for most companies (Santos; Pereira, 2022).

The term ESG was introduced in 2004 by the United Nations (UN) with the publication of the report “Who Cares Wins” in partnership with the World Bank, establishing the goal of regrouping three main pillars of ethical finance: environmental, social, and governance (Billio *et al.*, 2021; Moreira *et al.*, 2022).

According to this UN document (2004), relevant ESG issues for investment decisions differ across regions and sectors and highlighted issues with a wide range of impacts on companies:

- environmental Issues: climate change and related risks; the need to reduce emissions and toxic waste; regulations expanding the boundaries of environmental responsibility concerning products and services; increased pressure from civil society to improve performance; transparency and accountability, leading to reputational risks if not managed properly; emerging markets for environmental services and eco-friendly products;
- social issues: health and safety in the workplace; community relations; human rights issues within the company and among suppliers/contractor facilities; governmental and community relations in the context of operations in developing countries; increased pressure from civil society to improve performance; transparency and accountability, leading to reputational risks if not managed properly;

- corporate governance issues: board structure and accountability; accounting and disclosure practices; audit committee structure and auditor independence; executive compensation; management of corruption and bribery issues.

As more investors adopt responsible investment approaches, the quantity and quality of ESG data disclosed by companies become increasingly important as investors consider incorporating ESG factors into their allocation decisions. Some researchers have suggested that the performance of companies and the quantity of their disclosed data in environmental, social, or governance dimensions are of significant value (Yu; Luu, 2021).

3. METHOD

This is a descriptive study with qualitative approaches, utilizing content analysis (Bardin, 2009). Research was conducted in the ScienceDirect database using the keywords “Brazilian ethanol,” “Brazilian sugarcane,” and “environmental, social and governance,” limited to types “review” and “research.” This database was chosen for its relevant journals, classified in the Qualis A1 stratum (2017-2020) of the Sucupira Platform of the Coordination for the Improvement of Higher Education Personnel (CAPES, 2022), including journals such as Biomass and Bioenergy, Journal of Cleaner Production, and Resources, Conservation and Recycling, among others, known for their high impact factor and ease of access. The research was conducted in May and June 2022, focusing on articles published up to the year 2021.

4. RESULTS

In the search of the ScienceDirect database, regarding the filter “Title, abstract, keywords,” 75 articles were found with the keywords “Brazilian ethanol,” 117 articles with “Brazilian sugarcane,” and 179 articles with the words “environmental, social and governance.”

Within the conducted research, no articles were found that directly relate the production of sugarcane and ethanol to ESG activities. Below, ten recent articles on the production of sugarcane, ethanol, and ESG activities will be presented, as outlined in Table 1.

Table 1. Evaluated articles

Nº	Ano	Título	Autores	Periódico
1	2021	A bi-objective mathematical model for integrated planning of sugarcane harvesting and transport operations	Aliano Filho; Melo; Pato	Computers & Operations Research, v. 134, 105419, p. 1-19
2	2021	Strategies to improve the environmental efficiency and the profitability of sugarcane mills	Gonçalves et al.	Biomass and Bioenergy, v. 148, 106052, p. 1-10
3	2021	Water-energy-food nexus approach at the core of businesses – How businesses in the bioenergy sector in Brazil are responding to integrated challenges?	Lazaro; Giatti; Oliveira	Journal of Cleaner Production, v. 303, 127102, p. 1-11
4	2021	Agronomic, economic, and environmental assessment of site-specific fertilizer management of Brazilian sugarcane fields	Sanches et al.	Geoderma Regional, v. 24, e00360, p. 1-11
5	2021	Unraveling the potential of sugarcane electricity for climate change mitigation in Brazil	Souza et al.	Resources, Conservation and Recycling, v. 175, 105878, p. 1-12
6	2022	The sustainability trap: Active fund managers between ESG investing and fund overpricing	Bofinger	Finance Research Letters, v. 45, 102160, p. 1-5
7	2022	Competition and ESG practices in emerging markets: Evidence from a difference-in-differences model	Martins	Finance Research Letters, v. 46, Part A, 102371, p. 1-9
8	2022	Environmental, Social, and Governance e o ciclo de vida das firmas: evidências no mercado de capitais Brasileiro	Moreira et al.	USP International Conference in Accounting, 22
9	2022	Crash risk and ESG disclosure	Silva	Borsa Istanbul Review, v. 22, n. 4, p. 794-811
10	2022	ESG performance scoring method to support responsible investments in port operations	Santos; Pereira	Case Studies on Transport Policy, v. 10, n. 1, p. 664-673

Source: Research data

Biomass is a promising option for the sustainable expansion of bioenergy and mitigation of greenhouse gas (GHG) emissions due to the considerable amount of agricultural waste, primarily sugarcane biomass. Brazil has enormous potential to decarbonize its energy sector by increasing electricity production through sugarcane (Souza *et al.*, 2021). Thus, integrating decisions about the implementation of harvesting and transportation resources will allow for better logistical coordination, rather than planning these operations separately, which is often a common practice, thereby minimizing the total cost of equipment used and the total time required to complete harvesting operations (Aliano Filho; Melo; Pato, 2021).

The implementation of appropriate fertilizer management practices can be a useful tool, as it helps balance and stabilize nutrient levels in the soil, enabling profitable sugarcane crops. Soil fertility decreases over cultivation cycles, indicating that fine-tuning fertilization recommendations is necessary (Sanches *et al.*, 2021). Ethanol is not only a biofuel but also a source of income for the population, an instrument for reducing GHG emissions, and an improvement for the Brazilian

economy, as the population can receive indirect benefits (Gonçalves *et al.*, 2021). However, Lazaro, Giatti, and Oliveira (2021) warned that decisions and policies implemented in the bioenergy sector can have consequences in other sectors, such as land, energy, water, and climate change. Integrated water-energy-food management addresses trade-offs and externalities among these three components, focusing on system efficiency rather than isolated sector productivity.

Regarding ESG practices, disclosure helps reduce capital costs, as it contains relevant information for assessing bankruptcy risk (Silva, 2022). The “ESG score” method can be understood as a risk score (Santos; Pereira, 2022). ESG policies of companies in emerging market countries differ from those of companies in developed countries, and there are undesirable effects of competition on the ESG practices of companies in emerging markets (Martins, 2022). Higher ESG ratings are associated with higher fund prices, thus the pursuit of greater fund sustainability leads to an active overpricing of funds (Bofinger *et al.*, 2022).

Moreira *et al.* (2022, p. 1) reported on ESG practices and the life cycle stage of Brazilian companies listed on B3 during the period 2010-2020: “companies in the early organizational life cycle and at critical moments show lower levels of ESG practices compared to companies in the maturity stage. For companies in growth and decline phases, there was no statistical significance to infer that ESG initiatives compared to those practiced by companies in the maturity stage.”

5. CONCLUSIONS

The objective of this research was to verify in the literature the association between sugarcane and ethanol production and environmental, social and governance (ESG) practices. Although the articles do not directly mention the relationship, what can be inferred is that the relationship was reported in several ways, such as concern about the environmental impacts of the crop/production, reduction of greenhouse gas emissions, better alternatives in fertilizer management, source of income, planning of equipment use during harvest, among others. According to Gonçalves *et al.* (2021), ethanol, in addition to not being just a biofuel, is essential to understand the strong connection that exists between technical, economic, environmental and social factors, since some alternative processes applied in a relevant industry in the country can result

in significant changes for the entire country. Regarding the research on ESG practices, it was found that the authors focused more on the relationship between companies and potential investors and evaluating practices, through indexes as indicators of good management, for example in preventing the risk of bankruptcy, etc. Investing in environmental, social and governance issues involves trade-offs. The key is to determine which investments in E, S and G activities and practices will create value for the company. In other words, to determine what will generate benefits greater than the costs of the investment, at a rate that is acceptable to the company (Whitelock, 2015).

Moreira *et al.* (2022, p. 1) reported in their research on ESG practices and the life cycle stage of Brazilian companies listed on B3 in the period 2010-2020:

[...] the findings indicated that companies in the birth and turbulence stages, that is, at the beginning of the organizational life cycle and at critical moments, have lower levels of ESG practices when compared to companies in the maturity stage. As for companies in the growth and decline phases, there was no statistical significance that would allow us to infer that ESG initiatives would be comparable to those practiced by companies in the maturity stage. The results also indicated that ESG practices have a significant and positive association with the market value of organizations, as well as with business profitability.

It is suggested that new research be conducted involving other databases and that these results be compared with those found here.

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CHAPTER 5

IOT-NODE FOR INDOOR ENVIRONMENT MONITORING BASED ON LORA NETWORK

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ABSTRACT: The concept of the Internet of Things (IoT), just by its name, presents itself as a network of physical objects, which are incorporated into a vast array of sensors, software, and any other type of technology, with the purpose of connecting and exchanging information with other devices and systems via the Internet. As we know it, the IoT is present in a wide range of devices ranging from simple household objects to complex tools spread across all sectors of industry. The means of communication used in IoT devices is based on Long Range (LoRa) technology. This technology stands out for its ability to operate with low energy consumption, which is vital for the use of IoT devices since they run on batteries. This paper will look at the development of an indoor space monitoring system based on an IoT Node made up of sensors supported by the LoRa network. To achieve the objectives, an in-depth study of the technology used in LoRa networks is carried out, followed by a presentation of the system's architecture and then the various tests carried out in indoor spaces to assess the functioning of both the sensors and the network itself. During the work, numerous tests were carried out over extended periods, which will be duly detailed throughout the document. These are used to ensure the stability of the monitoring system and gauge the environmental status of the space where it is installed.

KEYWORDS: LoRa, IoT, LPWAN, communication networks, electronics, telecommunications.

RESUMO: O conceito de Internet das Coisas (IoT), só pelo nome, apresenta-se como uma rede de objetos físicos, que são incorporados a uma vasta gama de sensores, softwares e qualquer outro tipo de tecnologia, com o objetivo de se conectar e trocar informações com outros dispositivos e sistemas via Internet. Como a conhecemos, a IoT está presente em uma ampla gama de dispositivos, desde simples objetos domésticos até ferramentas complexas espalhadas por todos os setores da indústria. O meio de comunicação utilizado nos dispositivos de IoT é baseado na tecnologia Long Range (LoRa). Essa tecnologia se destaca por sua capacidade de operar com baixo consumo de energia, o que é vital para o uso de dispositivos de IoT, pois eles funcionam com baterias. Este artigo analisará o desenvolvimento de um sistema de monitoramento de espaços internos com base em um nó de IoT composto por sensores suportados pela rede LoRa. Para atingir os objetivos, é feito um estudo aprofundado da tecnologia usada nas redes LoRa, seguido de uma apresentação da arquitetura do sistema e, depois, dos vários testes realizados em espaços internos para avaliar o funcionamento dos sensores e da própria rede. Durante o trabalho, foram realizados inúmeros testes em períodos prolongados, que serão devidamente detalhados ao longo do documento. Esses testes são usados para garantir a estabilidade do sistema de monitoramento e avaliar o status ambiental do espaço onde ele está instalado.

PALAVRAS-CHAVE: LoRa, IoT, LPWAN, redes de comunicação, eletrônica, telecomunicações.

1. INTRODUCTION

Since the 1990s, the IoT has been present in our daily lives, and there are articles pointing to the presence of IoT devices – around 22 billion by 2025 [1] – which, in a way, confirms the exponential technological development that has been observed in recent decades. In addition to the interest in developing new IoT devices and their enormous versatility of use, there is a need to automate, control and simplify processes in different economic sectors. Today, it has been proven that practically everything produced in industry (except for a few sectors) uses an IoT device to make processes more efficient, economical and with substantially lower energy consumption, and the main aim in introducing these devices is to keep them running constantly, thus alleviating high energy burdens, and speeding up mass production. The growth of the IoT for sensing, monitoring and other applications brings with it a high demand for autonomous devices with low power, but also for extremely affordable Systems on Chip (SoC) [2] that combine a radio chip with the baseband signal and digital processing.

In this paper, we study the use of the LoRa technology in a sensory system for monitoring indoor spaces and present the development of a project that consists of a IoT system which is uses a wireless point-to-point communication to monitor several environmental characteristics such as humidity, temperature, sound level and concentration of Carbon dioxide (CO₂). Firstly, we begin by looking at the state of the art (section 2) and some related work that serves as a contribution to this document. In section 3, we provide a general overview of the LoRa Network and its key features. In section 4, we present the system's architecture with all its main components from the sensors to the microcontroller, the LoRa modules and the monitoring system. In section 5, we show results and critical analyses. Finally, section 6 finalizes this paper with conclusions.

2. RELATED WORK

The state of the art for the IoT is marked by continued growth and innovation. IoT has transcended its early stages of basic connected devices and evolved into a sophisticated ecosystem of interconnected sensors, devices, and platforms. Edge

computing is increasingly integrated to process data closer to the source, reducing latency and enhancing real-time decision-making. AI and machine learning play a pivotal role, enabling predictive analytics and automation across various industries, from smart cities to healthcare and manufacturing. Security remains a paramount concern, driving advancements in IoT security protocols and practices. Standardization efforts are also gaining momentum to ensure interoperability and scalability. As IoT continues to expand its reach, it promises to revolutionize industries, improve efficiency, and enhance our daily lives in remarkable ways.

LoRa technology has currently become a recurring option when it comes to developing IoT solutions. This is due to its versatility and adaptability to the communication medium. Pires M. Luis wrote the article "Importance of the effects of propagation factor interference on LoRa radio interface collisions". In this article [3], the author discusses the importance of Spreading Factor (SF) interference and the effects of collisions on the LoRaWAN radio interface. To this end, the author carried out an in-depth study of the different types of wireless sensor network as theoretical support for the practical tests carried out to understand the problem and its impact. Numerous measurements were made between an LG02 gateway (two-channel LoRa gateway) and a LoRa device (LoRa Bee module v1.1) connected to an Arduino microcontroller. After meticulously analyzing the results, it was possible to conclude that Time on Air (ToA) increases as SF increases. In addition, the author concluded that with a high SF value a greater distance is obtained in urban and rural environments, but the transmission time increases considerably and therefore the number of collisions increases. In contrast, with low SF values, channel occupancy is lower, and collisions are reduced. These conclusions are important because the project uses a point-to-point LoRa configuration and therefore enriches the theoretical basis described in this article.

Another focus of the project that gave rise to this article is the environmental factor associated with its main objective. Air quality is a topic that has always been in the media, but in recent years humanity has faced an unprecedented war that has changed the way human beings live. S. Vaheed, P. Nayak, P. S. Rajput, T. U. Snehit, Y. S. Kiran and L. Kumar took the initiative to write the article "Building IoT-Assisted Indoor Air Quality Pollution Monitoring System". In this article [4] the authors focused on air pollution, especially in buildings, where ventilation or lack of it can cause serious

health problems for the people inside. Thus, air pollution can cause suffocation, Chronic Obstructive Pulmonary Disease (COPD), lung cancer, infections and more. For this reason, there is a need to monitor indoor air quality for the safety of human life, and indoor air pollution is even more dangerous than outdoor air pollution. The research work carried out by the authors was to design a new system based on IoT technology that monitors indoor air quality and provides an online portal for visualizing the data. This system consists of several gas sensors that help read seven of the most polluting pollutants such as CO₂ (Carbon Dioxide), CO (Carbon Monoxide), O₃ (Ozone), NO₂ (Nitrogen Dioxide), Volatile Organic Compounds (VOC) and Particulate Matter, along with humidity and temperature. Based on an Air Quality Index (AQI), which acts as a sensitizing concept for the public on issues of well-being and health, the intelligent system developed by the authors made it possible to calculate this index using real-time data provided by the IoT devices present. This article is particularly interesting from the perspective of this paper's project, as it addresses the purpose of the paper, which is to monitor almost all the most polluting gases as well as temperature and humidity, producing suggestive alerts for users.

3. LORA NETWORK

LoRa is a low power wide area network (LPWAN) technology owned by Semtech [5] based on chirp spread spectrum (CSS) modulation. In digital communications, CSS is a spectral spreading technique that uses broadband linear frequency modulated chirp pulses to encode information [5]. Chirp pulses are sinusoidal signals whose frequency varies monotonously, i.e., the frequency increases and decreases with time. If the frequency is decreasing, this signal is called down-chirp and if the frequency is increasing, it is called up-chirp. This technique allows a balance between sensitivity and transmission rates with a bandwidth of 125 kHz, 250 kHz, or 500 kHz. Apart from this, the frequencies used may vary depending on the region, as they are unlicensed, those being: 433 MHz and 868 MHz for Europe [2]. LoRa is highly efficient in terms of power usage, wireless data transfer and license-free sub-gigahertz radio frequency bands, which is why it is often used in IoT systems.

LoRa is often used with the LoRaWan protocol. This protocol enables an expansion of the network with the use of terminal nodes which capture environmental

data, the terminal nodes communicate with the LoRaWan gateways which in turn forward the data to a central node that processes the received data.

LoRaWan is a communication protocol that uses packet forwarding as the method of data transfer. This protocol allows communication at a very long range, it has a high capacity for multiple sensors on the network and provides data security with its point-to-point cryptography.

LoRa can also be used on a point-to-point communication. This type of communication only needs two transceivers configured with the same frequency, bandwidth, SF and coding rate (CR). The use of SF provides an extended battery life of all the connected nodes. SF is thus defined as the representation of the number of modulation bits, with one or more data bits representing a symbol, in this context 2^{SF} represents the possible values (equivalent to several SF bits, in binary). In addition to the above, the SF can, in a way, translate the duration of a chirp, i.e., the higher the SF, the longer the chirp and consequently the more bits will be transmitted per chirp. The range of SF values vary between 7 and 12, considering the environmental conditions the lower the SF the higher the number of chirps are sent per second [5][6]. In addition, LoRa modulation also includes a variable error correction scheme which, once applied, aims to substantially improve the robustness of the transmitted signal. It uses the Forward Error Correction (FEC) technique that enables error correction on the receiver by inserting redundant parity bits for each useful bit. There is therefore a need to define the concept of the CR, which is the proportion of useful bits and redundancy. This coding rate can/should be adjusted considering the conditions of the transmission channel to be used. The CR typically is set to 4/5, 4/6 or 4/8 [6] [7], meaning that for every four useful bits there are one, two or four parity bits. If the interference is too great, increasing the CR can help to reduce the amount of channel errors. However, the greater the CR value, the longer the transmission duration [2]. Thus, the bit rate (R_b) can be described by the expression (3.1):

$$R_b = SF * \frac{BW}{2^{SF}} * CR \quad (1)$$

It is well known that to implement any network (of any kind) it is necessary to consider various factors and the trade-offs that exist between them, such as baud rate, distance, energy consumption, bandwidth, and transmission channel.

4. SYSTEM ARCHITECTURE

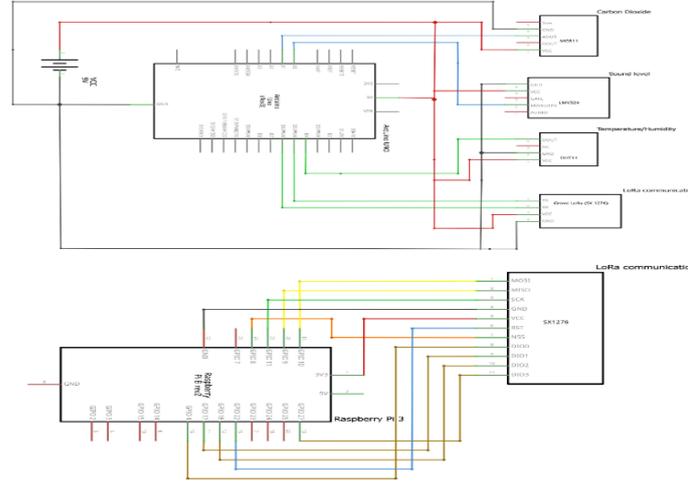
The system's architecture is divided into two blocks: the transmitter block and the receiver block.

The transmitter block contains the DHT11v2 sensor [8] responsible for measuring temperature in degrees Celsius (°C) and humidity in Relative Humidity (%RH); the MG811 sensor [9] which measures CO₂ concentration in parts per million (ppm); the LMV324 sensor [10] capable of measuring sound level in decibel (dB or dBA); an Arduino UNO board [11] with an ATmega328 microcontroller [12] based on Alf and Vegard's Reduced Instruction Set Computer (AVR) Computer Unit (CPU) architecture and finally a Grove LoRa - 868 MHz module [13] based on the Semtech SX1276 chip [14] (5 V or 3.3 V supply voltage, 100 mW transmission power, 300 kbps communication speed, RX current at 10.3 mA and sensitivity up to -148 dBm). This module can transmit up to 27 dBm with a range of 10 km in Line-of-Sight (LoS) conditions and has a Universal Asynchronous Receiver Transmitter (UART) interface for easy communication with the microcontroller. It offers a frequency range of 433, 868 and 915 MHz, with 868 MHz frequency and 5 V supply voltage being used in this project. All the sensors and the LoRa module are directly connected to the Arduino Uno, where set of specific functions was developed (using the proprietary software Arduino IDE) to obtain the correct measurements from the sensors and to control/customise the LoRa parameters. This is also where the data frame was constructed, which is made up of a set of data provided by the sensors.

The receiver block contains: a Raspberry Pi3 (RP3) board [15] made up of a BCM2837 microprocessor based on the Advanced Reduced Instruction Set Computer (RISC) Machine (ARM) architecture [15] [16]; an SX1276 LoRa module operating at 868 MHz (compatible with the module in the transmitter block) with a Serial Peripheral Interface (SPI) and powered by 3.3 V supply voltage, and finally a small display. Here, functions were developed to control/customize the LoRa module and process the data sent by the transmitter. This processing involves not only reading/decoding the data frame but also manipulating it to display the sensory measurements (instantaneous values and average values).

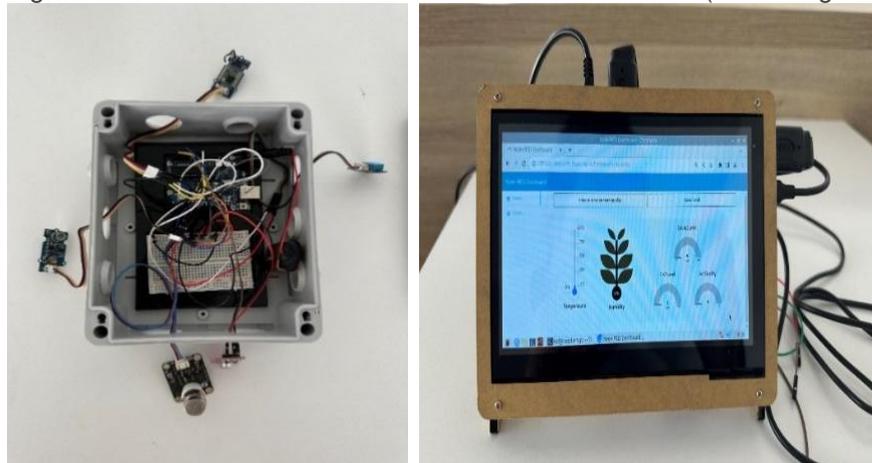
Figure 1 shows the electrical schematics for the transmitter as well as the receiver and Figure 2 shows both the transmitter block and the receiver after assembling.

Figure 1. Electrical schematics of the transmitter and receiver blocks



Source: Authors

Figure 2. Final looks of the transmitter and receiver blocks (author Figure)



Source: Authors

5. TESTS & RESULTS

This fifth section aims to describe the tests carried out on the system and present the results obtained. Firstly, the methodology used to acquire and process the data provided by the sensors will be discussed. This is followed by extensive testing of the sensors to check their validity and accuracy. Finally, the results of the data integration in the RP3 environment and its sampling in the application developed in Node-RED [17] will be demonstrated.

5.1 METHODOLOGY

As already stated, the project has been divided into two main blocks. In the transmitter block and putting into context what is typically used in many telecommunications systems, the data is collected by the microcontroller in instantaneous form. Sequentially, the data is sent to the LoRa module which has the task of transporting these instantaneous values to the receiver via radio communication. This approach aims to balance the computational effort and, therefore, although the Arduino Uno board can carry out all kinds of operations, whether more complex or simpler, the receiver will have a higher computational efficiency because all the RP3 hardware components perform very well, and the processing capacity is high.

The receiver block is responsible for the data processing and displaying. After receiving the instantaneous data, the RP3's function is to run a set of algorithms developed to calculate the averages with 30 samples associated with the values received. In addition to this function, it is here that these already processed values are sampled in a Node-RED application, where they are displayed on a dashboard. The average values will be displayed in real time using line graphs where we can visualize the variation in temperature, humidity, sound level and CO2 concentration over time. In addition, there will be a main page where we can see the instantaneous values produced by the sensors and quickly understand the state of the environment in which the system has been implemented, i.e., you can easily see what the noise level is, what the temperature and humidity are, what the CO2 concentration is and, via text, briefly inform the user of the environmental conditions of that location.

5.2 TESTS

The LoRa data frame used in the radio communication is displayed on Figure 3.

Figure 3. Data frame used in LoRa communication (author Figure)



Source: Authors

As we can see from the figure, the data frame contains: a preamble with a size of 12.25 symbols; a Header and Header Cyclic Redundancy Check (CRC) with a combined size of 4 bytes and a Payload of 19 or 20 bytes depending on the data sent by the sensors. It can therefore be concluded that the data frame used in point-to-point LoRa communication has a dimension of 20 bytes. If we add the variable size of the preamble, i.e., it depends on the SF to be used for the radio channel and as an example, if the SF is set to 8 chips the total size of the data frame described above will be 32 bytes.

The results presented here already include the parameterizations made to guarantee stable and reliable radio communication. The parameters used are summarised in Table 1.

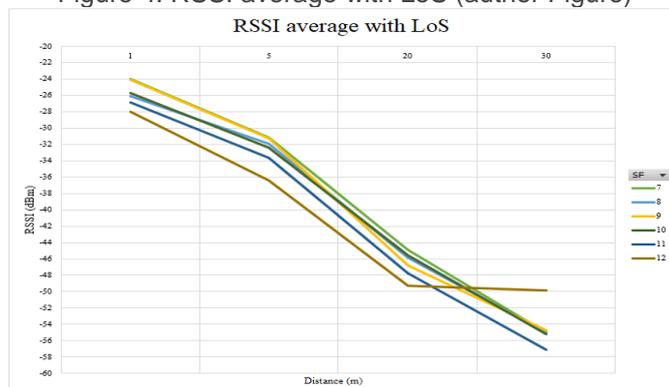
Table 1. Radio parameters for LoRa communication (author Table)

SF	8
Frequency	868 MHz
Data frame	20 bytes
CR	4/5
BW	125 kHz
Transmission power	5 dBm

Source: Authors

One of the tests made, during the development of the project, was the variation of the SF and distance between transmitter and receiver and how it affected RSSI (Received Signal Strength Indicator) with LoS on Figure 4 and without LoS on Figure 5.

Figure 4. RSSI average with LoS (author Figure)

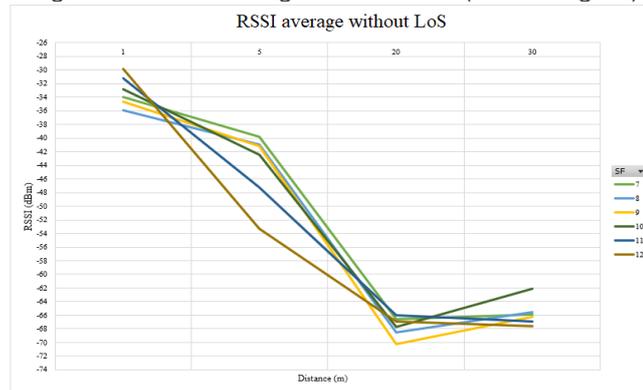


Source: Authors

With LoS the RSSI was higher with lower SF values with 1 meter of distance. The same trend repeats until the 30-meter mark where the signal with SF of 12 has a

much higher RSSI than the rest. With higher SF values the signal becomes much easier to detect as spreads the whole signal in frequency which results on average in lower interference, a signal with lower interference gets detected much easier and that results in higher RSSI.

Figure 5. RSSI average without LoS (author Figure)



Source: Authors

Without LoS the RSSI values were on average lower than the values of the test with LoS, the signal lost strength because it needed to penetrate the obstacle to reach the receiver. The RSSI was higher with higher SF values with 1 meter of distance. With 5 meters of distance the RSSI was lowest for a SF of 12 and highest for a SF of 7. With 20 meters of distance the values of RSSI are very close between all the values of SF. At the 30 meters mark there is an increase of RSSI for the higher SF values being the SF of 10 the best. The values obtained show that on average the higher SF values tend to have higher SF values, which can be explained by the lower interference that signals with higher SF tend to receive. That lower interference results in easier detection by the receiver.

Having configured the SF to 8 through the tests carried out, it was necessary to configure the bandwidth as this parameter has a direct impact on the bit rate, range, network capacity and radio interference mitigation. To obtain a satisfactory value for the bandwidth required for the system to work properly, some tests were carried out in a closed environment. These tests consisted of varying the bandwidth for fixed distances with a SF=8. By doing this, it is possible to measure the arrival time of the data being sent. The delay configured for the transmission of sensor measurements was removed so that the system's performance is more noticeable without any restrictions.

The transmitter was placed about 5 m away from the receiver and the bandwidth was set in the range [7.8 kHz; 500 kHz] and the results were as follows:

- BW 500 kHz - The data frame arrived at the receiver without any errors and with a sampling time of ≈ 240 ms;
- BW 250 kHz - Very similar results to those obtained in the 500 kHz, with only a slight increase in sampling time to ≈ 270 ms;
- BW 125 kHz - Few changes, just a rise in the sampling time to ≈ 330 ms;
- BW 62.5 kHz - In this configuration we can see that the sampling time has almost doubled, to ≈ 440 ms. However, the data frame remained intact;
- BW 41.7 kHz - Slight increase in sampling time to ≈ 550 ms and intact frame;
- BW 32.5 kHz - Increase in sampling time to ≈ 660 ms and intact frame;
- BW 20.8 kHz - A drastic variation in sampling time was observed and the data frame was completely lost. In this configuration, the time went up to ≈ 26 s on the first send and ≈ 73 s on the second. The entire data frame was received with errors, no useful information was visible and the RSSI dropped considerably to -88 dBm. It can be assumed with some certainty that this value is the maximum bandwidth limit that can be used in this system.

Having verified the behaviour of radio communication with a BW of 20.8 kHz, it was concluded that all values above this limit could be used in the system that was developed, so that, only as isolated tests, it was not even possible to measure the sampling time for values below 20.8 kHz, leaving the feeling that communication was lost in these configurations.

It was therefore concluded that although there is some flexibility in terms of bandwidth, the most suitable value to guarantee a satisfactory binary output is 125 kHz. Referring now to equation (3.1), the bit rate was calculated as per below:

$$R_b = 8 \cdot \frac{125 \text{ k}}{2^8} \cdot \frac{4}{5} = 3.125 \text{ kbps} \quad (2)$$

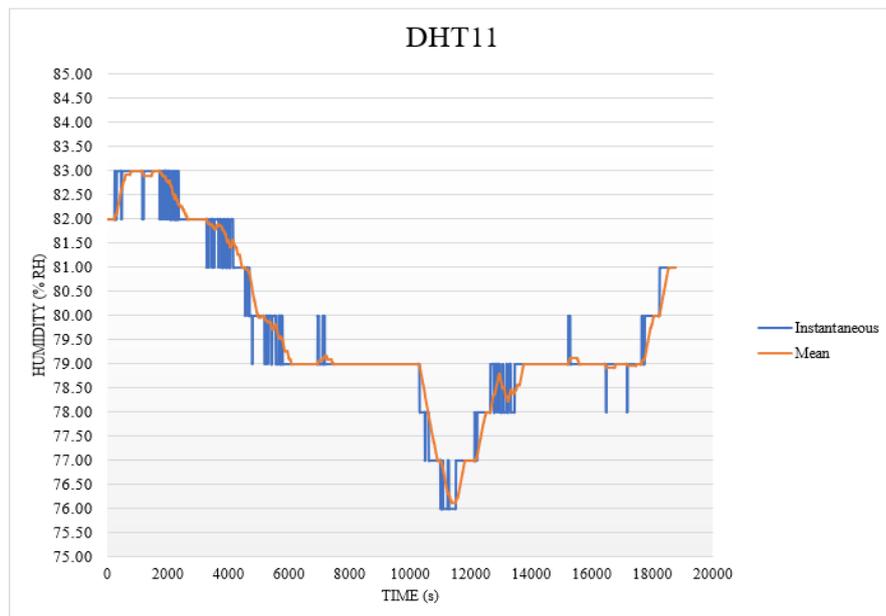
It should also be noted, despite the BW parameterization having been completed and that with a bandwidth of 125 kHz and an SF = 8, the transmission power can be set to its minimum value. In this case, this value is 5 dBm, thus guaranteeing

stable and robust radio communication and at the same time reducing the energy consumption of the transceiver in the transmitter block.

5.3 SENSOR RESULTS

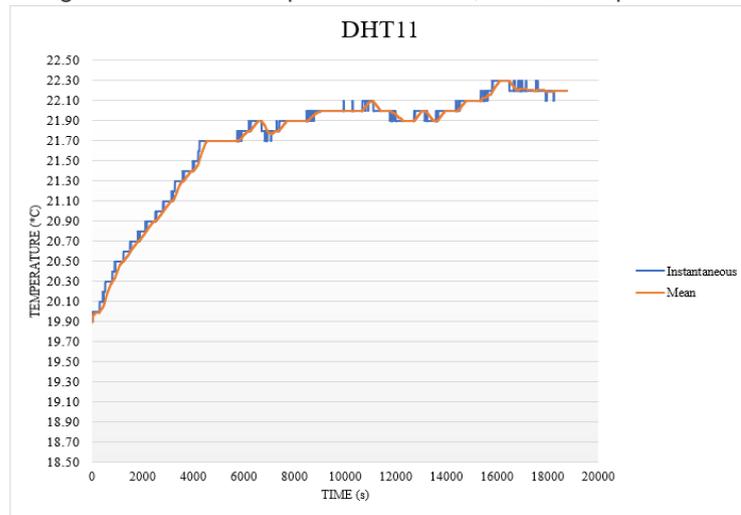
As part of the project, the results obtained from the actual measurements taken by the sensors and their operation in the system are presented shortly. When testing the sensors, it was taken into consideration that to obtain the most accurate values, the sensors need to be in constant operation for some time. The sensors were therefore kept connected and collecting data for around 3 hours. Before presenting the figures related to the results obtained, it is important to note that the response time associated with the DHT11 sensor is limited to 2 seconds, according to the supplier therefore all the measurements were taken every 10 seconds, thus allowing for a considerable margin. There is also the need or not to calibrate the sensors, which in this case only applies to the MG811 sensor due to its physical nature, i.e., no other sensor needs to be calibrated. Figure 6 and show the results of the sensor DHT11.

Figure 6. DHT11 humidity results, with $\pm 5\%RH$ precision



Source: Authors

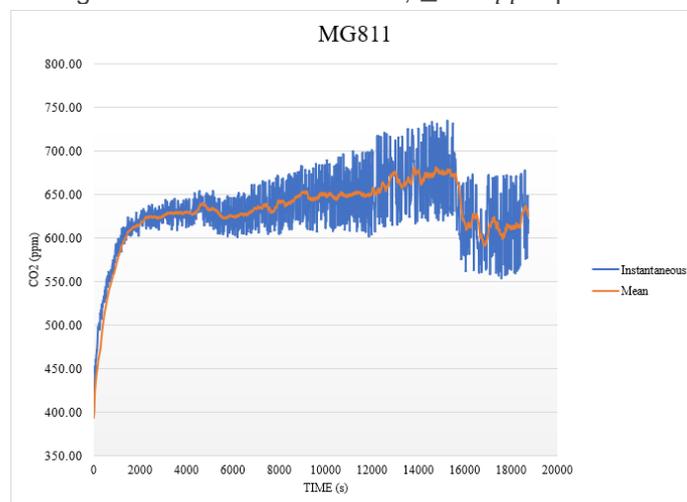
Figure 7. DHT11 temperature results, with $\pm 2^\circ\text{C}$ precision



Source: Authors

After looking at the graphs above, although the DHT11 sensor is simple and easy to use, it shows somewhat disparate values over time. Its measurement accuracy is considered and there is a somewhat abrupt variation in humidity measurements, as we know humidity in a closed room does not change as dynamically as the sensor makes it seem. On the other hand, although this model of DHT is the weakest in terms of performance, the temperature measurements appear to be more in line with reality, as the measured value stabilizes over time. In short, this sensor presents somewhat anomalous measurement data, but looking at its monetary value and the purpose of the project, the DHT11 turns out to be a choice that meets the main objective and so its performance is considered satisfactory. Figure 8 shows the results of the MG811 sensor.

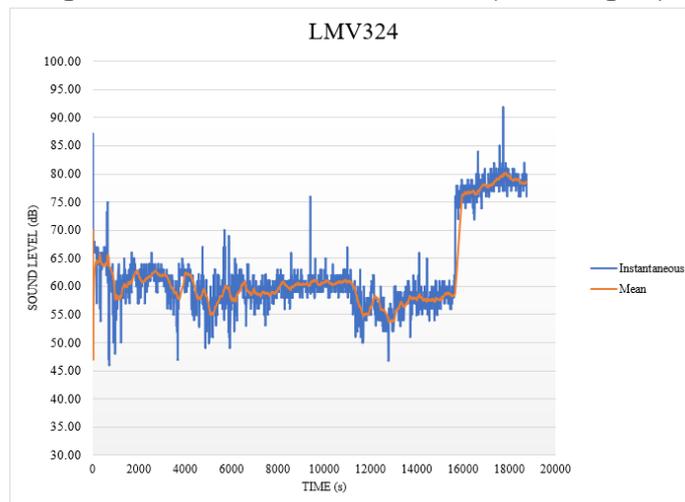
Figure 8. MG811 CO2 results, $\pm 100\text{ ppm}$ precision



Source: Authors

From the results observed in the figure above, it can be concluded that this CO_2 concentration sensor takes readings with a considerable level of precision, presenting values that mirror its economic value. The MG811, despite needing time to warm up to work properly, manages to produce results that are very close to reality and since there are not many systems that use this metric as a basis for operation, it is believed that this is one of the most relevant sensors for this project. The possibility of measuring the concentration of CO_2 in a potentially dangerous place for human health with the precision of the MG811 is undoubtedly a strength of what has been developed. The sensor doesn't show any anomalous measurements over several hours of testing. Figure 9 shows the results of the LMV324 sensor.

Figure 9. LMV324 sound level results (author Figure)



Source: Authors

From the figure of the measurements taken by the LMV324, one thing that is clearly visible that is the relatively high noise levels. As we can see, the values are around 65 dB and 80 dB, meaning that we appear to be in the presence of an extremely noisy environment. However, we considered after research that these values may indicate another side of the sound level measured. Thus, the measures are mostly in the moderate-to-moderate high noise level for a long period of time, as there was some noise from loud conversations at the time of the tests. The sudden rise to values around 80 dB could be caused by several factors external to the sensor, however it is important to note that the LMV324 is a sensor with extremely high measurement sensitivity and a small vibration or contact with it can cause extreme and anomalous readings. Taking

all these factors into account, this sensor performs acceptably for the project ideology and although there were other options, the LMV324 was chosen because it also has a considerably low economic value.

5.4 MONITORING SYSTEM

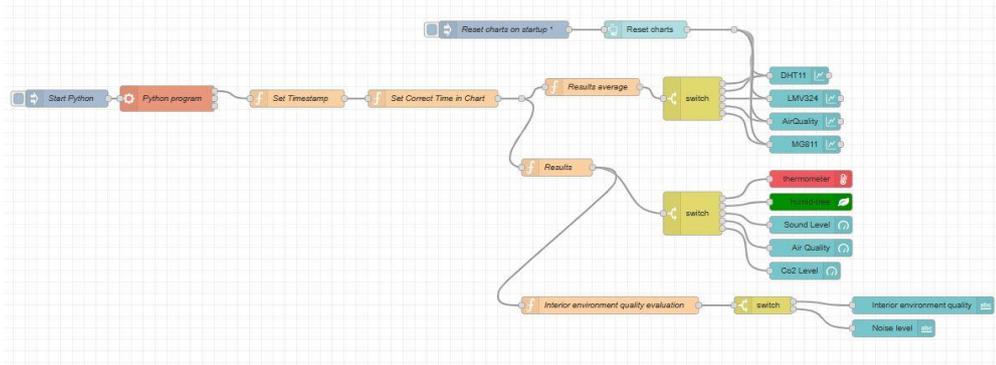
In this project, the monitoring system includes a RP3 (responsible for processing and analysing the data) and a LoRa transceiver (responsible for collecting the data). In this relatively simplistic monitoring system, there is a 7-inch touchscreen display with a resolution of 1024x600, connected via HDMI to the RP3 and used to display the data to be monitored. The LoRa transceiver is directly connected to the RP3 via the General-Purpose Input/Output (GPIO) pins.

The RP3 is equipped with a proprietary and globally used Operating System (OS) called Raspbian [18] which is free and open source based on the Debian Linux. On the project, we used Debian version 11 with kernel 6.1.21-v7+. This OS is ideal because it has all the tools needed for the project's main objective: monitoring air quality levels in indoor areas. This monitoring makes a key contribution to the project, and its development was based on Node-RED.

Node-RED is a graphical programming tool that allows users to easily create and deploy IoT applications. It is an open-source graphical environment, based on flows. Flows are created by dragging and dropping nodes from a predefined palette and establishing links between them. Each node represents a different function, such as data input, processing, or output. Nodes can be configured to perform specific tasks, such as reading data from sensors, processing that data, and displaying the results on a server or dashboard. Node-RED version 3.0.2 was used in this project. The graphic aspect developed in Node-RED will depend on the specific objectives of the project and the blocks used. In our case, a dashboard consisting of real-time line graphs was used, with the aim of sampling the measurements taken by the sensors and presenting these values on the display in a customized window.

The flow developed is based on four large blocks of well-defined functions with their own algorithms. Figure 10 shows the basic structure of the flow developed for sampling the results.

Figure 10. Flow structure developed in Node-RED (author Figure)

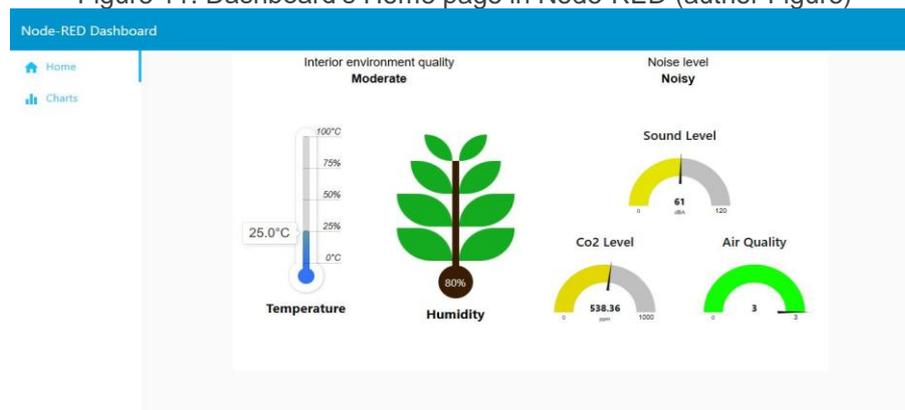


Source: Authors

We can see from the figure that there is a division of the values produced by the sensors. These values are displayed on the dashboard so that the instantaneous values can be seen on one page and the average values on another. There are two pages in the application, the "Home" page, and "Charts" page.

The Home page shows brief and more relevant information about the environmental characteristics. The goal of this main page is to provide the user with a very simple and clear picture of the indoor environment. The values associated with each environmental characteristic are of the instantaneous type so that we can see any abrupt changes in them in real time. Figure shows the dashboard's Home page and its content.

Figure 11. Dashboard's Home page in Node-RED (author Figure)



Source: Authors

At the top of the page, we can see some suggestive messages for a quick interpretation of the values presented by the dynamic graphs. Regarding the messages related to the quality of the environment in general, these are slightly more complex to present because all the temperature/humidity, CO₂ level and air quality sensors have

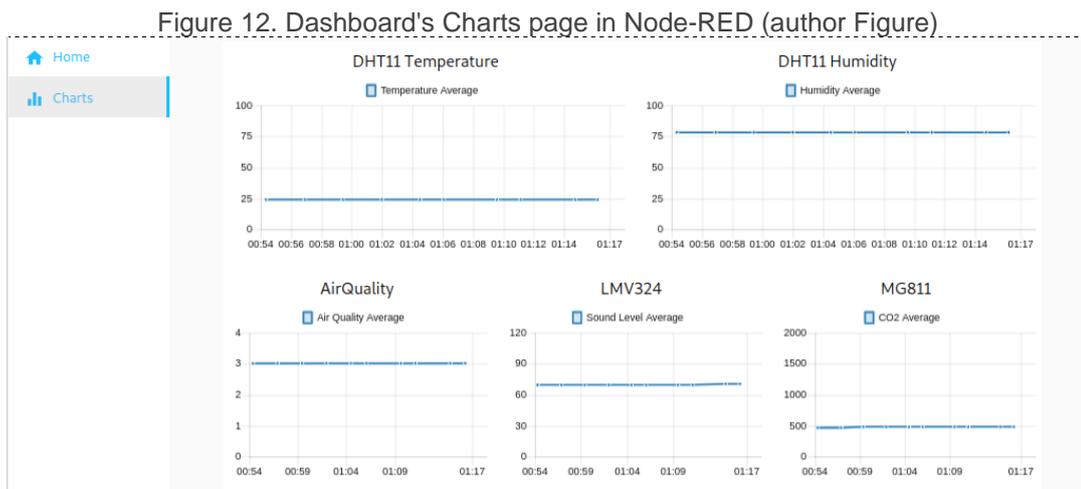
been considered. To this end, the messages are presented dynamically according to the following assumptions:

- the messages associated with the air quality status are "Very Good", "Good", "Moderate", "Unhealthy", "Very Unhealthy" and "Hazardous".

Just as the air quality messages are displayed dynamically, the same logic was implemented for the sound level, thus giving a more intuitive meaning to the measurements taken by the LMV324. The following has been considered:

- the messages associated with the sound level are: "Very quiet", "Quiet", "Moderate", "Moderate High", "Noisy" and "Very noisy".

In addition to the main "Home" page, the "Charts" page was also developed. This page is intended to inform the user of the history associated with sensory measurements. Figure 12 presents the Charts page and its appearance.



Source: Authors

If we look at the figure above, we can identify each of the sensors implemented in the transmitter block and the measurements they take. The values sampled in each line graph are average values, thus fulfilling the assumptions described in previous chapters. This approach adds value to the results obtained because it is only by sampling average values that we can get a sense of how the sensors are working and how the environment is. Another important factor to mention is that only through average values can we get a real sense of the measurements, since instantaneous values often show extreme values that don't match the real state of the space where the system is implemented.

It should also be noted that, due to a limitation of the Node-RED tool, it is not possible to add explanatory labels to the vertical axis of each of the graphs. Also, it's not possible to set a customized spacing on this axis, which to some extent makes it appear that the measurements being processed are constant when this is not the case. The simple fact that it is not possible, for example, to add a spacing of 0.1 between each value on the vertical axis for the DHT11 sensor measurements, makes incorrect measurements appear. However, we can always use the cursor to check which value is at which point on each graph.

6. CONCLUSION

The aim of this project was to develop an IoT monitoring system within the LoRa network with wireless point-to-point communication to monitor environmental characteristics in an interior space such as humidity, temperature, sound level and CO_2 level. Throughout the project, important results were achieved that contributed to the expansion of IoT as a technological area and to the development of monitoring systems in general.

The results obtained demonstrate the reliability and effectiveness of using LoRa technology in projects of this nature, presenting it as one of the best options currently available in the wireless communication spectrum given its easy implementation, configuration, and operating cost (both in terms of equipment and energy consumption). The IoT Node developed using different types of sensors was able to collect important and generally accurate data, such as temperature and humidity, CO_2 concentration, sound levels and air quality.

The contributions of this project are relevant to the technological advancement of IoT and environmental monitoring systems. In a world where there are countless technological possibilities for wireless communication, the importance of using the LoRa network is reinforced, as it is the most viable alternative in all spectrums and is fully compatible with an IoT architecture in the image of what has been developed, with no major computational or functional challenges in its implementation. Besides that, the availability of real-time data and its transport capacity has revealed its full potential as a technology that was totally unknown to the authors of this project.

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CHAPTER 6

HEALTH, SAFETY AND ENVIRONMENTAL PRACTICES (HSE) IN A MANGROVE FOREST RESTORATION PROJECT IN GUANABARA BAY – RJ

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ABSTRACT: Mangroves, ecosystems found in tropical and subtropical regions, play a crucial role in maintaining marine biodiversity. However, they face increasing threats due to unplanned urbanization and coastal pollution. Forest restoration is a strategy to reverse these damages; however, the lack of adequate Health, Safety, and Environment (HSE) practices can compromise both environmental outcomes and the safety of the workers involved. This article presents an experience report where HSE programs and protocols were implemented in a mangrove forest restoration project in Guanabara Bay - RJ, involving members of a traditional community of fishermen and crab harvesters. It discusses the measures adopted to ensure worker safety in a unique environmental setting, emphasizing the importance of integrating HSE practices in forest restoration.

KEYWORDS: occupational health, worker protection, risk management, forest restoration, mangroves.

RESUMO: Os manguezais, ecossistemas encontrados em regiões tropicais e subtropicais, desempenham um papel fundamental na manutenção da biodiversidade marinha. No entanto, eles enfrentam ameaças crescentes devido à urbanização não planejada e à poluição costeira. A restauração florestal é uma estratégia para reverter esses danos; no entanto, a falta de práticas adequadas de Saúde, Segurança e Meio

Ambiente (SSMA) pode comprometer tanto os resultados ambientais quanto a segurança dos trabalhadores envolvidos. Este artigo apresenta um relato de experiência em que foram implementados programas e protocolos de SMS em um projeto de restauração de manguezal na Baía de Guanabara - RJ, envolvendo membros de uma comunidade tradicional de pescadores e catadores de caranguejo. Discute as medidas adotadas para garantir a segurança dos trabalhadores em um cenário ambiental único, enfatizando a importância da integração das práticas de SMS na restauração florestal.

PALAVRAS-CHAVE: saúde ocupacional, proteção do trabalhador, gerenciamento de riscos, restauração florestal, manguezais.

1. INTRODUCTION

The mangrove swamps, coastal ecosystems that occur in tropical and subtropical regions around the globe, are widely recognized as nurseries of marine life and stand out as one of the most productive ecosystems on the planet, being fundamental for the maintenance of a vast biological chain (Amador, 2013; Schaeffer-Novelli *et al.*, 1990; Cintrón; Schaeffer-Novelli, 1985).

On the Brazilian coast, the ecosystem finds suitable environments for establishing itself, developing itself and maintaining itself, with the exception of the coast of Rio Grande do Sul, since in these latitudes the climatic conditions necessary for its development do not prove to be compatible. Along more than 7,000 kilometers of coast, mangrove swamps are now well distributed, sometimes confined to indentations marked by the presence of small estuaries (ICMBio, 2018). In our country, mangrove swamps are protected by one of the main environmental laws, the new forestry code (Law No. 12.651/2012), which designates them as Permanent Areas of Preservation in all their extent (Matsumi; Freitas, 2018). However, even though they are of great importance, they are vulnerable to a number of threats, such as: loss and fragmentation of vegetation cover due to disorderly urban expansion, deterioration of aquatic habitats due to industrial and domestic pollution, as well as changes in hydrodynamics caused by coastal infrastructure activities (ICMBio, 2018; MMA, 2010). Given the severity of such environmental problems, it is essential to take measures to restore the quality of the impacted environments. Amongst these measures, one can highlight the application of techniques for restoring native vegetation, which aims at restoring ecosystem functionality, allowing mangrove swamps to reassume their roles in the environment, by means of the re-establishment of their forest cover. Forest restoration is a way of restoring ecosystem complexity, re-establishing plant communities and consequently providing habitats for associated fauna (Souza; Batista, 2004).

Given this scenario, the implementation of forest restoration projects appears as a strategy to reverse significant environmental damage. Due to the expansion of forest restoration activities in the country, a significant demand for a large contingent of labor has been observed, mainly in the forest implantation stage, where most activities are carried out using manual and/or semi-mechanized methods, unlike the commercial

forest sector, which uses high technology and productivity machinery and equipment (Lima *et al.*, 2020). In addition, restoration actions are carried out in open environments, where workers usually remain exposed to unfavorable environmental conditions and continuously use equipment and tools that require high physical effort and inadequate postures (Vosniak *et al.*, 2011). These conditions are potentialized in the mangrove swamps, since their substrate, being unconsolidated, not only makes it difficult for the team to move in the field, but can also favor work accidents involving twists, fractures or perforations, unleashed by the vegetation itself. To guarantee the success of these projects, it is essential to adopt Health, Safety and Environment (SMA) practices in all the activities carried out. The integration of SSMA practices with forest restoration initiatives not only seeks to promote the restoration of the ecosystem, but also aims to ensure the protection and safety of the workers involved in these activities.

Recently, an increase in the dissemination of forest restoration projects of mangrove swamps in our country was observed, which, can be consulted in Rodrigues *et al.* (2023) and Rodrigues *et al.* (2022). However, there is still a significant knowledge gap with respect to SSMA approaches in restoration, in particular in this ecosystem. Given the importance of occupational safety of workers, this work aimed to present the programs and protocols of health, safety and environment used in a forest restoration project carried out in the mangrove ecosystem, which has as operational team members of a traditional community of fishermen and crab hunters of Guanabara Bay.

2. MATERIALS AND METHODS

2.1 STUDY AREA

The restoration project is being developed over an area of 10.0 hectares within the Guapi-Mirim Environmental Protection Area (APA), managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) (Figure 1). According to its Management Plan (ICMBio, 2004), the APA covers the municipalities of São Gonçalo, Itaboraí, Guapimirim, and Magé. Located between geographic coordinates 22°40' and 22°46'S and 42°57' and 43°07'W, the APA encompasses approximately 14,340 hectares, housing the largest preserved continuous mangrove coverage in the state of Rio de Janeiro. The region's climate, classified as Köppen AW, is hot and humid, with

a rainy season in spring and summer. The average annual rainfall is 1,709 mm, with spring and summer being the wettest seasons and winter the driest. The average annual temperature is 23°C, with January being the hottest month (average 26°C) and July the coldest (average 20°C) (ICMBio, 2012).

Figure 1. Location of the forest restoration area (10.0 hectares)



Source: authors

The restoration site is remote and difficult to access, reachable only by boat due to the lack of direct roads. Two aluminum boats, each capable of carrying up to 8 passengers plus 1 crew member, are used to navigate the rivers to the location. Both boats are equipped with 40 HP outboard motors (Figure 2).

Figure 2. Operational team on board a vessel, en route to the work area.



Source: authors

The APA, established in 1984, still shows patches of deforestation that occurred before its creation. The site chosen for the project is one of these areas. After deforestation, the soil was exposed to high levels of solar radiation and consequently elevated temperatures, promoting the uncontrolled growth of opportunistic plant species, such as *Acrostichum aureum* L. (marsh fern). This species, due to its density and dominance, acted as a natural barrier, reducing the potential for natural regeneration of native tree species and interfering with the ecosystem's natural resilience (Rodrigues *et al.*, 2024).

2.2 INSTITUTIONS INVOLVED

The project is coordinated by the NGO Guardiões do Mar, with the Manguezal Fluminense Cooperative as a partnering institution. This cooperative is formed by traditional communities from the Baía de Guanabara (crab catchers and fishermen) who live in and are familiar with the realities of the region's mangroves, serving as the operational team for field activities. A total of 15 cooperative members were involved in the project activities. The project is financed by Nova Transportadora do Sudeste (NTS) and managed and monitored by Grupo Index. It is a forest compensation measure implemented by NTS for the GASDUC III gas pipeline, which was licensed by the State Environmental Agency (INEA) with the approval of ICMBio.

2.3 HSE MEASURES APPLIED IN THE MANGROVE

The restoration of mangroves presents considerable challenges due to the unique characteristics of this ecosystem. For example, the unconsolidated substrate can create obstacles for operational teams moving through the restoration area, and fluctuations in tidal levels can either inundate the work area or create very low tides that impede navigation. Additionally, the workers involved are exposed to various risks, such as accidents, injuries, occupational diseases, and negative environmental impacts, necessitating specific approaches to ensure safe operations. Therefore, it is essential to implement rigorous Health, Safety, and Environmental Management (SSMA) measures to mitigate these risks. This approach plays a crucial role not only

in protecting the health and safety of those involved but also in ensuring the success of the restoration and the reestablishment of ecological functions.

A forest restoration project with a focus on SSMA can yield several benefits, such as compliance with relevant labor laws and Regulatory Norms (NRs). Furthermore, safety and environmental practices contribute to a positive reputation for the executing organization, enhance stakeholder trust, and can facilitate access to funding and partnerships. Another important aspect is the prevention of workplace accidents, which can impede project progress and lead to delays and additional costs. Thus, adherence to SSMA helps minimize these risks and keeps the project on schedule and within budget.

Guardiões do Mar and the Manguezal Fluminense Cooperative have adopted a robust SSMA program, developed by NTS and Index Florestal, in all their restoration activities, recognizing its importance for the success and safety of field operations. The SSMA Program includes various measures aimed at protecting the health and safety of workers and preserving the environment throughout all stages of the project. These measures include:

1. Risk Management Program (PGR):

Aims to identify, assess, control, and monitor occupational risks present in the processes and activities of an institution. This program focuses on providing workers with healthy environmental working conditions.

2. Occupational Health Medical Control Program (PCMSO):

The main objective is to protect and preserve workers' health concerning occupational risks defined in the Risk Management Program (PGR). It includes regular preventive and monitoring medical examinations aimed at protecting workers from work-related occupational diseases.

3. Emergency Response Plan (PAE):

Defines procedures to be followed in the event of emergencies at the activity site, ensuring a prompt response to unplanned events.

4. Health, Safety, and Environmental Management (SSMA):

Establishes minimum requirements for Health, Safety, and Environment to ensure compliance with regulations and standards.

5. Contingency Plan (COVID-19):

During the pandemic, specific measures were adopted to protect employees, including information about the disease, preventive measures, and actions in cases of suspected or confirmed infections.

6. Environmental Aspects and Impacts Assessment (LAIA):

An environmental diagnosis that aids decision-making to mitigate environmental impacts.

7. Preliminary Risk Analysis (APR):

A preliminary assessment process of risks associated with field activities. This analysis identifies and quantifies potential risks, enabling the adoption of adequate preventive measures to mitigate them. The APR is not a static document; it is reviewed every 90 days to ensure that all information is up to date. During the review, a detailed inventory of identified risks and action plans for mitigation is conducted, ensuring preventive measures are aligned with current conditions and best safety practices.

8. Non-Conformance Management (NC Management):

Used to ensure quality and compliance in projects. All parties involved—contractor, oversight team, and contracted staff—must identify and report any non-conformities. Opening an NC allows for the correction of errors and prevents their recurrence through root cause investigation and the implementation of corrective and preventive measures. This collaborative approach fosters a culture of learning and continuous improvement, ensuring that established standards are met and that the operational team remains vigilant in identifying and correcting deviations from established requirements.

Forest restoration projects must comply with Portaria No. 3.214/1978, which approves the Regulatory Norms (NRs) related to Occupational Safety and Medicine, as required by Chapter V, Title II of the Consolidation of Labor Laws. Below are the specific NRs that are followed and applied in the operations of our projects:

- NR 01 – Occupational Risk Management Program (PGR): To promote a healthy work environment by effectively managing environmental risks inherent to the processes and activities carried out;
- NR 06 – Personal Protective Equipment (PPE): Provision of PPE with Certificate of Approval (CA) suitable for the activity's risks, free of charge. Furthermore, it is necessary to provide guidance and training for workers on the proper use,

storage, maintenance, and immediate replacement in case of damage or loss. The executing entity is also responsible for the periodic cleaning and maintenance of PPE and for documenting the provision through PPE Records. In activities conducted for mangrove restoration, the main equipment is highlighted in the table below:

Table 1. List of equipment and specifications used in the project:

EPI/Item de SSMA	Specificity
Safety glasses (clear)	Protects eyes against impacts and solid particles when handling materials and equipment in the mangrove swamp.
Solar safety glasses	Provides eye protection against ultraviolet (UV) solar rays, essential during long exposure to the sun in the natural environment.
Pigmented knitted glove	Provides hand protection against abrasion and debris, maintaining dexterity during equipment and material handling activities.
Cowhide glove	Protects hands from cuts and abrasions, especially useful when handling tools and rough objects.
Nitrile glove	Provides protection against chemical products (e.g. gasoline for fueling boats), ensuring safety for your hands.
Anti-cut glove	Recommended for use in situations where there is a risk of contact with sharp tools, providing additional protection against cuts and punctures.
PVC high-top boot (galosh)	Protects feet against moisture and impacts, providing safety and comfort during activities in the mangrove swamp.
UV protection shirt	Provides sun protection for the skin, minimizing the harmful effects of UV rays during long exposure to the sun while working in the field.
Jeans	Durable and comfortable clothing, offers protection for the legs against scratches, insects and possible contact with thorny plants present in the mangrove swamp.
Sunscreen factor 60	Provides high sun protection for the skin, essential to prevent burns and sun damage during outdoor activities.
Insect repellent with icaridin	Protects against insect bites and acts to prevent diseases transmitted by insects.
Cap with neck protector	Protects the face and neck from direct sun exposure, offering comfort and safety during long working hours under the sun.
Raincoat	Essential for protecting against rain and moisture, keeping your team dry and comfortable on rainy days.
Life jacket	Essential flotation equipment for safety while sailing.
PFF2 mask with valve	Utilizada para proteção contra vírus e bactérias, especialmente durante o período da COVID-19. Também eficaz contra partículas finas, fumos e névoas tóxicas, proporcionando proteção respiratória em ambientes com poeiras e outros contaminantes aéreos.
Forestry kit combined with face and hearing protection	Used by brush cutters, it is a piece of equipment to protect the head, face and ears. It has a screen against impacts and debris, a muffler to reduce excessive noise and a helmet to prevent damage from falling branches or other environmental risks in the forest.

Source: Authors

- NR 07 – Occupational Health Medical Control Program (PCMSO): Implementation of the PCMSO aims to protect the health of workers against incidents, accidents, and occupational diseases related to their work. It also includes the provision of first aid kits. The table below lists the essential items, developed based on the activities conducted and the number of personnel in the field.

Table 2. First aid items

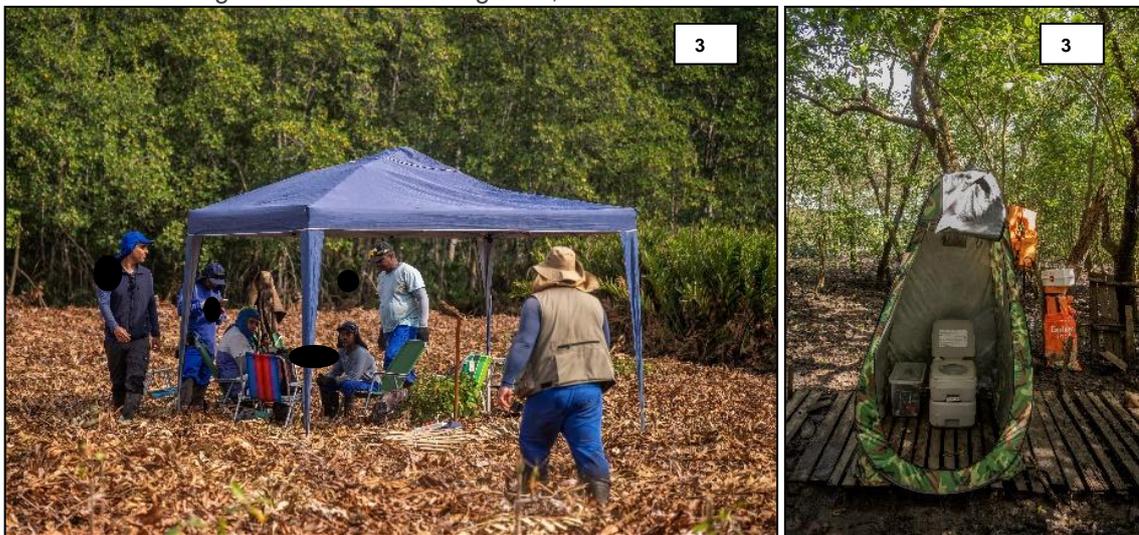
Materials	Amount
Adhesive dressing (Band-Aid – 2 ½ cm x 7 cm)	20
Sterile gauze pack (10 m x 10 cm)	6
10 cm wide crepe bandage	3 units
Adhesive tape	3 units
Procedure gloves	1 roll
Protective face mask (with disposable protection)	5 pairs
Digital thermometer	1
Paramedic scissors without tip	1
Clamp	1
Garbage bag (common/small)	1
Saline solution (300 ml)	2 bottles
Flexible stretcher type Sked Envelope	1

Source: Authors

- NR 09 – Evaluation and Control of Occupational Exposures to Physical, Chemical, and Biological Agents: This standard establishes the requirements for assessing occupational exposures to physical, chemical, and biological agents identified in the Risk Management Program (PGR) outlined in NR-01, and supports preventive measures for occupational risks;
- NR 12 – Safety in Work with Machines and Equipment: This consists of a set of safety procedures directed at the transportation, installation, operation, and maintenance of machines in work environments, including training;
- NR 15 – Insalubrious Activities and Operations: This standard sets tolerance limits for physical, chemical, and biological agents present in the workplace, which, when exceeded, may pose health risks to workers. These agents can cause harm to health either acutely or chronically, depending on the intensity and duration of exposure;
- NR 21 – Outdoor Work: Adoption of protective measures against adverse weather conditions, such as shelters for protection against sun exposure, heat, cold, humidity, and adverse weather events;

- NR 31 – Safety and Health in Agriculture, Livestock, Forestry, Logging, and Aquaculture: Conducting risk assessments and adopting preventive and protective measures in the work environment. Elimination, control, and reduction of risks, conducting medical examinations (ASOs) and additional assessments, informing workers of the results. Furthermore, provision of first aid equipment, ensuring training on its use, vaccination, personal protective measures (EPIs), and appropriate living areas, including a 3x3m tent with ultraviolet protection, a portable Ecocamp toilet, rest chairs for the team, and filtered water stored in thermal bottles (Figures 3A and 3B).

Figure 3. A. Staff in living area, B. Portable toilet installed in field



Source: Authors

In the context of operations conducted in mangroves, in addition to complying with labor laws and regulations, additional measures have been implemented to mitigate risks during activities, in accordance with the peculiarities and challenges inherent to the ecosystem. For example, the use of pallets has proven to be an effective technical solution aimed at reducing the risk of bruises, enhancing the efficiency of labor activities, and improving productivity. The placement of pallets to form pre-established and strategic trails provides firm and elevated surfaces, thereby reducing the likelihood of twists, falls, and getting stuck—issues common due to the instability of the mangrove substrate. These trails not only enhance worker safety but also facilitate the transportation of tools, operational equipment for restoration, and

seedlings for planting. The uniform surface offered by the pallets allows for faster movement, saving time and reducing physical effort (Figure 4).

Figure 4. Pallet track on mangrove substrate: logistics solution for practical access of staff and tools



Source: Authors

Another important advantage is the reduction of environmental impact. By avoiding direct trampling on the mangrove substrate, the pallet trails minimize disturbance to the environment, preserving substrate characteristics and preventing the trampling of regenerating individuals. It is essential to highlight that the pallets are subject to regular inspections and undergo periodic maintenance to replace damaged or decayed wooden parts. Additionally, after the project's activities are completed, they will be removed from the environment and disposed of in an environmentally appropriate manner.

In addition to the measures reported, the implementation of periodic drills in the field, checklists, Daily Safety Dialogues (DDS), and Routine Management is fundamental to SSMA management. Each of the practices listed below plays a specific role in promoting safety and raising worker awareness:

- periodic field drills: conducting drills is essential for preparing the team for emergencies, such as incidents or accidents. These exercises allow the practice of safety procedures and emergency responses, ensuring that everyone knows how to act in critical moments. For example, First Aid drills train the team to respond swiftly to medical emergencies, such as injuries or fainting, practicing

techniques for immobilizing fractures and controlling bleeding. These exercises ensure that the team is capable of providing initial care until healthcare professionals arrive or until transportation to a hospital can be arranged. Furthermore, continuous review of procedures during drills helps identify and correct potential gaps in the safety plan, thereby enhancing the effectiveness of response measures. The figures below depict a drill for sudden illness and field removal, utilizing a Sked rescue stretcher (Figures 5A and 5B).

Figure 5A and 5B. Sudden illness simulation and field rescue



Source: Authors

- checklist: ensures that all safety and environmental steps are systematically followed. The checklists include items such as proper use of Personal Protective Equipment (PPE), assessment of environmental conditions, and inspection of vehicles, boats, and tools. They structure the review of procedures before and after activities, preventing errors and ensuring compliance with safety regulations. Figures 6A and 6B illustrate the inspection of the first aid kit items that the operational team brings to the field.

Figure 6 A. Checking the items in the first aid box, B. First aid box in the field.



Source: Authors

- daily safety dialogues (DDS): these are brief meetings held daily before activities, aimed at raising awareness among workers about safety, the environment, and associated risks. During DDS, team members share information, identify risks, and discuss preventive measures, reinforcing a safety culture and attention to safe practices (Figure 7). Discussion topics may reference the Preliminary Risk Analysis (APR), the Emergency Response Plan (PAE), the Contractor's Sustainability Policy, or periodic campaigns, such as "Yellow May," which focuses on raising awareness for reducing traffic accidents. Examples of topics covered include: "Not every day is a field day: observing weather conditions," "Adverse atmospheric conditions and lightning strikes," "Keeping your partner in sight while in the field," "The importance of staying hydrated," and "Proper storage of fuel containers: containers approved by INMETRO."

Figura 7. Realização de DDS pela equipe técnica da Guardiões do Mar e NTS à equipe operacional.



Source: Authors

- routine management / completion of the Daily Log: the Daily Log is a management tool for daily activities in the field. Its main purpose is to systematically record all activities for a specific workday, allowing for control over the actions taken. Additionally, it facilitates the planning and execution of tasks, documenting the need for operational adjustments, preventing failures, and ensuring the continuity of field actions. Another fundamental aspect is monitoring environmental conditions, such as tide levels and weather, or any other factor that may impede the planned activities for a given date. This record is essential for planning tasks in hard-to-access areas, where environmental conditions can directly impact task execution. Documenting this information allows for more efficient scheduling and adaptation of work timelines, avoiding unforeseen interruptions;
- use of vessels: due to the constant need for navigation, the project vessels undergo regular maintenance in accordance with manufacturer specifications: every 100 hours of use or every 6 months, whichever comes first. This schedule is crucial to ensure that the operational team uses vessels in optimal conditions, ensuring their safety and the efficiency of restoration activities. Throughout the journey, all project personnel are required to wear life jackets (model Canga Class III), which are certified by the Directorate of Ports and Coasts (DPC), a military organization of the Brazilian Navy, in accordance with the Maritime Authority Norm - NORMAM - 321.

Due to the nature of the work being carried out in a natural environment, it is essential to address the issue of field team care regarding insects. In mangrove ecosystems, the presence of maruim, a small insect usually measuring less than 3 millimeters, belonging to the family Ceratopogonidae, is common; it is also known as the "mangrove mosquito" (Figure 8). These insects are notorious for their tendency to cause discomfort, as females feed on the blood of animals, including humans, to obtain the essential nutrients required for the maturation of their eggs, resulting in highly irritating bites that can cause itching and swelling.

Figure 8. Presence of maruims (small dots) on the field technician's hand.



Source: Authors

From a health, safety, and environmental management (SSMA) perspective, the field team may face challenges due to the activity of these insects. It is often necessary to temporarily suspend field activities during periods of intense maruim presence to avoid discomfort and potential allergic reactions among the operational team. It is important to note that halting restoration efforts is a necessary measure to ensure the health and well-being of the team.

It is observed that the use of repellents in the field, even those that are highly effective and long-lasting (such as those containing Icaridin), is often insufficient to mitigate the discomfort caused by these insects.

Regarding the work schedule in the mangrove, activities are strongly influenced by tidal levels. At certain times, conditions may be favorable for navigation, while at other times, low tides impede passage through certain areas. It is also worth mentioning that during high tides, the area may become flooded, hindering the progress of activities. Therefore, constant adaptation to environmental conditions is necessary to ensure safety in restoration operations.

Thanks to the knowledge of the traditional peoples of Guanabara Bay, we have learned that the presence of maruim tends to increase significantly around the full and new moon phases; thus, these are moments when field activities are likely to be interrupted. Due to the activity of the maruim, interruptions to fieldwork can impact compliance with deadlines, as they may last from 3 to 5 days or until the presence of these insects diminishes to tolerable levels. Therefore, the management and planning

of restoration activities in mangroves must take this particularity into account as an integral part of the process, ensuring the health and safety of the field team.

3. RESULTS

3.1 ESTABLISHING AN HSE CULTURE

The implementation of Health, Safety, and Environmental Management (SSMA) measures faced significant challenges at the beginning of the project, as both field collaborators and the technical team were unfamiliar with the subject, resulting in a lack of experience regarding SSMA practices. However, over time, a significant evolution was observed among all involved. An example of this is the success achieved during emergency drills. Initially, collaborators displayed hesitation and uncertainty in executing safety measures; however, with the progress of training and awareness, they became more agile and efficient in responding to simulated emergencies.

According to Rodrigues *et al.* (2023), to enhance the outcomes of forest restoration activities in mangroves, it is essential to prioritize the hiring of local labor, as these individuals possess profound knowledge of natural cycles, facilitating the employment of management and restoration techniques in the worked environment. Activities in mangroves are subject to a series of environmental conditions not observed in restorations conducted in other phytophysionomies of the Atlantic Forest, such as restingas, ombrophilous, and seasonal forests. For example, the strong influence of tidal regimes and lunar phases, as well as prior knowledge necessary for better navigation on unconsolidated substrates, not only reduces the risks of workplace accidents but also enhances the productivity of actions.

In this sense, strengthening nature-based solutions is amplified when we recognize the importance of traditional knowledge and ancestral wisdom in conjunction with academic approaches. This integration of knowledge is termed social technology. It is important to highlight that the valuable traditional knowledge of the members of the Cooperativa Manguezal Fluminense regarding the peculiarities of the mangrove was fundamental in implementing safety measures. This knowledge was particularly relevant in a context where there were no prior technical-scientific records of SSMA initiatives in mangrove restoration, necessitating an innovative approach from all

involved institutions. In close collaboration with members of the local traditional community, safety strategies were developed that took into account the unique characteristics of the region's mangrove.

It is noteworthy that throughout the forest restoration project, no workplace accidents were recorded. This positive result is a direct reflection of the SSMA actions implemented throughout the activities, which included the rigorous application of safety protocols, continuous training of the operational team, constant monitoring of environmental and working conditions, and the active participation of traditional community members.

4. DISCUSSION

Work in the forestry sector presents very unique characteristics that differ significantly from other productive sectors (Santos, 2022). The working conditions and environment vary considerably depending on the stage of work, greatly impacting labor issues, safety, and the well-being of workers in this segment (Valeriano, 2009). Several authors report that in forestry establishment activities, workers may engage in tasks requiring significant physical effort, adopt potentially harmful postures, and handle loads exceeding tolerable limits (Fiedler *et al.*, 2011; Silva *et al.*, 2007; Toupin *et al.*, 2007). Such situations can compromise productivity, cause discomfort, and increase the risk of accidents and health issues (Lida, 2005).

According to Moreira (2009), workers should be regarded as the human capital of the company and an integral and interdependent part of the entire production system. Therefore, for organizations to achieve success, they must continuously seek proposals to improve working conditions and worker satisfaction. In this context, occupational safety is a key element that should integrate the management system of native forests within an organization (Lima *et al.*, 2020).

Risk assessment plays a crucial role in ensuring a safe and healthy workplace. It is a dynamic process that allows companies and organizations to implement a proactive risk management policy in the workplace. However, to carry out this practice, the involvement of all participants in the process, from employers to employees, is essential (Freitas, 2011). This was the case in this work, where the community's deep knowledge of the peculiarities of the mangrove allowed safety

professionals involved in the project to conduct a more accurate risk assessment, contributing to a safer work environment with no accidents.

By identifying human factors and working conditions, it is possible to pinpoint opportunities to improve work methods and techniques. This ensures more comfortable, safe, and healthy conditions for the operational team, resulting in increased productivity and quality of work (Sant'anna; Malinovski, 2002; Fiedler, 1998; Minetti, 1996; Grandjean, 1982).

Britto *et al.* (2015) studied human factors and working conditions in eucalyptus plantation and maintenance activities in Paraná and found that regarding physical fatigue at work, 81.1% of workers considered their work moderate, 11.3% heavy, and 6.5% light, highlighting that 68.8% of the operational team reported feeling very fatigued after work. According to the respondents, this fatigue was due to constant movements during the workday and unfavorable environmental conditions, which are common during silvicultural activities.

Depoi and Silva (2021) found that although ergonomic and personal protective equipment is widely promoted in the sector, much remains to be explored, as there is a lack of clarity about which PPE should be used according to the tasks performed. Thus, a relationship between activities and protective equipment, established by safety professionals, should exist to reduce risks to which workers are exposed (Da Silva, 2013).

Vosniak *et al.* (2011), evaluating the posture of workers engaged in planting and fertilization activities in planted forests in Paraná, observed that most postures adopted by workers during planting are harmful to health, necessitating prompt corrective measures. Additionally, the authors found that planting seedlings was considered the activity requiring the worst postures, as workers' backs remained bent for most of the workday. Consequently, the body regions most affected were the lower back, due to frequent bending of the lumbar spine. The authors concluded that establishing job rotation among workers is necessary to improve their postures during activities. Fiedler *et al.* (2003) state that in forestry work, some tasks are performed while standing, sitting, or crouching, with the torso twisted and involving repetitive movements, where workers may assume incorrect postures during their work shifts, causing health issues.

Oliveira *et al.* (2014) assessed the physical and biomechanical workload of workers in manual and semi-mechanized mowing activities for forest planting and observed that

the manual mowing method imposed a greater physical load on workers, categorizing the activity as heavy and indicating the need for improvements in ergonomic conditions.

Lima *et al.* (2020), analyzing occupational safety in native forest management systems, found that in Brazil, the main occupational safety issues in native forest management activities are related to non-compliance with labor legislation. Non-conformities mostly pertained to issues with subcontracted workers and non-compliance with health and safety regulations (NRs), particularly NR 31, which pertains specifically to the sector (Basso *et al.*, 2011; Paiva *et al.*, 2015). Regarding occupational safety in native forest management, limited access to information (Yovi; Yamada, 2015) and the generally basic training of forestry workers (Zhao *et al.*, 2011) are reasons to conduct regular training and periodic reviews of SSMA procedures.

Santos (2022), in a integrative review on occupational safety in the Brazilian forestry sector (commercial forests), highlighted a considerable deficit in scientific production on the subject of occupational safety in the Brazilian forestry sector. Lima *et al.* (2020) assert that the number of scientific articles published on management and occupational safety in native forest management activities is quite scarce and that the publications found suggest that safeguarding the integrity and health of workers can be ensured not only through compliance with health and safety legislation but also through the implementation of enforcement mechanisms for the activity. This factor is present in this project, as both NTS and Index Florestal strongly enforce these requirements.

Given the importance of forest establishment, which involves many workers and the lack of sufficient research on occupational safety in this area, it is crucial to analyze the conditions of workers while they perform their activities and to disseminate scientific findings (Vosniak *et al.*, 2011). This measure, according to Alves (2001), will enable the implementation of new techniques adapted to the occupational reality of workers, promoting improvements in their comfort, safety, and health.

5. CONCLUSION

SSMA practices are essential for the success of any environmental project, particularly those focused on forest restoration that operate in challenging conditions and sensitive environments. The implementation of these practices demonstrates a commitment to the safety of the operational team and the

sustainability of the project. Identifying, assessing, and mitigating risks creates a safer and more sustainable work environment.

It is strongly recommended that all projects adopt a robust SSMA program and consider hiring specialized professionals, such as engineers and occupational safety technicians. This ensures compliance with current labor and environmental legislation, as well as enhancing the reputation of all involved institutions. Incorporating these measures not only fulfills legal and regulatory obligations but also positions the executor as a reference in integrating health, safety, and environmental practices, fostering better integration with the local community.

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CHAPTER 7

THE FORMATION OF COOPERATION NETWORKS IN RESEARCH/EXTENSION WITH REFERENCES TO ALLIANCES TO STRENGTHEN ENVIRONMENTAL EDUCATION

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1. INTRODUCTION

The occurrence of the collective calamity of the socio-environmental disaster in Rio Grande do Sul in 2024 raised a broad range of demands and questions concerning environmental vulnerability and the flood protection system. The reconstruction effort calls for consolidating the role of multidimensional solutions advocated by academic knowledge and actions stemming from the affected communities. The development of environmental education (EE) for environmental sustainability has increasingly established itself as a relatively consistent epistemic field with growing local and global relevance, encompassing scientific colloquia, teacher training, and cooperative social practices. This text results from the effort of reflection and articulation concerning the construction and activities of the research group “Araucárias: Research-Training in Networks and Education for Sustainability,” which adds to other forms of exchange, both in terms of teacher enhancement and public schooling, as well as in research as an educational principle in the environmental field*. The network appears to consolidate the hybrid dimension of educational movements: online, digital technologies, and face-to-face interactions.

The complexity in formulating a research and training network lies at the intersection of cooperation within a society filled with socio-environmental conflicts and the competition imposed by work schedules. A cooperative arrangement or pact among different actors expands the fertility of research and makes practices systemic in communities or territories. Here we have one of the structured experiences in the south of the country, which seeks to integrate academic production in EE within one of the unique ecosystem territories, commonly known as the *campos de cima da serra* in northeastern Rio Grande do Sul. The researchers of the Araucárias Network come from various fields of knowledge, which ultimately guided them toward establishing a research network at the State University of Rio Grande do Sul (UERGS) with a cooperative perspective and a systematic exchange network, focusing on different aspects of work concerning sustainability. This network includes various professionals (teachers,

* A version of this text is published in Ruscheinsky, Aloisio; Reinehr, Rosmarie; Richter, Marc Francois. Cooperation networks in research and training for adherence to socio-environmental sustainability. *Boletim de Conjuntura (BOCA)*, v. 13, n. 37, p. 63-82, 2023.

students, managers, researchers, and community actors) whose interactions can be generated within the micro and macro spaces of environmental governance.

The forms of solidarity demonstrated during the flood disaster in the south of the country were already incorporated into the goal defined for the present work, which is to disseminate the proposal for a research network in the field of Environmental Education, based on interdisciplinary reflections and pedagogical practices, and to justify inviting other regional actors to engage in this cooperative experience for environmental protection. This attempt to converge actors has its rationale in the discussions within the research field, as interactions of sociability within institutional contexts and even within school networks bring significant appeal to the concept of “sustainable development” and its recently reorganized goals, if not common usage. This is not a mere opposition but an effort to delineate boundaries in the discussion of alternatives in everyday life and in a network of relationships, drawing closer to anthropological knowledge and other fields of study. Broadly speaking, our aspiration includes a highlighted output—to portray certain circumstances of the Araucárias Environmental Education Network, emphasizing the intertwining of its multiple actions amid theoretical, methodological, interdisciplinary, ethical, and political conceptions.

The proposed and relevant focus to understand the trajectory of the narrative presented in this study lies in elucidating the research problem: the question consists of highlighting, through a strategic and factual discussion, how this research network can promote critical reflection around the perspective of environmental sustainability on a regional level, involving scientific procedures, the skills of students, teacher-researchers, and environmentalists.

Explicit references to support alliances or pacts among actors aiming to strengthen environmental education practices become increasingly urgent in the face of climate change. In this sense, in considering transparency factors, the authors aim to delineate their perspective, focusing on a horizon of public debate, the academic universe, and knowledge production. Acknowledging the social location from which one speaks is fundamental for understanding issues of inequality, environmental and social sustainability, as well as the role of science and information dissemination in fostering solidarity, recognition, and empathy within the ecosystem. To some extent, our analysis intertwines “starting from points of departure, the social position of discourse, and the solutions presented as alternatives to the environmental crisis”

(Ruscheinsky, 2008, 327). In short, this entails an alliance between traditional and scientific knowledge, with consideration of the “other's science.” Here, the place also refers to where actions related to the theme are carried out, the aim of the effort—namely, the social place of discourse and socio-environmental practices, whose premises are:

1. in the boldness of interdisciplinarity, this academic work attempts to explore the interfaces between education and environmental sustainability, like a razor's edge shaped by the distinct professional action trajectories of the authors;
2. as citizens of a society that enshrines humanity as arbiter or ruler over nature, with a mandate for its conservation and/or exploitation;
3. the acknowledgment that connections are established between myths, with their respective sustainability attributes, and the formulation of utopias projected beyond materially present projects in daily life;
4. the recognition of conflicting dynamics within social phenomena, which can differentiate and substantiate a paradoxical combination of empathy, cooperation, estrangement, and conflict;
5. purposeful conflicted cooperation alludes to a complex and multidimensional reality of movements, conjectures, interactions, and negotiation;
6. the social context is permeated by the normativity and everyday presence of the nation-state, whether as an institution or as a determinant of circumstantial aspects, such as the endorsement of our daily currency or personal identification documents;
7. the commitment to developing personal and collective capacities that underpin the freedom to discern, to deliberate as rights-bearing subjects, and to participate in formulating environmental relationships and policies;
8. the acknowledgment of the trajectory of engagement in environmental issues, as well as the sharing of socio-environmental movements, with research focused on sustainability and the environment;
9. the empirical research conducted in an interdisciplinary manner involved territorial conflicts, simultaneously framed by a steadfast political will to affirm the relevance of each of the Brazilian biomes;

Engagement in networks of exchange and sustainability aims to foster research and holistic human development in southern Brazil, which logically entails: a) encouraging

dialogue between social and environmental movements; b) awakening the interest of those unfamiliar with the complexity of environmental issues; and c) outlining environmental policies to guide sustainability education practices, which require the emergence of environmental sustainability networks in a territory interwoven with actors, empathy, and shared sympathy for common objects and objectives.

The publication of this text results from the effort of research and educational action using new tools for remote communication, employing primary empirical data obtained through interactions with municipal environmental agents and secondary data from consultations of institutional documents regarding the different dynamics launched for a process of technological development and environmental sustainability. The formation of the network inevitably highlights the role of population distribution in the territory, the institutions, and the social actors shaped by their historical opportunities.

This text has the following structure: a) first, the establishment of a network called EA, in the field of research and training with a cooperative bias, serving as mechanisms of innovation in a particular territory and initiating a mobilization for a different vision of the future for environmental goods or common uses in the territory we inhabit; b) the second part addresses aspects related to environmental awareness, including the humanization of worldview, didactic aspects, the importance of waste recycling processes, unequivocal forms of cooperation, and the unease regarding consumption; and c) the third part focuses on how cooperation is organized to underpin processes and interfaces of regional planning, environmental protection development, and population mobilization to conjecture and generate social practices of socio-environmental sustainability, among which are water security and the “preservation of common-use goods of the territory” in question. Finally, the concluding remarks emphasize that throughout the activities of the network in focus, the qualification of teachers and students was established, and multiple exchanges took place to develop the scientific “habitus,” generating commitments within the network for social transformation with sustainability.

Thus, the endeavor to consolidate networks for exchanging environmental information as strategic areas of investigation in the face of climate disasters and others remains a challenge, beyond the strengths of each member and their adherence to socio-environmental sustainability practices.

2. THE PERSPECTIVE OF TRAINING THROUGH RESEARCH IN INTERLOCUTION NETWORKS

The production of knowledge in organizations and institutions appears to be one of the frameworks for planning in a society living in uncertainty and uncontrollability when it comes to climate emergencies. The emergence and articulation of the research group “Araucárias: Research-Training in Education for Sustainability” aim to gather, articulate, and strengthen a network of researchers in an interdisciplinary dimension. The effort made in this endeavor seeks to dismantle the fragmentation of knowledge and ensure the integration of know-how. In this academic arena, there are still more promises than achievements: evaluation institutions resist implicitly recognizing the prevalence of interdisciplinarity.

The systematization of research as a survey of environmental reality presents itself as a movement converging on the recognition of problems, conflicts, resolutions, agreements, and local actors. Adherence to socio-environmental sustainability encompasses the concerted action of social actors in consonance and in conflict (school organization, community perspective, participation, territorialities, environmental services, partnerships). Therefore, there is a commitment to the logic of equitable access to environmental goods, despite the ongoing conflict between cooperation and competition.

The assertion and intertwining of researchers listening to socio-environmental practices forge knowledge about ordinary processes of collective management of the common-use goods of citizens, under a transindividual and intergenerational logic. By forging a research network for dialogue, a solidary or cooperative dimension between social relations and environmental goods was projected, as well as the possibility of projecting, calibrating focus, and improving environmental education policies.

A research network delineated in action encompassed the intention to articulate academics and structure a network also guided by action, comprising a scenario in which possible paths were intended to be drawn to transform the reality of inequalities, injustices, and environmental degradation. The actions targeted by the network concentrate on situations where pathways can be identified for people to assimilate mechanisms to discern the circumstances, attributing and modifying the meanings that permeate their worldview regarding the intertwining of social relations and the

environment. These questioning activities about the socio-environmental context highlight actions of cooperation and solidarity, both among peers and with environmental goods.

Everyday experiences began to be understood as complex relationships, as well as crowded with conflicts in the face of a participatory and democratic environmental management project (Layrargues, 2000). Environmental education initiatives, usually in the form of projects, are recognized institutionally in the municipalities covered by the research network in focus.

The primary focus considers the reach of social practices of an environmental education network, understanding the joint modifications of social and curricular practices, while also pondering historical processes with their technological, cultural, social, economic, and environmental transformations. This goal is directly connected with the perception that participants express when involved in the socio-environmental relations of their surroundings, intertwining with the place, their territory, and cultural dimensions.

The social position of the actors generates an environmental perception resulting from the consolidated sense of belonging to the place where they live and apprehend socio-environmental relations. At the same time, the profiling for action and research serves as support for the essays related to the curriculum/environment nexus, whose mediations collect and encompass relevant information that supports negotiations in the face of conflicts. Cooperation refers to the type of environmental practices suited to public policies with relevance or establishment of environmental education.

From this perspective, with the endorsement of the research group, academic events were also held with the purpose of grasping and undertaking new theoretical horizons, as well as promoting the proximity of new actors, contributors, and stakeholders. This configuration signifies a deepening of discussions contemplated through themes focused on the problems perceived in the territory.

Thus, the role of preservation areas for the subsistence of ecosystems, the role of educational networks for structuring, effecting, and strengthening research and social practice comes into focus. In the territorial space, the logic follows not far from a sustainable path with socio-environmental justice. Prada and Reali (2018) draw attention to the fact that the initiative for academic enhancement mediated by research,

in a perspective of real complexity in the “Campos de Cima da Serra*,” with its multiple knowledges from social and cultural agents, should not become a parallel curriculum in the management of public education.

Although seemingly simple, the territorial circumstances and landscapes present a typical imagistic and cultural melting pot, with vast biodiversity and conflicting interests upon closer examination. By proposing to ally “everyday research/training curricula in environmental education,” new categories are sculpted to redesign the curriculum. In this, the complexity amid nature is recognized, where its elements can be in deep cooperation or in competition, which is why the blossoming of reflexivity becomes a predominant goal.

To seal this strategy, historical and bureaucratic obstacles must be faced, leveraging potentials to confront the paradox between epistemological blindness and favorable conditions for problematizing ordinary phenomena as a prerequisite for research (Traversini; Reis; Steffen, 2018). Likewise, research/training promotes “listening to new or old voices,” as well as other narratives as an emerging and prolific agenda of experiences in democratic and civic participation.

In this perspective, the project of humanistic construction of historical subjects is based on a vast research field of socio-environmental relations and forms of action regarding social relations. Thus, amid the recognition that competition is a social fact in everyday life, the initiative favors cooperation and solidarity. In this rhythm, the network encourages frugality regarding consumption, hence against waste or the profusion of goods as a source of happiness.

Meanwhile, it recognizes in-between spaces that acknowledge movements of differentiation of spaces while simultaneously integrating the curriculum based on cooperation. The attempts to recognize reality, for which agents begin to draw innovations in their social practices, forge the statement that within this restricted territory, multiple boundaries also intersect (Pinheiro; Mattos, 2004), among which: a) material/natural within the ecosystem; b) symbolic, cultural, and cognitive prism; c) processes of technological transformations impacting environmental dimensions.

* It is a geopolitical region located in the northeast of the state of Rio Grande do Sul, with altitudes close to a thousand meters above sea level, an area adjacent to the Santa Catarina mountain range, known for its mountain climate with harsh winters, with tourism and livestock farming in native fields being an economic activity, together with the araucaria forests, the pine nut and the relief of the canyons, together with a low population density.

Environmental practices stem from symbiosis and contrast the interactions between society and nature, considering the peculiarities of ecosystems in environmental education. In other words, the ecosystem in which agents are inserted forms a movement of many threads or delicate balances. Therefore, the research/training methodology refers to types of inquisitive perspectives, as asking the right question is one of the principles of knowledge, as well as observing how diverse learnings about oneself and others propagate.

Participatory experiences and the contribution of environmental education, specifically regarding citizenship, enable the construction of political action, aimed at fostering a collectivity responsible for caring for environmental goods that underpin their survival. Above all, it is essential to recognize oneself as a being among many others sharing the same territory, being aware both personally and collectively, immersed yet not submerged.

In the struggle to understand multiple experiences, to portray the intertwining forms and strategies in the face of socio-environmental phenomena, beliefs, myths, knowledge, rationalities, values, feelings, practices, among others, stand out. Thus, the foundation for developing critical thinking capable of formulating value judgments based on solidarity in decision-making in different social circumstances is established.

Promoting the discussion of “pedagogies of everyday life,” especially regarding the constitutive dimension of public, structural, and participatory policies in a territory, implies focusing on the dimension of negotiation of conflicts experienced in everyday life. The dialogue proposed by the extension courses promoted by the network goes beyond the so-called problematization of generated waste, ordinary educational practices, as well as legal norms.

Nonetheless, nothing would justify dismissing the issue of the effects of consumption processes that generate various wastes. This is because the municipal management of São Francisco de Paula, even in 2018, according to the “Synthesis Report on the Supply of Potable Water and Sanitary Sewage^{*}” proposes in the Basic Sanitation Institutional Management Program the boldness to only consider an environmental education policy with an impact on sanitation in the medium term. In other words, a policy in this field lies on the horizon of future planning, but not on the agenda of the day.

* Available at: https://www.saofranciscodepaula.rs.gov.br/arquivos/plano_municipal_de_saneamento_23114238.pdf

The idea of abandoning the territory of the Campos de Cima da Serra implies that it is situated without support, without development, without care, without protection, or without progress. The abundance of material goods can distort the deep intertwining of the life of the population, waters, lands, mountains, canyons, animals, and trees. The idea of integration into modernizing civilization may even sound strange or allied with foreign forces.

3. THE METHODOLOGICAL DIMENSION IN THE FACE OF AN ENVIRONMENTAL APPROACH

A socio-environmental disaster is a moment of great distress and multiple tensions that even constrain the construction of knowledge about the ongoing phenomena. Controversies arise regarding the approaches and perspectives of public policies in a context where Environmental Education (EA) is akin to labor pains in the face of emerging disasters. To clarify for the reader, it is important to explicitly state the analytical assumptions: the State has functions and presents itself as a space for negotiation. Undoubtedly, this space is reduced or narrowed for marginalized social sectors and for those who clearly propose a change in the course of existing inequalities.

The discussions undertaken to elucidate a positive teaching trajectory have assumed paradoxical dimensions (Ruscheinsky, 2021): a) on one hand, a focus on theories of knowledge, epistemology, and historical and ethical phenomena; and b) on the other hand, the search for sensory phenomena to accurately analyze the multicultural arena and its practical knowledge of EA. On one side, we endorse the abandonment of the notion of intervention as a mechanism for change, while on the other, we stimulate reflexivity, which comprises participation associated with recognizing the other as an unequivocal interlocutor, cooperation, and commitment. Therefore, research/training emerges as a transformative impetus for the perspectives or conceptions of the relationship between humans and ecosystems.

In this trajectory, ongoing dialogue and the qualification of information characterize the emergence of dispositions, so that all participants enjoy equitable opportunities to express themselves in a public sphere. Socio-environmental issues, as a contemporary challenge, especially for the humanistic vision of teachers, seem to

imply adopting an interdisciplinary perspective (Ferreira, 2018). By adopting this perspective, one can finely understand the intricate threads between society and nature; moreover, it allows for a focus on the political rationality that governs our daily lives and the broad socio-environmental transformations underway.

Simultaneously, the practical perception is spreading that any form of consumption is connected to forms of cooperation, the energy crisis, and environmental sanitation. This perception is supported by an increasingly consistent and sharpened theoretical framework capable of underpinning new pedagogical practices and a reconstruction of worldviews grounded in the awareness of the complexity paradigm. This will contribute to combating predatory markets, racism, the primacy of the aesthetic, prejudice, among others, to endorse gender equality, human and environmental rights, and the public and inclusive dimension of education (Traversini; Mello, 2020). EA highlights practices of empathy and appropriation, as well as knowledge production supported by democratic management, as substrates of citizenship aimed at reducing inequalities.

The initiative for training mediated by research aims to understand the complexity of environmental circumstances and their agents at the regional level, which somehow displays its canyons, forests, and other natural beauties. The multiple knowledges and technological innovation processes that underpin the social and cultural practices of agents are also subject to planning due to their public conflict nature. In this territory, there is a "unique association between natural fields and araucaria forests" (Scur; Marchett, 2017), to which we add other characteristics such as conservation areas, pine and eucalyptus plantations, and potato or soybean crops.

These landscapes engender, in some way, scenarios and inquiries to be addressed in the formatting of curricula, whether for the educational system or for socio-environmental agents. It seems fundamental, from a methodological perspective, to understand that both in the management of public education, a hidden curriculum remains due to various cleavages, and in the social reality, different parallel curricula nestle, propelled by circumstances, actors, and non-school educational spaces.

Knowledge in the field of EA aims to bridge distinct yet non-exclusive curricula, reflecting on a diversity of agendas concerning care for environmental goods as an otherness (Ruscheinsky, 2020; Soeiro; Pinheiro; Bautista, 2017). Furthermore, the idea of an ethic of care for the other and for the environment seems, above all, to be a

dimension of education and environmental management. Environmental care as a language can impact all learning, from literacy to post-graduation. All these stages are conducive to new perspectives on old themes, as demonstrated by experiences, both within the network and through reports gathered from extension activities.

As a relevant and socially perceptible social aspect, the parallel curriculum derives from options or deliberations that encompass a tapestry of knowledge (environmental, cultural, artistic, ethical, culinary, sanitary, relational) operating as mechanisms for managing solidarity, serving as symbols of exchange, negotiation, communication, and translation. In this context, the constitution of social action influencing worldviews, with methodological innovation in environmental approaches, encompasses complexity and reflexivity, incorporating the perspective of the ecological crisis with its aspects of uncertainties, undesirability, uncontrollability, invisibility, unpredictability, and yet incalculable reach.

The methodological innovation proposed by adopting the research/training binomial seems largely favored by the dimension of hermeneutic circles in local life due to the impact of reformulating some dimensions of worldview. It must be said that we live in a "wounded and torn world," marked by the fragility of solidarity as fundamental in interactions, whether among humans or the entire biodiversity (Thiemann; Oliveira, 2013). The drama of a wounded world involves subjectivity, or it can only be profoundly perceived with a heartfelt gaze and pain in the heart. However, this does not underestimate the socio-political consequences, the tragedy of indifference, aspirations for luxurious consumption, and the scientific justifications for environmental degradation.

In light of EA projects conducted in the region, it has been found that intersubjectivity, or the effective way of "wearing the shirt" as a form of commitment, consistently serves as a reference for networks and qualifies their constitutive levels. It is also essential to point out that results tend to depend on specific collective actors, addressing particular or comprehensive demands within the territory of action. In a project, all citizens are called to reflect on the reasons for making decisions that shape cooperative practices and worldviews.

When the planned dialogues at the regional level and EA practices do not remain superficial or merely phenomena resulting from supposed progress, but dare to emphasize a critique of ongoing development—deprivation from mining, waste,

deforestation, the energy crisis, river contamination, food poisoning, and obsolete consumption—it becomes clear that products once labeled as "durable" are now facing their end! Fashion seems to permeate all dimensions of life: all mechanisms of planned obsolescence engender fleeting and exhausting consumption.

Moreover, as important as contact with "nature" may be, it alone is not enough to foster sensitivity or generate reflexivity. On the contrary, the thousands who frequent beaches or enjoy the mild climate of the mountains in summer would not necessarily become ardent defenders of environmental goods. The combination of research/training aligns the perspective of collaborating on a social pact in which reciprocity and solidarity prevail, while also amplifying commitments and ethics in the relationships between the daily lives of citizens and environmental goods.

4. RESEARCH NETWORKS AND STRATEGIES FOR SOCIO-ENVIRONMENTAL EMPOWERMENT

Networks and Empowerment Strategies are aspirations and demands when it comes to mitigating the impacts of both environmental and humanitarian disasters. Network investigations are also, in some way, captured by the insecurity regarding the trajectories of developments in devastating scenarios. Network activities allow for the broadening of knowledge to create a space for developing meanings around an ethics of care for others. In this interim, local cultural experiences, when dialogued with planning and cultural development tools, delineated through the enhancement of research, enable interfaces of local knowledge and enhance cooperation and reflexivity among the involved subjects. The socio-environmental dimension seems so broad that it connects with the struggle against racism, all forms of prejudice, especially a commitment to climate issues in the face of denialism and human rights (including environmental rights, no matter how controversial this issue may be).

Environmental Education (EE), by recognizing the relevance of different contributions of environmental sanitation*, focuses on everyday relationships between society and nature, as well as the various roles of social agents. Transformations in

* Federal Law No. 11,445/2007 defines the following as components of basic sanitation: a set of services, infrastructures and operational facilities for the supply of drinking water, sewage, urban cleaning and solid waste management, drainage and management of rainwater.

urban spaces comprise a field of negotiations or mediation of interests and social rights. It is imperative to add cooperation mechanisms to highlight the dimension of EE (Richter; Lara; Andreazza, 2021) aiming at citizen engagement in its effectiveness, or furthermore, the notion of "environmental sanitation" is broader than "basic sanitation," including disease control and land use.

According to the National Sanitation Information System (SNIS, 2020), about 20% of Brazilians do not have access to treated water supply, and about 50% have access to sewage collection networks. In the "Campos de Cima da Serra," public authorities have not yet established a collective sewage system, with data from 2018 indicating that sewage is usually treated through septic tanks*, with the most complete system comprising a tank, filter, and soakaway. However, this is an individual and primary solution for sewage treatment.

The city of São Francisco de Paula "does not have a collective sewage system, relying only on individual primary sewage treatment solutions" (São Francisco de Paula, n.d., p. 13). The care to prevent medium and long-term contamination of groundwater effectively requires planning and the development of a social pact or a cooperation arrangement among diverse partners. This is because this treatment system requires periodic draining and cleaning, an operation that residents do not perform according to recommendations. Hence, it is up to the public authority to provide control services, as well as a transportation and disposal system.

On the other hand*, the website of the Municipality of Canela/RS reports on 10/20/2021 that five new small sewage treatment stations are nearing completion and will soon be operational, thereby aiming to treat approximately 60% of urban sewage, marking a new level of sanitation for the mountainous region.

Regarding the real neglect and low sanitation standards, the circumstances result from both deficiencies in state management aimed at public welfare and the (ir)responsible actions of citizens (Soeiro; Pinheiro; Bautista, 2017). Even the development of elite tourism does not imply a complete sanitation system, as is the case in Gramado and Canela.

* In this regard, see the Summary Report on Drinking Water Supply and Sanitation, available at: https://www.saofranciscodepaula.rs.gov.br/arquivos/plano_municipal_de_saneamento_23114238.pdf

* Available at: <https://canela.rs.gov.br/noticia/avancam-as-obras-da-ete-do-lago/>

Sanitation has a connection to education for recognizing environmental goods, focusing on management with an emphasis on citizenship (Layrargues, 2000). Much broader than this colloquium might seem, the establishment of a link between the implementation of sanitation and an open and inclusive anthropocentrism, as stated by Murad (2021), treats the care for common-use goods as recognizing the dignity of each being and the whole of living creatures.

One of the weaknesses of these themes in the “Campos de Cima da Serra” refers to the lack of definition in implementing a participatory governance process with actors, agreements, and social practices. Something in this sense was projected by Law No. 11.445/2007, proposing a governance arrangement to modify requirements regarding the direction of environmental policy development, guiding participation as an efficient and legitimate practice within a complex view of political challenges in this domain.

Beyond the singularity of the human being, we understand that in EE, a multicentric conception is adopted, a choice corroborated by the phenomenon of the pandemic, where understanding connects the biosphere, biodiversity, and humans in continuous and interdependent relationships. Recently, the COVID-19 pandemic highlighted the power of a microorganism that moves, touches, and made humanity a hostage to its own recklessness (Ruscheinsky, 2022).

Another aspect in forming networks and strategies for socio-environmental empowerment refers to the adoption of recycling to aim for education for the circular economy. Natural resources are finite, and some are considered scarce, with almost all products being reusable after fulfilling their original purpose, or waste being far from useless. In fact, most of the waste from human activities has recycling value. It is estimated that up to 75% of all waste can be reused or recycled (Razzaq *et al.*, 2021). Almost everything can be recycled, although different materials require different techniques for reuse. This topic is also known as reverse logistics, meaning a set of planned operations related to the reuse and recycling of products and materials.

In the region, according to 2012 data, Canela collected 29 tons of solid waste daily, while São Francisco de Paula collected 14 tons. Another facet of economic irrationality relates to the transportation of waste to Minas do Leão, about 200 km away from the waste's origin.

However, if we truly want to focus on recycling, it is important to change the way we deal with it, both personally and socially. Recycling, in a sense, extends the utility of what has already served its initial purpose, turning it back into something usable. It is part of the golden rules of sustainability (reduce, reuse, and recycle, as well as rethink, restore, or repair). Practically all local or regional territory is impacted by either the irregular disposal of waste or the more advanced recycling processes.

There is also an estimated deficit in selective collection, which is also a deficit in education for future planning, which is evident both in small towns and in metropolises. Generally, recycling practices are more complex the larger the city's population, whose air and soil are already sources of ongoing contamination. Metals, for instance, are repeatedly recyclable, maintaining most or all of their properties.

The adoption of the circular economy makes more sense if it encompasses regional or comprehensive planning and, as such, requires an educational process, as well as an unusual search for the right balance between humans and nature, without imposing that natural goods adapt to human whims. It would be, then, a social and historical process of planning, production, circulation, consumption, and disposal that seeks to ensure environmental sustainability over time (Tiozzi; Simon, 2021; Machado; Richter; Figueras, 2021). In this sense, it is characterized by an economy whose process has among its qualities the restorative and regenerative dimension, or material cycles. With the circular economy, it is possible to boost resource optimization, reduce the consumption of raw materials, and recover waste through recycling or giving it a second life as a new product.

Education for the circular economy consists of applying sustainability measures: reducing, reusing, and recycling, among other "r's." Thus, the life cycle of products is prolonged or efficient and sustainable. The idea comes from imitating nature, where everything has value and everything is reused, where instead of waste, there is a new resource. The circular economy establishes, as the name suggests, a circular or sustainable process in which what seems like an end is also a beginning: extraction, production, information, circulation, consumption, and recycling or return to the process (Ruscheinsky, 2010). However, how to endorse this modality without renouncing sumptuous consumption, the superficial cosmetics of life's meanings? The vision of a circular economy has purposes that coincide with solid waste policies.

5. SOCIAL PACTS IN EDUCATION AND SUSTAINABILITY PLANNING

The path to restoring balance and accessing clean water from one's own well means identifying social actors and their explicit or manifest forms of cooperation, as well as implicit or latent ones, taking place in a given territory. The pact for sustainability requires nurturing a profound hope that aims to restore values that do not prioritize human dominance over the other dimensions of biodiversity. In the existence of social relationships, one can observe the presence of cooperation or care: simply put, humans are beings that can only exist through care, as they are born unable to provide for themselves. Similarly, throughout life, they coexist with cooperative forms of sustaining social life (Machado; Richter; Figueras, 2021).

The planet's overload and the rate of consumption of natural resources have become concerning in light of the ecosystems' regenerative capacity. Alves (2022, p. e5942) confirms this phenomenon, asserting that "a new geological era, the Anthropocene, has emerged, during which anthropogenic activities have become such a powerful force that they have surpassed the Earth's carrying capacity." Never in history has a single species induced such radical changes across diverse habitats, impacting the climate worldwide (Acsehrad, 2022), while neglecting the primacy of education for socio-environmental justice.

The interfaces established in the areas of regional planning within the research network and the development of skills to comprehend the complexity of the webs within the territory have led to arrangements or negotiations. The dimension of Environmental Education (EA) has been the subject of research within the Araucárias network, aiming to understand the impacts on the ecosystem of the Campos de Cima da Serra and the region of Hortênsias. Meanwhile, we face a paradox: on one side, there is a call for reducing inequalities and poverty through public actions, transfers, and access to consumption; on the other, there is a demand to decrease extraction and degradation of environmental goods. Environmental educators must observe the fields of action; the various components of the ecosystem coexist in contradiction: while competing with one another, they also survive through collaboration or interaction. This is the foundation of a dynamic nature.

Socio-environmental cooperation established by individuals and their relationships, or social groups and their alliances, in the face of a phenomenon considered an obstacle

to well-being, generates the conditions for joint action based on a collective conception shared for the care of our common home. EA projects thrive on social relationships within networks, built on trust and the exchange of cooperative practices.

Cooperation for the development of a research and training plan can only be realized through arrangements of solidarity, the recognition of otherness, and tolerance towards the different. This allows us to address investigations for effective EA due to the cooperation of socio-environmental actors, the multifaceted movements in different municipalities, the territorialization, and diversities in training, agency, devices, and the production of subjectivities. Among the environmental goods, paradoxes also exist: on one side, competition is encouraged in some circumstances; on the other, existence is sustained by networked work in the field of biodiversity (Miller; Spoolman, 2015). If we consider the requirements of cooperative EA, these principles will be present in the willingness to foster a sustainable society.

Socially recognized and legitimized pacts are foundational to society, and as such, they feed back into and necessitate a survey of social demands concerning environmental issues related to their respective territory. This investigative action with social agents and local leaders serves to identify the absorption or subjectivation of legal guidelines and environmental policies, as well as their positioning regarding mediation solutions and the possibility of negotiation in the face of conflicts.

Betting on a rationale for existence and the relevance of reflections on the research network means understanding an antagonistic collaboration between consuming and protecting, as well as interrogating the mechanisms of cooperation. In this realm, elements of conflict and socio-environmental solidarity coexist, perpetuating a relational view. In scientific practices, the exceptional credits of humanity amidst biodiversity are asserted, without neglecting the logical flow of the rationale for existence and the relevance of environmental education practices.

EA aims to re-establish a perspective that views natural goods as otherness, with dialogue being the most suitable form of interaction. In reality, there occurs an articulation of individual competencies that collectively compose the joint efforts of a network, shaping social capital within a territory.

Through the commitment of socio-environmental actors to forge planning and institutional arrangements for development, it becomes possible to establish a sustainable relationship from both environmental and social perspectives with

ecosystems. Over time, they exercise the capacity to negotiate conflicts, aiming to generate public collaboration pacts or deliberate on common resources, under a transindividual and intergenerational perspective.

From the perspective of EA, the methodological approach to understanding cooperation mechanisms in daily life requires attention to reciprocities. Risks and uncertainties have brought climate, biodiversity, forest areas, and the water cycle, among other components of this system, closer to their tipping point. However, it is important to recognize a dual movement or mutual influence; as noted by Acsehrad (2022, p. e5930), "the implications of human action on the climate and the return effects of climate on living conditions on Earth."

In this scenario, it is urgent to establish collective discernment processes regarding the adaptation of communities to natural ecosystems, ensuring that lifestyles, businesses, physical structures, and technologies do not sacrifice the capacity for life renewal. One of these arrangements is observed in almost all municipalities covered by the research network, revolving around the qualified collection of dry waste and recycling plants in social inclusion cooperatives, with a positive ingredient corresponding to the municipal population: between 20,000 to 50,000 inhabitants. However, beyond the political and financial capacity of local government, a collective planning process, collective action, and individual commitment are essential.

6. FINAL CONSIDERATIONS

The events prompted by the major flooding in May 2024 in Rio Grande do Sul emphasize the importance and value of knowledge, contrasting with the disregard seen in the organization of a risk society. When addressing the capabilities and potential of Environmental Education (EA) networks being built in a specific territory, such as the Campos de Cima da Serra, it is supported by the understanding that persistent demands are both implicit and explicit in the practices of regional sustainability planning. This call can be translated into perceptions, symbolic actions, and projects that reflect aspirations for care for the environment; such initiatives have gained more solidity in the proximity of social groups and individuals within networks that construct collective identities and converge on environmental policy agendas.

In a sense, this text proposes to disseminate the concept of a "research network," thus presenting this product prominently. In summary, the presentation of the Araucárias Network for Environmental Education identified actions and also exposed its theoretical, ethical, and political conceptions.

Based on interdisciplinary reflections, it invites other actors to engage in ratifying the viability of this experience, as well as to plan for exceeding regional limits. In this regard, another aspect worth highlighting is the diversity of actors in a territory, both within and outside the school context, which allows for an understanding from these different perspectives while aspiring to establish a network of contacts.

The fundamental argument maintains that the creation of networks is one of the essential mechanisms for the emergence or robustness of actions in the field of socio-environmental sustainability, as well as for the development of networks for exchange and sustainability in southern Brazil, contributing to the primary scope of innovation aimed at sustainability in the socio-economic domain.

Regarding the controversial relevance of an academic text about a research network situated in the specificity of Environmental Education, we posit a rationale that can be identified with the uncertainties and insecurity faced due to integration into a consumer society. We conceive the effects of networking as a temporal manifestation arising from antagonistic relationships, with the territory as a phenomenon that triggers the requirements for a socio-environmental pact.

Periodic and systematic observations in the territory in question allow us to conclude that, from the discord of a plurality of environmental demands, the Araucárias Network tends to articulate pathways for recognizing and specifying a conflict arena. In this disposition, alliances and consent are also formed, parallel to the definition of adversities and systemic opponents. Socio-environmental actors, in light of socio-environmental projects, contemplate and encourage the participation of individual and collective subjects, forging networks of exchange.

For members of the research group, it becomes increasingly evident that understanding the potential of research and the cognitive and cooperative arrangement arises from a focus on regional reflexivity. The connections between social and environmental phenomena among individuals, social groups, and actors in a specific territory consolidate one of the results of action activities based on reflexivity. Political adherence to forms of organization around environmental themes tends to

solidify when material demands for common goods or everyday deprivations are intertwined with the abundant or socially perceived waste, incorporating a subjective and critical sense of adversity.

In the territory where the Araucárias network is formed, social and environmental deprivations, such as political and cultural scarcity, are confirmed in light of the dilemmas expressed in planning for environmental sanitation and the tendency to understand intrinsic forms of cooperation in school and societal contexts. The insistence on translating the binomial research and training as two intertwined dimensions of educational planning is justified to the extent that the directing body dares to generate connections and expressive forms of communication among subjects capable of establishing collective political and cultural agendas. All of this similarly requires the emergence of collective identities concerning environmental issues specified in a city whose universe is a source of permanent sanitary contamination, despite regional actors being attuned to technological innovation processes and valuing scientific knowledge.

Despite all the effort exerted, there are still aspects to detail and incorporate into the agenda of the Araucárias Network, such as engaging with NGOs and associations of residents in conservation areas that work in monitoring and EA practices. The margins of granting environmental preservation and tourism areas to private initiatives give us a sense of rituals and violence in the intersections of humanity and nature. The forms of interaction, interdependence, solidarity, and complementarity amid the goods offered by nature—the relationship between humans and non-humans—are at stake. Perhaps more than this, in the midst of this socio-biodiversity (as both realms recognized by interfaces and diversity), the paradigm of constructing the rights of nature enters the scene.

Thus, it is crucial to emphasize at the end that raising awareness for adherence to socio-environmental sustainability practices within networks, among others, such as planning for EA, recycling waste, cooperation, and technological innovation in education, constitutes a hallmark of citizen engagement. The establishment of everyday forms of articulation and cooperation among peers constitutes, therefore, suitable devices for implementing practices pertinent to sustainable development.

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CHAPTER 8

ENVIRONMENTAL CRIME IN SÃO MANUEL-SP AND BOTUCATU-SP: A RETROSPECTIVE STUDY OF CAUSES AND CONSEQUENCES

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ABSTRACT: The Trafficking of Animals, in Brazil, has gained ample ground representing the total of 15% of the values transacted internationally. These illegal exploitation practices remove more than 38 million species from their natural habitats annually. Thus, the present work contextualizes whether the chronic problems, faced transnationally, are confirmed in an isolated, autonomous, or fragmented way in the municipalities, seeking to anticipate the increase in local social violence. The objective was to collect data on environmental crimes in wild animals in the cities of São Manuel/SP and Botucatu/SP, through qualitative and quantitative analyzes of occurrences in the Environmental Police of Botucatu between 2015 and 2019, seeking to identify: prevalence, types of crimes committed, age and gender of those charged, total number of complaints made, number of animals apprehended and environmental education projects carried out by the police. 680 records were analyzed for the study, identifying 18 articles of the applied environmental legislation. Conclusion: the male gender is the one that commits the most crimes, with an average age of 53.55 years for São Manuel and 51.88 years for Botucatu. Once the prevalences were sequenced, the casuistry revealed the same problems faced nationally in the city as well, in addition to detecting a "Top3" of the most frequent crimes in these locations and the direct and indirect causes that correlate with the crimes recorded.

KEYWORDS: illegal animal trade, environmental crimes, brazilian fauna.

RESUMO: O Tráfico de Animais, no Brasil, tem ganhado amplo terreno, representando atualmente o total de 15% dos valores movimentados internacionalmente. Essas práticas ilícitas de exploração retiram mais de 38 milhões de espécies dos seus habitats naturais anualmente. Assim, o presente trabalho busca contextualizar se os problemas crônicos, enfrentados transnacionalmente, confirmam-se de forma isolada, autônoma ou fragmentada nos municípios, buscando antever o aumento da violência social local. Objetivou-se levantar dados de crimes ambientais em animais silvestres nas cidades de São Manuel/SP e Botucatu/SP, por meio de análises quali-quantitativas das ocorrências na Polícia Ambiental de Botucatu entre 2015 à 2019, buscando identificar: prevalência, tipos de crimes cometidos, idade e sexo dos autuados, total de denúncias realizadas, quantitativo de animais apreendidos e projetos de educação ambiental realizados pela polícia. Foram analisados 680 registros para o estudo, identificando 18 artigos da legislação ambiental aplicados. Concluiu-se: o sexo masculino é o que mais comete crimes, com média de idade dos autuados em 53,55 anos para São Manuel e 51,88 anos para Botucatu. Sequenciadas as prevalências, constatou-se pelas casuísticas os mesmos problemas enfrentados nacionalmente também a nível municipal, além de detectar-se um “Top3” dos crimes mais ocorridos nestas localidades e as causas diretas e indiretas que se correlacionam para os crimes registrados.

PALAVRAS-CHAVE: comércio ilegal de animais, crimes ambientais, fauna brasileira.

1. INTRODUCTION

In-depth study, it is identified, that the crimes directly linked with the fauna, specifically, are split into means and ways for the State to simulate, conclude and map how damaging in the long term will be the increase of social violence and human aggressiveness, whether in urban centers or in the countryside (Nassaro, 2013).

And, considering that Brazil is an environmental transgressor, with high levels of recidivism and criminality, which has assumed contrasts of recent inefficiency in the control of crimes, intensifying the destructuring of the whole of its system of socio-environmental justice, it is opted for carrying out an empirical survey, focusing the retrospective conjectures of data and prevalences in percentages of the environmental crimes that occurred in São Manuel and Botucatu (inner cities).

Therefore, the responses extracted regionally in the cities studied, seek to explain, state or deconstruct if the phenomenon of crimes against fauna/flora at the national level - also happens in the interior of the State of São Paulo.

Having outlined the objective, a stimulating relevance of research is justified: both in the social and legal spheres: identifying environmental crimes that occurred during 5 years (2015/19) - in order to awaken the importance of public policies for the prevention, mitigation and containment of these regionalized crimes.

In the theoretical part, it brings a contributory look at how the legislation of Decree 6.514/2008 - which provides for offenses and administrative penalties to the environment has been applied in the day-to-day in an autonomous and centralized manner in certain cities and how this instrument is used by the police (which crime most occurred in the inspections?).

In the practical contribution, with the cases organized, it is possible for the agents to identify the most relevant and minor crime(s), so that guidelines and plans are defined on how to effectively combat and improve police action in a given locality and crime.

Thus, the hypothesis of the work started from the following assumption: would there be environmental crimes in municipalities? if positive: what are the prevailing crimes? the age of the perpetrators? and who carries them out? annually: is there an increase or decrease in the cases?

Starting from these premises and questioning, the research problem was delimited: in the light of the Brazilian scenario of increase and concentration of environmental crimes, it is tried to understand, by which factors this occurs and if this phenomenon also happens at the regional level (Cerqueira, 2021).

Once the prevalence was detected, it would then also be possible to associate and instruct ways of containing and controlling present and future occurrences. (IPEA 2015; CNJ 2019). After all, to know what crimes are committed it is appropriate for the public manager and the other actors to centralize their measures of centralized and joint combat under environmental offenses in better equipping the municipality and municipal public bodies in the multifocused prevention of local occurrences (Marques, 2021).

To answer these questions, a study was carried out in two border cities, one with a larger population and a high HDI (Botucatu) - with an estimated population of 149,718 inhabitants, a population density of 85.88 inhabitants/km² and a projected territorial area of 1,482.642 km², and the other with a smaller population and a regular HDI (São Manuel) - with an estimated population of 41,287 inhabitants, a population density of 58.92 inhabitants/km² and a projected territorial area of 6550.70 4 km², in order to identify whether in cities with a larger or smaller population there is concentration or fractionation of environmental crimes (IBGE, 2021).

As for the variables, they were conditioned to the records of the crimes by the Environmental Police: if they would bring the necessary information for selective filing such as: age of the accused, sex, type of crime recorded, descriptive of the complaint, among others.

2. MATERIAL AND METHODS

For the development of the research was approved by the Council of the Commission of Ethics in the Use of Animals - CUSA of the School of Veterinary Medicine and Zootechny of the São Paulo State University (UNESP) - Botucatu - attestation No. 0097/2020 in 15/07/2020 11/02/2021, and the project was expressly agreed by the Military Environmental Police of Botucatu for access to the data the methodology traced, besides the authorization of the Ethics Committee in Human Research of the Faculty of Medicine of the São Paulo State University (UNESP) - Botucatu as opinion No. 4,536,682 on 02/11/2021, according to CAAE No

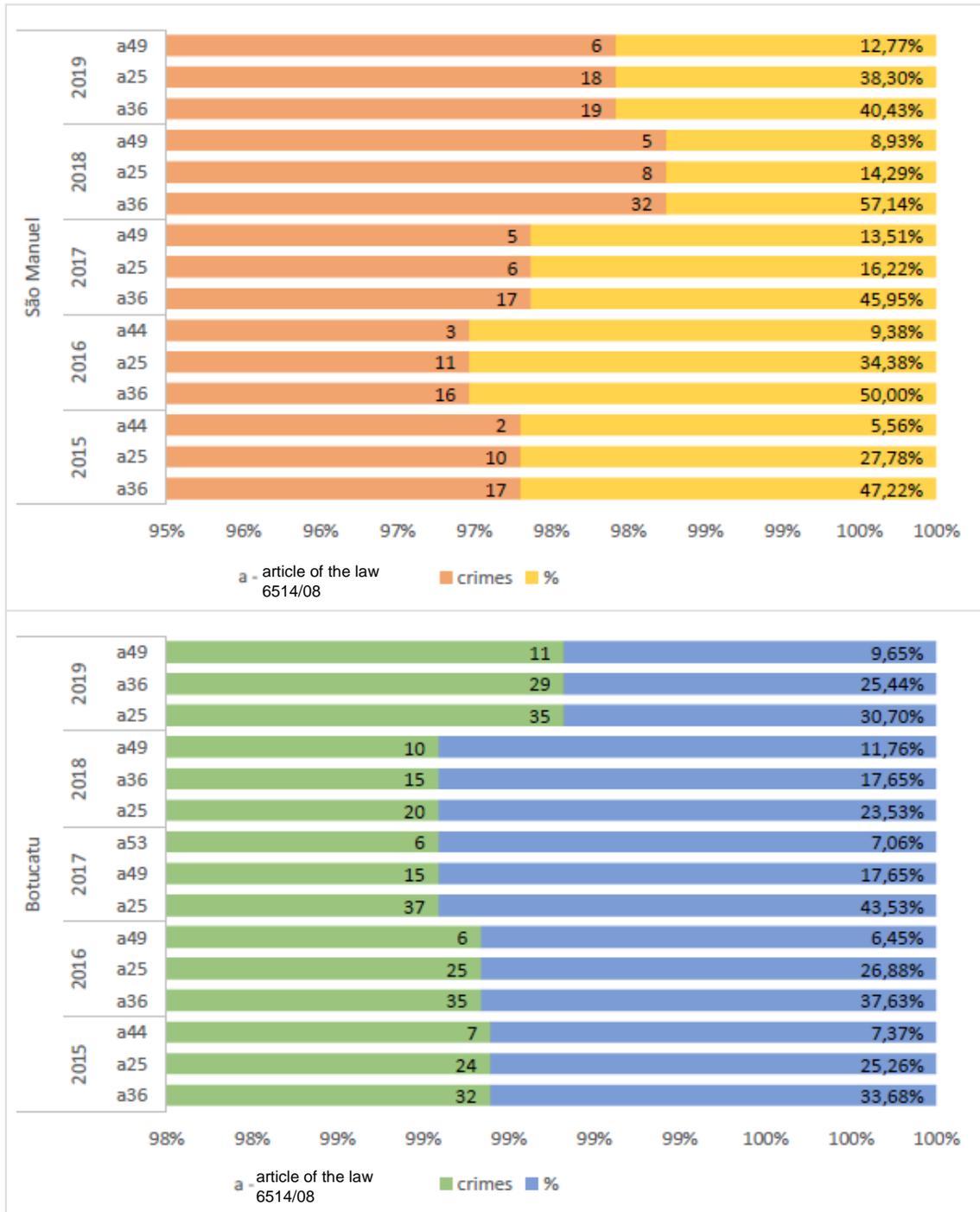
35432620.8.0000.5411. Although the request for authorization of SISBIO was optional, an application was also forwarded for its approval. The data obtained were tabulated, corrected and broken down. Of the 680 samples, 208 environmental crimes were recorded in São Manuel: a) 2015: 36; b) 2016: 32; c) 2017: 37; d) 2018: 56; 5) 2019:47; in Botucatu, 472 crimes: a) 2015: 95; b) 2016: 93; c) 2017: 85; d) 2018: 85; (e) 2019: 114. During the accounting of the records, there were no exclusion criteria of the samples obtained that would interfere with the purpose of the research.

For crime rankings ("TOP3"): we added the prevalence of both sexes during the years 2015-2019 - to reach the result. For articles with third highest score among the cataloged and with percentages of equal values (Example: article 44: 5.56% and article. 29: 5.56%) - prioritized those that directly impacted the fauna (Example: article. 44: 5.56% / article. 29: 5.56% - was described in the third position of "TOP3", the article. 29, for dealing with the crime of ill-treatment and the article. 44 - on the cutting of trees). However, if the articles in the third position equal the percentages and are linked to the crimes involving the fauna, the one that contains the greatest punishment prevails in the "TOP3" (Example: article. 29: 5.56% (Fine from 500,00 to 3,000,00 reais) / article. 25: 5,56% (Fine of R \$ 2.000,00) - in that case, it would be allocated, the article. 25 in the third position of the "TOP3 with 5.56% prevalence of registered cases).

In the concept of assimilation for the purposes of the study of the ICMBIO/MMA proposed in the discussion, we add the percentages of articles 44, 49 and 53 in Figure 1, for corresponding crimes approximate to the forest devastation occurred, seeking a general sum, to arrive at the quantitative in (%).

3. RESULTS AND DISCUSSION

Figure 1. "Top 3" of environmental crimes in São Manuel and Botucatu.



Source: Prepared by the authors (2022).

Based on the assumptions made in Figure 1 - "Top 3" of the most common environmental crimes committed in São Manuel and Botucatu, we saw: fishing by the use of explosives or other toxic substances (article 36), the illegal introduction of

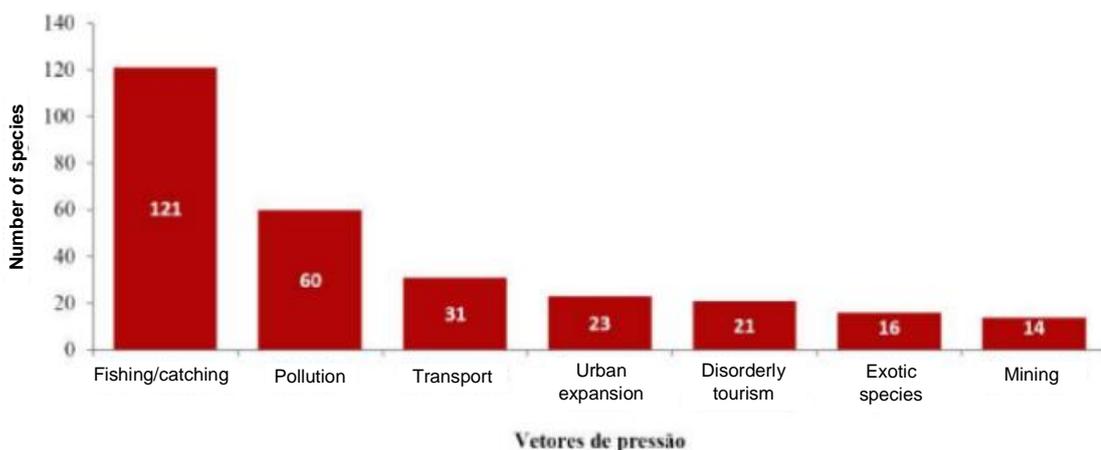
animals without due technical advice (article 25), the cutting of trees in preservation areas (article 44) and the destruction of specially protected forests or outside the legal reserve (article 49 and 53) - the most prevalent (Brazil, 2008).

As for the other incidences that obtained the same numbers of cases and records to allocate themselves in the third position, which did not figure in the final index by the methodology adopted, were all linked to the crime against flora (Brazil, 2008).

Although with regionalized clipping, the "Top 3" of the crimes verified corroborate and (re)affirm the equal practices of Defaunation occurred at the national level, by illegal fishing activities, destruction of the green areas of native vegetation and forced introduction of specimens outside their natural habitat that harm the local settled fauna (Diniz, 2017; ICMBIO/MMA, 2018).

Each location, therefore, source of the research in which the materiality of crimes against the fauna or flora is sought, must be guided casually, considering the culture and customs of the region (Diniz, 2017). According to data from ICMBIO/MMA (2018): "The most impactful activities vary between biomes.", a fact that confirms Figure 2 and the other cases of São Manuel/Botucatu, in which each municipality according to its seasonality practiced distinct and sometimes similar crimes.

Figure 2. Marine species affected by the main threat carriers.



Source: ICMBIO/MMA, 2018.

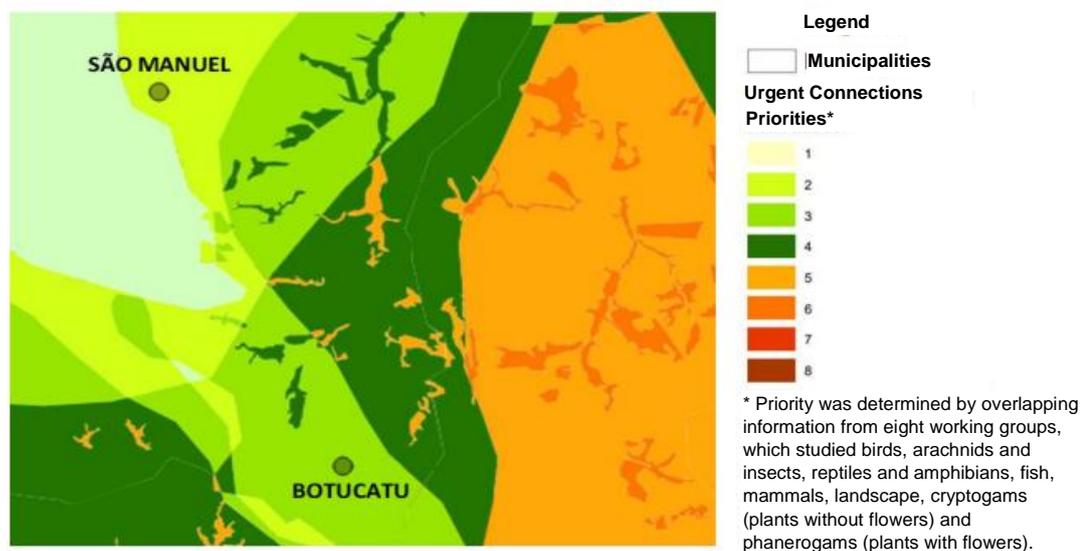
Comparing Figures 1 and 2, it is noted that the prevalence of the impact factors that directly threaten the fauna/flora are linked both nationally and regionally (São Manuel/Botucatu). Figure 2, for example, reveals itself as the biggest impact and threat factor: fishing/capture, as well as the results found in the "Top 3" of the most recorded

environmental crimes, where the practice represented in the overall sum: 355.14% of all committed between 2015 and 2019, followed by the introduction of animals: 280.87% and the destruction of forests: 92.44% (mining) (ICMBIO/MMA, 2018).

Given these perspectives, at the meeting of casuistry students in São Manuel and Botucatu, they were directly concerned by the following factors:

Biome connectivity/Proximity between cities, and the prone region between municipalities harbor high levels of native wildlife (Magorbo, 2023).

Figure 3. Connectivity Map of the State of São Paulo.



Source: Adapted from DATAGEO, 2008; São Paulo, 2020.

It is noted that proximity alone is not a determining factor for the cases in Figure 1, however, if coupled with relevant connectivity of fauna/flora as happened, environmental crimes can be directly influenced as seen in the "Top 3" (Veash, 1999 apud Zimmerman, 2013).

Therefore, if there is supply (connectivity/proximity) and demand (interests), possibly, as one of the effects, there will be an increase in environmental crimes, unless, in this region, there is no connectivity, but only proximity.

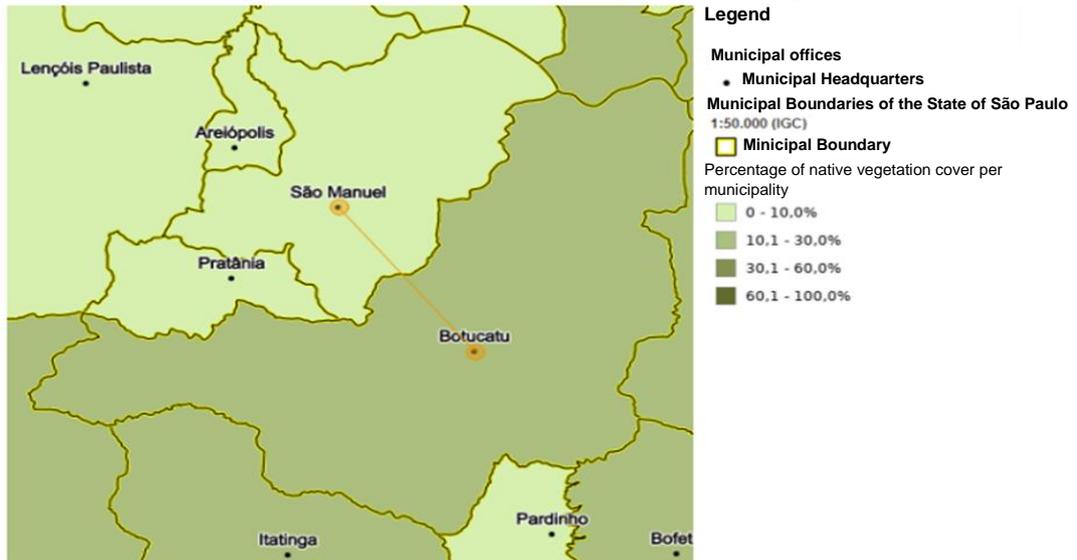
Another factor that corroborated the findings of the "Top 3", was about the types of native biomes and the relevant levels of the territorial vegetation cover of these cities:

Figure 4. Biomas of Botucatu and São Manuel.



Source: DATAGEO, 2004.

Figure 5. Native vegetation cover per municipality.

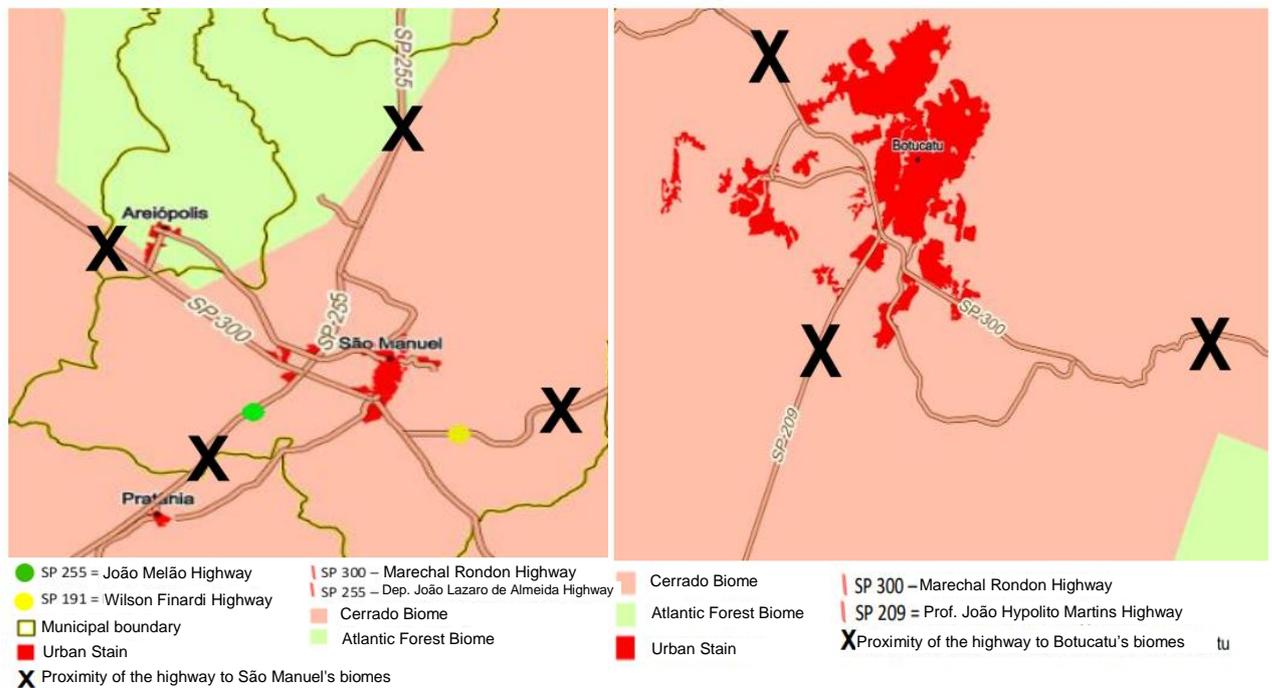


Source: DATAGEO, 2009.

From this point on, considering that the Atlantic Rain Forest and Cerrado biomes are the ones that most harbor the regional fauna/flora, it is conclusive, given the casuistics of Figure 1, to identify how such assertions are relevant for the occurrence of environmental crimes in such cities. As can be seen, the crime of deforestation was also one of the most characteristic and evident during the years 2015-2019, that is, crimes directly linked with the possibility of immediate financial return (Silveira; Uezu, 2011).

In this context, still as a direct factor, one can cite, the land routes also as the cause of the crimes verified.

Figure 6. Highways that interconnect with the fauna of Botucatu and São Manuel.



Source: Adapted from DATAGEO, 2012.

Land routes, as well as the other factors that explain casuistry, also have a strong impact in concluding the increase in crime annually. Analyzing Figure 6, we were able to identify that by the highest prevalence, it is possible to use some of the land transport for the concreteness of the environmental crime committed, mainly in the use of the Marechal Rondon Highway (SP 300), one of the busiest in the interior of the state of São Paulo.

Therefore, the "Top 3" articles may somehow make it possible to use the land routes to achieve the final profit from that illegal exploitation. We have seen that the SP 300, highway that interconnects these cities - by the "X" demarcated in Figure 06, it is noted, as it is extensive and are close to the land routes with the Biomas Cerrado and Atlantic Forest where the fauna of these municipalities are concentrated, a situation that explains the causes and why the increase of environmental crimes annually (DATAGEO, 2012).

It also becomes possible, to increase, that in addition to the difficulty in tracing the illegally transported cargo (animals or timber), it becomes an easy means to conclude the environmental crime given the extensive existing mesh (DATAGEO, 2012).

Finally, it is worth mentioning the possible indirect causes for the environmental crimes committed in São Manuel and Botucatu in these years of study: a) by the expansion of complaints and communication channels; b) increase of surveillance and operationalization of joint action by entities to curb and combat regionalized crimes; c) the computerization of data systems and records of these crimes; d) by the Environmental Education projects, which expand the spectrum of awareness in the local population to more and more denounce the environmental crimes in their region.

But how to report an environmental crime? If the animal is domestic and the alleged offense involves some diseases, for example: Leishmaniasis, Rabies, etc., or health surveillance matters, the report should be carried out: 1) In the municipal Health Department or Department; or 2) In the Zoonoses Control Centers. If cruelty/ill-treatment occurs, it is directed to report the crime, in: 1) the municipal Environment Department or the subsidiary bodies of joint action, such as: 1.1) Animal Surveillance Units (UVA's); 1.2) Municipal Ombudsman; 1.3) Municipal Civil Guard (GCM) (Meirelles, 2008; Meirelles, 2016).

If the crime involves the illegal transport of animals within the municipality, it should be activated: 1) the municipal Traffic Department/Department; or 2) the Environmental Department/Department or the UVA's/GCM's (for domestic animals); or the Environmental Military Police (for wild animals). If illegal transportation takes place on state highways, it must be jointly enforced: 1) Environmental Military Police; 2) State Highway Police.

Specifically to wild animals, the complaint should be addressed to the Environmental Military Police of the city district, for example: if the environmental crime occurs in São Manuel, the competence to investigate the complaint will remain with the Environmental Police of Botucatu, and the complaints can be made: By the mobile application: "Environmental Denunciation"; On the portal: <http://denuncia.sigam.sp.gov.br/>; or by the, Telephone of the units: <https://www.policiamilitar.sp.gov.br/unidades/ambiental/localize.html>.

They also investigate the complaints and environmental crimes, the State Prosecutor's Office and the Federal Public Prosecutor's Office, besides IBAMA and ICMBIO (Lenza, 2020).

To cyber crimes, specifically those involving mistreatment and cruelty, whether domestic or wild, it is directed that the complaint be directed to the SaferNet Brazil website by the address: <https://new.safernet.org.br/denuncie>, as a complementary channel to the aforementioned ones.

It is well known that the reports of local crimes have been intensifying annually, proving that the increase in casuistics also has a correlation with the records made to the police by the population, being a very important fact, therefore, the importance of practicing and repeating such conduct in a wide and general manner.

After all, does the law — on its own, does it protect fauna? does it discourage environmental crime? does it control the extinction of species? Does it prevent crime, inhibit recidivism, control violence?

Are the penalties for environmental crimes effective in Brazil? are the penalties consistent? is there ideological interference or not in the creation and enforcement of laws? what measures to take in controlling environmental crime and social violence - if not by reporting these crimes and by Environmental Education? (Blaselbauer, 2022; Boselli, 2022; Freitas, 2022; Hygidium, 2021).

4. CONCLUSIONS

Having extracted the results, it can be said, that the problems rooted in the transnational orbit (environmental crimes in high growth), has also grown between the years in the cities researched, that is, it has been confirmed with all the records of the casuistics and factors of their incidence, that in the regional ambit - there is indeed a gradual increase of environmental crimes in a heterogeneous way, with variation and fragmentation between the types of crimes observed, mainly in the most worrying ones: introduction of animals in other habitats, fishing and illegal exploitation of the forests.

With this, our scenario becomes worrisome, since it is already consolidated in recent theories and studies on criminology, as an example the Theory of Link (or Link), that environmental crimes specifically involving the fauna, has a great correlation with

the increase of urban social violence, let us see, that those who commit crimes against animals are prone to also commit crimes against life (Nassaro, 2013).

Accordingly, the present research, shows itself to be relevant in its conditions, since it tries to delve into the casuistics found, another look, at the importance that the theme still invisibilised and little debated in society, in the academic world and in the journalistic environment, is extracted in the question of environmental and urban violence. For, it opens with work, the attempt/opportunity, to inaugurate a propositional debate and with real and applicable proposals: of when and how - to contain the unbridled advance of environmental crimes in Brazil, bringing significant gains for society and science.

Comparing the casuistics of São Manuel and Botucatu, one can see that, in the locality that the territorial range is more extensive, the greater will be the fractionation of the environmental crimes committed - as in Botucatu. In the city with the lowest territorial level, according to Figures 01 and 05 (São Manuel= 10%), the crimes concentrate qualitatively, and in the one with the largest territorial extent of Cerrado and Atlantic Rain Forest (Botucatu= 60%) the crimes sprawl quantitatively (DATAGEO, 2009).

This is also attested, so it was cataloged in São Manuel/SP between 2015-2019, where we observed 07 types of crimes of Law 6.514/2008: articles. 25, 36, 49, 50, 53, 58 and 75, and in Botucatu/SP, city with greater territorial extension "green", there were 13 different crimes: articles. 25, 26, 29, 36, 44, 45, 48, 49, 50, 53, 57, 58 and 78, a minimum difference, but one that reinforces the need to observe the types of biome for an effective action to the regionalized crimes (Nassaro, 2013).

In the light of the results, it could be concluded that:

1. environmental crimes, involving wild animals from the municipalities observed, increase annually, concentrating crimes in São Manuel in the city with the smallest population and dividing in Botucatu - in the one with the largest population;
2. the cases of the prevailing crimes occur both by direct and indirect factors such as: connectivity and proximity of the fauna between municipalities, types of biomes, size of forest cover, land routes, as well as, by the creation of laws, expansion of complaints, increase of controls, computerization of systems and promotion of Environmental Education projects;

3. the environmental crimes committed in São Manuel and Botucatu between 2015-2019 were more prevalent in males than in females, the most common being illegal fishing, the introduction of animals without the authorization of the competent bodies, the exploitation and deforestation of forests/vegetation;
4. the concept of Empty Forest and Defaunation are regionally affirmative, when found the prevalence of art. 25 in São Manuel and Botucatu between 2015-2019 and the map of seizures of 2020, 2021 and 2022;
5. the creation of new laws, organization or simplification of existing ones, are not the main objective of effectively combating environmental crimes, but the creation of affirmative actions, public-policy and environmental education planning in all social strata of the country;
6. it can be said, that the size of the population, such as income and schooling, also had significant relevance in the formation of the casuistics;
7. crimes involving wild fauna in constant growth in Brazil nationally or regionally, besides a chronic safety problem, also becomes a worrying problem in public health and zoonotic;
8. despite the favorable results of the hypothesis, there is a need for more studies and a new in-depth survey also of the environmental crimes committed by companies, which can raise the regional crimes and identify new prevalences. Thus, the following results are expected with the present research:
9. that society has prior knowledge of the amount of legislation and institutional norms that Brazil has for environmental/animal affairs;
10. provide transparency in the actions of the Botucatu Environmental Military Police and demonstrate to the population the types of crimes that are committed in their city and in what quantity/prevalence;
11. foster an understanding that crimes involving fauna and flora are public health and not only public (transnational) security problems;
12. disseminate and institutionalize the theme of Environmental Law at all social, legal, political, investigative and journalistic levels;
13. to carry out continuous and permanent research and studies in the creation of yearbooks, primers or atlases for environmental crimes in municipalities;
14. to recognize that the work has attempted to assimilate the UN Sustainable Development Goals (SDGs) into goals 11, 13, 14, 15, 16 and 17;

15. encourage the establishment of basic and effective environmental education programs along the lines of the Drug Resistance and Violence Educational Program (PROERD);
16. strengthening public and private institutions, bodies and actors with a focus on preventing environmental crimes;
17. structure campaigns, task forces, specialized groups and study commissions for the fauna and flora of the municipality and the adoption of climate forums;
18. to make the channels and importance of the population a reality in the long term, always denouncing environmental crimes in their region.

Finally, as to the limitations of the research, they are cited as conditioning of greater impact: the cut-off of specific time periods (2015-2019), as well as, the limitation of the police records accessed contain complete information of the crimes committed.

In spite of these limitations - which do not jeopardize the results detected, it is recommended: as a future study and complement of this research, the in-depth realization also on the environmental crimes committed by the legal entities, generating a greater engagement to the theme, and can also be verified if the crime picture aggravates or not annually between them.

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CHAPTER 9

CONJECTURES: BRAZIL'S ENVIRONMENTAL REGULATORY HISTORY

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ABSTRACT: This work seeks, in a synchronized and synthesized way, to explore the entire set of Brazilian legislation in the environmental and animal protection field in the enacted Brazilian constitutions, covering the entire positive framework from the Constitution of Brazil Empire in 1,824 to the Citizen and Green Constitution of 1,988. The article also provides summarized and compiled comments on the landmark articles of environmental and animal law, with the aim of historiographing the entire legislative catalog of the constitutions in a homogeneous way, starting from the first Brazilian constitution and its disposition, to the process that gave impetus to our constitutional environmentalism. In addition to the historical value it brings, it is also possible to follow all the political developments that shaped the political decisions of each era for the creation of our peculiar environmental/animal law. In addition to a systematized compilation of the years in which the rules have been in force, the aim is to contextualize the importance of this incipient and little-disseminated topic in the legal, educational and social fields, in order to recover the bottlenecks and constitutive

intricacies that have made the Brazilian dynamic one of the most debated, respected and pioneering. In the end, we see how complex the Brazilian system is in terms of its theoretical composition (creation) and practical application (sanctions), even though the current constitution has been settled internally for a long time.

KEYWORDS: animal law, environmental history, legislation, regulatory system.

RESUMO: O presente trabalho, busca, de uma forma sincronizada e sintetizada, explorar todo o conjunto normativo do Brasil na seara ambiental e de proteção animal nas promulgadas constituições brasileiras, percorrendo todo o arcabouço positivado desde a Constituição do Brasil Império em 1.824 até a Constituição Cidadã e Verde de 1.988. O artigo também traz comentários resumidos e compilados sobre os artigos de referência do direito ambiental e dos animais, pretendendo-se historiografar de uma forma homogênea, todo o catálogo legislativo das constituintes partindo desde a primeira constituição brasileira e sua disposição, até o processo que impulsionou nosso ambientalismo constitucional. Em complemento ao valor histórico transportado, pode-se também acompanhar todos os desdobramentos políticos que sedimentaram as decisões políticas de cada época para a criação do nosso peculiar direito ambiental/animal. Assim, objetiva-se, além da compilação sistematizada dos anos de vigência das normas, contextualizar a importância desse tema incipiente e pouco difundido no campo jurídico, educacional e social, a fim de resgatar os gargalos e meandros constitutivos que fizeram a dinâmica brasileira ser uma das mais debatidas, respeitadas e precursora. Ao final, constata-se, como o conjunto brasileiro é complexo em sua composição teórica (criação) e aplicação prática (sanções), mesmo estando a atual constituinte sedimentada internamente já há um bom tempo.

PALAVRAS-CHAVE: direito animal, história ambiental, legislações, sistema normativo.

1. INTRODUCTION

As in every gradual, natural historical movement, Brazil's environmental legislative history (1824-1988) was no different - marked by advances, setbacks and innovations throughout its structuring and modernization (Milaré, 2018).

Taking this line of reasoning, it is then established that between the periods 1934 to 1988 - the general normative structure of Brazil is characterized environmentally, and from 1989 to 2000 - there is the beginning of its modernization (Brazil, 1988; Milaré, 2018).

And even with a somewhat consolidated positioning after the 2000s, with the emergence of the "new" gaps and situations legally "unforeseen" environmentally, the country continues in search of strengthening and legislative expansion in its institutional improvement (Milaré, 2018).

Starting from this point, the research problem is delimited: when, in fact, was environmental law consolidated in Brazil? (what good did you seek to protect?). And animal rights, when did it happen? How was the process of creating and managing our constitutional and legal normative system drawn up? Were they founded with an authoritarian, industrial or ecological bias during their implementation? Was "ecologism" thought of from the beginning or not? (Magalhães, 1998; Silva, 1999).

Thus, the hypothesis of the work and objectives, based on the following assumptions: the need to carry out a historiographic survey directed at the consolidated constitutions of Brazil starting from the first letter in order to understand, if such construction was effective for the protection/conservation of biodiversity and what issues Brazil has already dealt with during the numerous social processes it experienced (Jordace, 2016).

In this way, the relevance of the work can be justified: exclusively by the technique employed for synchronizing and compiling (annually) the constituents approved in a single space - simplifying the easy consultation of its collection.

Finally, as the compilation started from a strictly exploratory survey and restricted to the Federal Government's public archives (planalto.gov.br), there were no variables that would condition the exclusion of any constitution found between 1,824 and 1,988.

2. MATERIAL AND METHODS

Bibliographical and exploratory reviews were conducted on the Federal Government's official law portal (planalto.gov.br/legislacao) to develop the study. For the design of the constitutional-environmental movement, some doctrines and all Federal Constitutions of Brazil (1824-1988) were analyzed - including the Constitutional Amendment of 1969, which is mostly considered by the doctrine, as a typical constitution, bringing in a centralized space all pertinent articles on the environmental and animal theme important in the Brazilian constituents including their degree of relevance and comments. For the temporal cutting of the legislations in a synchronized manner, research was broken, from the year 1824 until the validity of our last and current constitution (1988). Therefore, there was no criterion for excluding the findings identified during the understood period, a situation that neither interfered with nor prevented the results in order to reach the desired legal condensation.

3. RESULTS AND DISCUSSION

Figure 1: Environmental constitutional evolution of Brazil in its constitutions

Ano	Contribuição	Dispositivo de direito ambiental/animal
1.824	Nenhuma relevância	Pode-se constatar pela história e historiografia, que até início da propositura da primeira constituição brasileira, caminhou-se apenas na positivação de direitos supostamente "ambientais" em leis extravagantes e não diretamente na própria constituição, exceto por alguns doutrinadores que corroboram que o artigo 157 tratou sobre a Ação Popular.
1.891	Pouca relevância	Art 34, a. "29".
1.934	Razoável relevância	Art. 5, i., XIX, a. "J" Art 10, i. III Art. 113, a. "38" Art. 148
1.937	Razoável relevância	Art 16, XIV Art 18, "a"; "e" Art 134 Art 143 Art 144.
1.946	Pouca relevância	Art 5, "I" Art 21 Art 141, §38 Art 152 Art 153, §1° Art 175.
1.967	Nenhuma relevância	Art. 5, i. XV, a. "I"; Art. 8, i. XVII, a. "h"; "i" Art. 172, §Ú Art. 175.
1.969	Razoável relevância	Art. 4, i. I, II, III, IV, V, VI Art 5 "caput" Art 8, a. "h", "i" Art. 172.
1.988	Notória relevância	Art. 5, i. LXXIII Art. 22, i. IV, X, XII, XIV, XXVI Art 23, i. VI, VII, XI Art. 24, VI, VII, VIII Art. 129, i. III Art. 170, i. VI Art. 174, §§ 1° e 3° Art. 186, i. II Art. 200, i. VIII Art. 220, i. II Art. 225.

Art - artigo da legislação correspondente; a. - alínea do artigo referenciado; i. - inciso do artigo referenciado;

§§ - parágrafos; §Ú - parágrafo único; "caput" - enunciado de artigo de lei ou regulamento.

Source: Adapted from Júnior, 2019.

Assessing Figure 1, it is noted that the core of the constitutions carries within them high charges of historicity and revolutions in a text that represents and protects the social and environmental relations specific to that period of composition (Silva, 1999).

According to Silva (1999, p. 41), the constitution consists of legislation at the primary level of a country, in a set of norms expressly based on the pre-existing social

customs and rules of that cycle, carrying with it also a series of tacit normativity about the internal relations of its population.

In this guideline, Brazil, in its institutional improvement, reached in its historical context the mark of promulgation of 8 constitutions - each with its legal and social particularities of the time (Lenza, 2013).

The Constitution of 1824 (Empire Brazil) was the first in the country. In 1891 came the second constitution (Brazil-Republic or Old Republic). And so, successively were being promulgated our constitutions: a) 1934 (Second Republic); b) 1937 (New State); c) 1946 (Redemocratization); d) 1967 (Military Regime); e) EC n° 01/69 - letter in which there are historical divergences in being considered or not a new constitution; f) 1988 (Citizen and Green Constitution) (Lenza, 2013; Milaré, 208; Júnior, 2 019).

In terms of validity, the first constitution lasted for 65 years, the second for 39 years, the third for 3 years. Fourth for eight years, fifth for 20 years, sixth for two years. Then the EC (n°01/1969) for 18 years and the current constitution, for 24 years computed until the year 2013 (Lenza, 2013).

As can be seen in Figure 1, the previous constitutions to the current one, in terms of contribution to an environmentally regulated, protective and social integration look, were not innovative. It is realized, that 1934 and 1937 brought a beginning of reasonable relevance to environmental law, however, it was only in 69 that the protection of this intangible asset gained body of partially focused norm (Milaré, 2018).

This right was therefore gradually formed due to the exacerbated anthropocentrism rooted at the time. Thus, the proposed measures for the protection and conservation of environmental goods were innovated in detail according to the social and legal evolution that the country lived through and the new economic and industrial objectives defined politically (Milaré, 2018).

Also based on Figure 1, by the constitution of 1824, it is noted an early evolution expressed in its text, to describe only the individual fundamental rights/guarantees, political and educational rights without any mention of the theme of protection of the environment (Brazil, 1824). A little different was the following constituent, which, inaugurated some forms of private competence of the National Congress to legislate: on lands and mines of the Union (art. 34, a. "29"), and to delimit the ownership of the unclaimed lands located in the territory of the States (art. 64) (Brazil, 1891).

However, the major concern of these periods was not the environmental one, but employment to protect economic, industrial, political and structural issues for the development of the country. This is true: in the adoption of the new form of government in a republic, in the formation of the Federal State, in the implementation of the presidential system, as well as, the annexation of all the old Brazilian provinces aiming at the direct formation of the United States of Brazil - in a unanimous, inseparable and permanent character (Silva, 1999; Júnior, 2019).

The structural strengthening of 1891 was so significant as the main objective of the republic, that at the time all the individual and political rights created initially in the constituent of 24, except for a range of people: such as beggars, illiterates and women (Brazil, 1891).

On the other hand, after 8 years without innovative environmental legislative changes, unlike the predecessors, as Figure 1 reproduces, the constitution of 34 leveraged important paradigmatic changes of environmental law, among them: the protective and competing attribution of the Union and States on the natural beauties, of the historical, artistic and cultural heritage (art. 10, i. III c/c art. 148) (Brazil, 1934).

Except for its womb of legal importance, such a constituent does not expressly mention environmental law in its text, but extends the competences of the Union to legislate on rights-determined and exploitation: such as fishing, hunting, water, forests, etc. It also opportunizes an indirect leveling of future opportunities in improving environmental and animal protection and issues (Art. 5, i., XIX, a "J") (Brazil, 1934; Milaré, 2018).

Also in this constitutional charter, it is indispensable judicial mechanism of protection of the heritage of the Union, States and Municipalities, with the creation of the Popular Action, which proposed in its article 113, letter "38": the judicial defense by any citizen, on public activities/actions that would be harmful to historical, artistic and cultural heritage (Brazil, 1934).

However, although directly expressed in the 1934 constituent, as Figure 1 shows, one can see historical dissent when regulating it. Some jurists maintain that the inaugural creation of Popular Action took place since the first imperial constitution of Brazil (article 157). Others maintain that it was regulated only in 1934 (Lenza, 2013).

In this sense, by the findings, it is possible to affiliate the second current as the most coherent, specifically because it is the study of environmental law, since the law

makes express mention of the environmental goods to be protected by the federal entities, different from the constituent of 1824, which regulated the "popular action" as an inhibitory form aimed more at the axis of criminal law than properly environmental against the crimes of bribery, embezzlement, etc. (Brazil, 1824; Brazil, 1934; Machado; Ferraz, 2014).

The decade of the 30s, in this manner, reserves the beginning of the changes of the main axis of the economic-social-industrialized order of Brazil. Still, it would last for a long time such a condition (Wolkmer, 2003). According to Medeiros (2004, p. 62), the decisions taken under the "environmental" protection and conservation of natural resources were based only on the imminent economic and industrial character that in an unexpected way, the rules to natural assets were extended by way of law.

According to Wolkmer (2003, p. 92), the 1934 constitution reflected and protected descriptive social rights in other model norms of expansionist center, such as the Mexican Charter of 1917 and the Weimer Charter in 1919, aiming in its structural bulge, the awakening of the most comprehensive constitutional modernization in the social character and the full extension of industrial-sustainable and limiting development in its explorations.

Therefore, the constitution of 34, brought an important final milestone for the industrial axis can be rethought a "new" development genuinely environmental, bringing new ideas and perspectives, both written and verbal in various fields of constitutional law (article 115, §single) (Antunes, 2010; Villa, 2011).

Sequencing the data of Figure 1, we now analyze the constitution of 1937, in which the internal and external decisions of the country and its development were funneled into a single power center. However, in spite of the exceptional period, the advances of 34 were maintained, still bringing important milestones in the environmental law of the time. In a nutshell: there were 187 articles, where 174 of them were aimed at the main structure, and 13, for the transitional and conclusive provisions (White, 2017).

In the peripheral question of the text, there were setbacks as to fundamental rights and guarantees - including in the exclusion of Popular Action as an available judicial measure, however, in the general summary it expands: the legal protection and competences of the States and the Union solely to animals and environmental goods (Article 18, a. "and"; article 16, i. XIV; Article 18 a. "a" and "e"; article 134 and article 144) (Brazil, 1937).

In Villa's opinion (2011, p. 50), the "environmental protection" described in Article 144 of the 1937 CF, only aimed at "nationalism" - in a maneuver of political makeup as a country supposedly developed and protective as to natural and related goods, but which, in fact, sought the opposite: to validate the financial-industrial and military structures for unrestricted exploitation.

Millaré (2018, p. 174) adds that the mere extension of the list of 'environmental' rights falling within the competence of the Member States and the European Union by Article 16(i). XIV; Article 134 and Article 18 a. "a" and "e" in 37, did not simply seek to aim at the conscious protection of natural riches and animals, but better ways to indiscriminately exploit the environment for internal and industrial development.

Along the same lines, in 1946, Brazil refounded a new constitution, based exclusively on the main objective of the Redemocratization. Despite being marked by the recovery of social and constitutional rights extinct in 37, there were those in the doctrine who defended that it, by raising its objectives equal to those of the past (1891/34), lost great opportunities to strengthen the country internally at the environmental level and to outline an in-depth debate of its real needs (Silva, 1999; Júnior, 2019).

In short, on animal rights, she has not expressly proposed anything. As for environmental law, it has played back with little contribution when compared to its predecessors, especially the letter of 37. As Figure 1 shows, in general, the direct competence of the Union over natural goods was maintained, excluding only mines from the context (Brazil, 1946).

Still observing Figure 1, it is concluded, that the letter of 46, preserved the artistic and cultural goods under the cloak of state protection and rescued in its article 141 again, the possibility of popular action for the harmful acts perpetrated in the country (Brazil, 1946; Milaré, 2018).

The constitution of 1967, even with an impulse generated by the extravagant legislations approved that aimed some benefit of sustainable production to the country, failed to reference these premises constitutionally, thus bringing no necessary contribution of environmental or animal protection or conservation in general (Brazil, 1967).

Fernandes and Saddy (2019) point out that "[...] under the justification of promoting the development of the national infrastructure, it has often prioritized developmental projects over preserving the quality and balance of the environment."

With 189 articles, the constituent of 67, reserved protection to cultural heritage, monumental, landscaping and archeological deposits (article 172, §only). The Union's powers to legislate on deposits, mines, mineral resources, metallurgy, forests, hunting, fishing, water and electricity have been maintained (Article 8(i)). XVII, a. "h" and "i"). The only changes in the text compared to 46 (Article 5, i. XV, a. "I"; and article 175), were the addition of the archeological deposits as environmental protection assets and the removal of the subsoil riches and mining competence of the Union (Milaré, 2018).

The Constitutional Amendment of 1969 (EC/69) was the first Brazilian constitution to found the term "Ecological" in its text and to pave the way of Brazil's environmental path (article 172) (Brazil, 1969; Furlanetto, 2013).

In this way, EC/69, is established as an intertemporal starting point and of intense preponderance in the spheres of ecological protection and conservation and inaugural for an effective environmental constitutionalism characteristic (Rodrigues, 2016). It maintained the same premises of the previous constitution, except in the novelty of the "Ecological Survey" on agricultural land and in the sanction of the misuse of land that would imply losses on the incentives and aid received from the Union by the owners (Brazil, 1969).

And it is starting from the "Ecologism" that emerged in 69, that the country disconnects its unruly industrial axis to ensure in the immediate horizon, a context of conscious and sustainable exploitation of its natural resources, including in the implementation of exchange policies and incentives for the sustainable use of environmental goods (Padilha, 2010).

Despite being exceptionally positive for its time, the Ecológico de 69 survey allowed so many advances in its successor constitutional charter of 1988 (article 225, item I), as it also provided the structural bases for the recent law n° 14.119/21, which permanently implemented in Brazil the National Payment Policy for Environmental Services (Amado, 2021).

In this continuity, 1,988 is assimilated into the period of greater socio-environmental disjunction that the country has passed. It is here that one of the greatest legal advances compared to his predecessors letters is founded. It was, therefore, the constitution that broadened environmental competencies most and that in fact structured and regulated animal rights in an effective awareness of protection and conservation of the environment homogeneously (Brazil, 1988).

According to Rodrigues (2016, p. 88): "[...] the advent of the 1988 Constitution brought the legal framework that was lacking for Environmental Law to be elevated to the category of autonomous science." In addition to becoming the first constitution with ecologically green standards and protectives of the country, it was composed of 250 articles, which have environmentally promoted such regulatory benefits (Milaré, 2018):

1. he became the definitive guardian of Popular Action (art. 5, i. LXXIII);
2. expanded the competences for the Union to legislate on: water and energy (art. 22, i. IV); inland waterway, maritime, air and aerospace navigation (i. X); deposits, mines, other mineral resources and metallurgy (i. XII); indigenous populations (i. XIV); nuclear activities (i. XXVI);
3. it created the common competence of the entities in environmental protection and in combating pollution (art. 23, i. VI); preservation of forests, fauna and flora (i. VII); registration, surveillance and monitoring of research, and exploitation of water and mineral resources (i. XI);
4. it created the competing competence of the Union with the States, Municipalities and Federal District: under forests, hunting, fishing, fauna, nature conservation, soil defense, natural resources, protection of the environment and pollution control (art. 24, i. VI); protection of historical, cultural, artistic, tourist and landscape heritage (i. VII); liability for environmental damage (i. VIII);
5. it established the function of the Public Prosecutor's Office to promote actions for the protection of public, social and environmental heritage (art. 129, i. (III))
6. in the Economic Order, highlighted differentiated treatment for environmental defense (art. 170, i. (VI));
7. regulated via incentive, national development practices, and organizing the entire production chain of the mining activity with respect to the environment (Art. 174, §§ 1 and 3);
8. established the Social Function of property with respect to the proper use of resources and preservation of the environment (art. 186, i. (II))
9. it proposed the collaboration of the Unified Health System (SUS) in the protection of the environment (art. 200, i. (VIII));
10. it aimed to protect the person or families against practices harmful to health and the environment (art. 220, i. (II))

11. it imposed the duty of public authorities and society to contribute to an ecologically balanced environment essential to the quality of life for the present and future generations (Art. 225).

And so, the beginning of the day of environmental and animal law in Brazil is enshrined in its constitutional cycle: laden with principles and rules indispensable to the legal, political, educational and social field (Brazil, 1988; Soares; Rosa, 2020).

4. CONCLUSIONS

Having extracted the results, it can be concluded that: Brazil's environmental law gained legal/political body with EC/69, however, only consolidated itself in fact after the promulgation of the letter of 1988 - which brought several rules, principles and special procedures.

But it is from 1988 onwards, therefore, that environmental law gains the typical definition of good and the "status" of socio-environmental relevance, seeking: to protect, conserve, educate, raise awareness and preserve for this and future generations the healthy environment (art. 225). It is during this same period that environmental law is effectively separated from animal law as autonomous sciences among themselves and rules of their own (Art. 225, VII).

Thus, it can be argued that: the consolidation of animal law in the constitutional ambit, is only enshrined in 1988, even though there are some sparse laws that dealt with the theme previously - as for example Decree No. 24.645/34.

For, for the process of creation and management of the system, it must be concluded from the perceptions found, that at first, environmentalism was traced in a natural and gradual way according to each epoch, there being no authoritarian bias in its legal conception and implementation, even when the constitutional charters of 37 and 67.

Finally, with the analyzes drawn from the doctrines and from the constitutional text itself, it is possible to delimit that the Brazilian constitutional "ecologism" was never thought of in a significant way since its construction began in 1824, having been designed preliminarily only with the Amendment 69, to whom was given the inaugural "title" of environmental protection.

However, it is clear that the provision of Article 172 of that amendment had been put in place suddenly, i.e. without any technical basis, given the exceptional and unstable period that Brazil was experiencing politically, as well as the evident lack of scientific and exempt studies for the period understood on the environmental damage and damages that industrialization and deregulated exploitation brought to society, fauna, etc.

This explains a lot, how the country currently deals with environmental and animal rights issues contemporaneously, which still, it is possible to find shocks and debates between exploitation versus protection/conservation, as happened since 1824, even though it is already positioned constitutionally and infrallicitly environmental goods and their importance for the healthy quality of life.

For these reasons, that history should be reread and reinterpreted to meet Brazil's current goals, aiming at social well-being and especially the sustainability and renewal of environmental and animal law in theory and practice, since there is no new constituent promulgated beyond the current one.

With the study, it is also expected:

1. strengthen environmental and animal law with a focus on the legal bases of UN Sustainable Development Goals (SDGs) 4, 13, 14, 15 and 16;
2. that society has prior knowledge of the constitutions that Brazil has already promulgated, and the levels of environmental improvement that they have brought;
3. sedimentary, and above all pacifying, the simplified interpretation of Brazilian law and norms with legal certainty and a scientific basis for all society in a general manner and without restrictions;
4. to publicize and democratize, the technical and scientific studies that deal with the history of Brazil under a determined field of knowledge, as in the case of this study - of environmental and animal law constitutionally.

As to the limitations of the research, they are cited as the conditions of greater impact: the delimitation of the temporal cut-off (what period to cut out?), as well as, which database and bibliographies would be used. Were there records of the oldest standard or not? In spite of the limitations - which do not impair the results detected, it is recommended: as a future study and complement of this research, the in-depth realization also on federal legislation (ordinary laws, decrees, etc.), in order to further subsidize the strengthening of these rights so important in the world of social and legal sciences.

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CHAPTER 10

WATER QUALITY DIAGNOSIS OF A PUBLIC SPA FROM POLLUTION INDICES

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ABSTRACT: The use of freshwater and public spas for recreational use can be beneficial for the health and well-being of people but also poses risks due to pollution and other hazards such as drowning and various injuries. Natural and anthropogenic pollution limit the use of water resources not only for human and agricultural consumption, but also for recreational and tourist activities. The study area is located at coordinates 33° 41.048' S 065° 29.346'W, which corresponds to the public spa in the vicinity of the Monseñor Eduardo Miranda bridge. The mineral contamination indexes (ICOMI), organic matter contamination (ICOMO), trophic contamination (ICOTRO) and pH contamination (ICOpH) are evaluated in the summer months where the greatest number of visitors to the spa is concentrated. The methodology followed is that of Ramirez *et. al.* (1997) and Ramirez *et. al.*(1999). The results obtained indicate medium-high contamination by minerals and average contamination by organic matter; the index of trophic contamination indicates oligotrophic and no contamination by pH is observed. The use of these indices makes it possible to carry out an integral water evaluation and to know the level of health risk that it represents in order to guarantee safe water for human health.

KEYWORDS: river, public spa, pollution.

RESUMEN: El uso de las aguas dulces y de los balnearios para uso recreativo puede ser beneficioso para la salud y bienestar de las personas pero también posee riesgos debido a la contaminación y otros peligros como ahogamiento y lesiones varias. La contaminación natural y de origen antrópico limitan el uso de los recursos hídricos no solo para consumo humano y agropecuario, sino también para las actividades de recreación y turísticas. El área de estudio se ubica en las coordenadas 33°41.048´ S 065°29.346´W, que corresponde al balneario público en las inmediaciones del Puente Monseñor Eduardo Miranda. Se evalúan los índices de contaminación por minerales (ICOMI), contaminación por materia orgánica (ICOMO), contaminación trófico (ICOTRO) y contaminación por pH (ICOpH), en los meses de verano donde se concentra la mayor concurrencia de los visitantes al balneario. La metodología que se sigue es la de Ramirez *et. al.* (1997) y Ramirez *et. al.* (1999). Los resultados obtenidos indican contaminación media-alta por minerales y contaminación media por materia orgánica; el índice de contaminación trófico indica oligotrófico y no se observa contaminación por pH. El uso de estos índices permite realizar una evaluación integral del agua y conocer el nivel de riesgo sanitario que representa a fin de garantizar agua segura para la salud humana.

PALABRAS CLAVE: río, balneario, contaminación.

1. INTRODUCTION

The Quinto River provides multiple benefits, such as the availability of water for human consumption and agricultural use, tourist and recreational activities and is also the channel for discharges of industrial effluents, sewage effluents and storm waters. In its tour of the city of Villa Mercedes, there are several specific areas that people use as public spas, one of them is the sector that is located in the vicinity of the Monsignor Eduardo Miranda Bridge, in Figure 1 an image of it is observed.

Figure 1. Image of Monsignor Eduardo Miranda Bridge.



Source: The author.

The areas intended for spas must comply with the quality requirements for recreational water that the legislation establishes. The use of water resources for recreational purposes poses disadvantages in areas close to settlements of high concentration of people where the need for recreation arises. The bacteriological quality of bathing water does not need to be so high as to drink it, however it must be kept free of pathogenic bacteria. Likewise, water for recreational purposes should be free of toxic chemical contaminants.

The development of pollution indices (ICO) has demonstrated advantages over quality indices (ICA) that can present problems of interpretation, for example a water sample can appear as good quality, despite the fact that some variable exhibits

a high degree of contamination since the joint presence of multiple variables hide or mask such a condition.

ICO values reflect zero or low pollution when close to zero and high pollution as close to one. The use of pollution indices allows the information to be quickly visualized.

Figure 2 shows a sector of the public spa and its surroundings; where the stadium of La Pedrera Park is seen in line with the bridge, while to the left are the sewage pipes of various origins that are poured directly into the river.

Figure 2. View of the spa and surroundings.



Source: The author.

2. OBJECTIVES

The objective of this work is to know the quality of the water for recreational use of the public spa, by estimating four (4) Pollution rates for the months of December 2016, January 2017 and February 2017, which corresponds to the summer season in which visitors attend the spa.

3. METHODOLOGY AND RESULTS

The indices of mineral contamination (ICOMI), organic matter pollution (ICOMO), trophic pollution (ICOTRO) and pH pollution (ICOpH) are used; The calculation methodology proposed by Ramirez *et. al.* (1997) and Ramirez *et. al.* (1999) is followed.

It follows the Protocol of Sampling, Transport and Conservation of Water Samples for Multiple Purposes (human consumption, animal watering and irrigation) recommended by the National Institute of Agricultural Technology (INTA). The study of the working area began in April 2016 and continues throughout the current year. The results of the complete physico-chemical and microbiological analyzes are presented, corresponding to the months of December 2016, January 2017 and February 2017.

The parameters determined in situ with portable laboratory equipment are dissolved oxygen (OD), hydrogen potential (pH), temperature (T) and turbidity. The analysis of chemical oxygen demand (COD), conductivity, alkalinity, hardness, phosphates and fecal coliforms, are performed in the physical-chemical and microbiological laboratories of a government agency. An empirical correlation is used to establish the current value of BOD, from the data obtained in previous sampling in 7 different points of the Fifth River where the BOD and COD values were analyzed in each of them.

Polyethylene terephthalate (PET) containers of two different sizes, some 2 liters of capacity to send to the laboratory and others of 500 cubic centimeters for on-site measurements were used for the sampling; for the samples for microbiological analyzes sterile high density polyethylene (PAD) containers of 120 ml were used.

The portable equipment used are Xplorer GLX Pasco Scientific PS-2002, Passport PS-2169 waterquality sensor Pasco Scientific, Turbidimeter PS-2122 Pasco Scientific, Conductivity DD9-699-06621 Pasco Scientific 10X, Pasco Scientific temperature sensor, pH meter, Pasco Scientific electrode FF9-699-195, Dissolved Oxygen Pasco Scientific FF9-213, 699-06320, Flowrate Pasco Scientific PS-2130, GPS brand Tremin model x 10 and room temperature meter.

The methodology used for the determination of fecal or thermotolerant coliforms followed ISO 9308-2, Water Quality. *Escherichia coli* count and coliform bacteria. Part 2: Most Likely Number Method.

For the determination of COD the method used is Reflux Oxidation with dichromate; for Total Solids the Gravimetric method is used while for the valuation of Nitrates the method is SM 4500 NO₃⁻ B. Selective Ultraviolet, 20th Edition. The method AOAC 22042:1980, limit of quantification 0.02 mg/l is used for the quantification of Phosphates.

From the analyzes of 7 different points of the Fifth River, where BOD and COD were evaluated, a numerical relationship between both measurements of 0.36 was established, compatible with the studies of Hidalgo *et al.* (2003).

According to the methodology used, the different pollution indices (ICOMI, ICOMO, ICOPH) are calculated with the proposed equations and with the corresponding categorization for the ICOTRO. The value obtained is the average of each of the variables involved, which are defined in a range between zero (0) and one (1); indices close to zero (0) reflect very low pollution, and indices close to one (1) the opposite. ICOTRO is based on the concentration of total phosphorus, which itself defines a discrete category.

4. RESULTS

The Mineralization Pollution Index, ICOMI, was calculated from the following expression:

$$ICOMI = \frac{1}{3} (I_{\text{conductividad}} + I_{\text{dureza}} + I_{\text{alcalinidad}}) \quad (1)$$

The values obtained are the following:

MONTHS	ICOMI (M. Miranda Bridge)
December 2016	0.66
January 2017	0.66
February 2017	0.66

The equation used for the Organic Matter Pollution Index, ICOMO:

$$ICOMO = \frac{1}{3} (I_{DBO} + I_{coliformes\ totales} + I_{Oxígeno\ \%}) \quad (2)$$

MONTHS	ICOMO (M. Miranda Bridge)
December 2016	0.5
January 2017	0.48
February 2017	0.51

For the index of contamination by hydrogen potential is performed based on the following expression:

$$ICOpH = \frac{e^{-31.08+3.45\ pH}}{1+e^{-31.08+3.45\ pH}} \quad (3)$$

MONTHS	ICOpH (M. Miranda Bridge)
December 2016	0.02
January 2017	0.06
February 2017	0.09

The Trophic Contamination Index, ICOTRO, for the total phosphorus value obtained:

$ICOTRO < 0.01$, categorizing the resource as oligotrophic.

5. CONCLUSIONS

The interpretation of the data is facilitated by the use of pollution indices that significantly reduce the number of parameters to an expression that makes the information more visible and easy to interpret between those responsible for the exploitation of the spa and the general public. The results obtained show medium-high contamination by mineralization, average contamination of organic matter, uncontaminated by hydrogen potential and characterized as oligotrophic in what corresponds to the trophic pollution index.

It is thought to contribute with studies of this nature to the knowledge of the resource and to provide a tool to those responsible for the administration so that the recreational use of this public space, is carried out without risks to human health.

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CHAPTER 11

ANALYSIS OF THE IMPORTANCE OF PILOTAGE IN THE SAFETY OF NAVIGATION AND THE PREVENTION OF ENVIRONMENTAL RISKS IN THE PORT OF SANTOS

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RESUMO: O presente estudo aborda a temática da praticagem e a sua relevância para a segurança e eficiência nas operações marítimas na integração do sistema ESG (Environmental, Social and Governance) com intuito de reduzir impactos ambientais. A finalidade do consequente trabalho é a análise dos benefícios advindos do prático em manobras marítimas e portuárias em virtude da segurança e responsabilidade ambiental. O mesmo evidencia a importância da presença do prático durante as operações de manobrabilidade por meio da metodologia qualitativa e quantitativa. Por fim, a conclusão do tema exposto demonstra alto teor estratégico legal do prático diante da sua positiva atuação na contribuição da segurança e na preservação do meio ambiente, que fora evidenciado por meio de gráficos e um aprofundado estudo exploratório no tema.

PALAVRAS-CHAVE: praticagem, impacto ambiental, segurança.

ABSTRACT: The present study discusses the issue of pilotage and its relevance to safety and efficiency in maritime operations in the integration of the ESG (Environmental, Social and Governance) system in order to reduce environmental impacts. The purpose of this work is to analyze the benefits of pilotage in maritime and port maneuvers due to safety and environmental responsibility. It highlights the importance of the pilot's presence during maneuvering operations through qualitative and quantitative methodology. Finally, the conclusion of this study demonstrates the high strategic legal content of the pilot in view of his positive performance in contributing to safety and preserving the environment, which was evidenced by means of graphs and an in-depth exploratory study on the subject.

KEYWORDS: pilotage, environmental impact, safety.

1. INTRODUCTION

Praticagem is used to drive ships safely in and out of ports, and is a service performed on board by the Pilot, for the purpose of assisting in maneuvers by restricted waters.

In today's troubled seas, ensuring the safety of maritime operations is of paramount importance. However, as the world directs its vision towards sustainability and corporate responsibility, maritime *praticagem* activity faces a double challenge: maintaining the highest safety standards while aligning with ESG (Environmental, Social, and Governance) principles.

As far as the subject is concerned, it is possible to identify three major continents that stand out because of the intense circulation of mercantile activities in ports: Europe, North America and Asia. In addition to these, we also find Latin America, Africa and Oceania, which do not enjoy the same level of benefits in comparison to the former mentioned.

In Brazil, there is a set of port facilities around its coastal region measuring about 7,500 km. In addition, the port of Santos is among the largest ports in Latin America. For the *Praticagem* of São Paulo, the Port of Santos holds the position of the main port of South America, in this way, for demonstrating its capacity for contribution in the Brazilian economy.

Against this background, the following question was raised: What are the benefits of using the *Praticagem* in the maneuver of ships considering the environmental and safety issues in the Port of Santos? Thus, it seeks to clarify the participation of the *Praticagem* as a factor of competitiveness for the port and at the same time as a collaborative agent for the application of ESG practices. The objective of this study is to identify the impacts of the *Praticagem* service on port security, and the contribution to ESG practices.

As a methodology, a field survey was carried out with employees in the *praticagem* of Santos, from interviews with pilots to administrative collaborators, in addition, the research was also explored inside a *praticagem* ship in operation, and there was a detailed analysis in articles on the theme.

2. CONCEPTUALIZING *PRATICAGEM*

The *Praticagem* service consists of the advice and guidance provided by the Pilots to the commanders who sail in restricted maritime areas, where conditions make it difficult for ships to enter for docking and undocking in ports, rivers or canals. This practice aims to prevent accidents that could result in fatal damage, as well as to preserve the port ecosystem and the environment, as well as to protect public and private heritage. (PRATICAGEM DA BACIA AMAZONICA, 2023).

The emergence of the Pilot was an active response to the existence of navigation. Its origin goes back thousands of years, being reported the existence of the Pilots in the era of Abraham, about 4,000 years ago, the city of Ur, in Chaldea, which had ports and docks. UNICAP, 2023.

In 18th century Brazil, the presence of Pilots was already observed in some ports. However, it was by means of the Decree entitled "Regiment for Practical Pilots of Barra do porto of this city of Rio de Janeiro", signed by the Viscount of Anadia and with the rubric of the Prince Regent D. João VI, that originated the expression "Practical Pilot". Over time, this expression has been simplified to "Practical", and is now internationally recognized as "Pilot" (FAGUNDES, 2017, p.12); (WELLINGTON, 2022, p.4-5).

In the existing records, it is possible to see that the *Praticagem* in Santos existed operating with rudimentary structures since the beginning of the 16th century, and then at the end of the 19th century there was concession of Porto to private investors. In 1890, the Companhia das Docas was founded, the holder of the concession that built 260 meters of quays in 1892, considered the first organized port in Brazil. Therefore, it is currently considered the largest port in Latin America (PORTO DE SANTOS, 2023).

2.1 CONCEPTUALIZING THE PILOT

The term " Pilot" is used to designate the specialized professionals working in the port areas known as *Praticagem* Areas. These professionals have a detailed knowledge of local and regional characteristics, such as depth, currents, obstacles and climatic conditions. Likewise, this knowledge is used to ensure safety and efficiency

during berthing and unberthing maneuvers. Its occupation is concentrated on minimizing the risks involved in navigation and in the maneuvering of ships in restricted or confined waters. Its function is manifest at the most challenging moment, unlike the commanders, who act on the high seas, the Pilots are trained to operate in more restricted areas, where traffic and environmental conditions are specific, such as wind direction, waves and tides (PRATICAGEM DO ESTADO DE SÃO PAULO, 2023); (PIMENTA, 2019, p.1).

3. THE IMPORTANCE OF THE PILOTS IN THE SECURITY OF MARITIME AND ENVIRONMENTAL PRESERVATION

Praticagem plays an essential role for security, this occurs in virtually all ports due to the incongruities of each region. Their relevance is evident in the face of the considerable reduction of accidents and damage to the environment, and their absence could harm marine life or cost life of thousands of people negatively affecting operations. The damage could cost millions of dollars due to the value of the goods and the repairs of large machines, such as the Costa Concordia ship in Italy (FERNANDES, 2017, p.5)

According to the International Group of P&I Clubs, the rate of accidents with Pilots on board in Brazil is only 0.002% (two thousandths per cent). (LOPES et al; 2019, p.84-101)

In addition, studies indicate that the navigation that has a Pilot acting on board decreases between 16 and 87 times the probability of accidents compared to navigation without the presence of the professional. In difficult monitoring situations, such as during night navigation and in foggy conditions, the absence of onboard pilots results in an estimated navigation failure that becomes unfeasible, exceeding 10%. However, this same situation having the *Praticagem*, the possibility of problems decreases to 1% (ABREU et al; 2019, p.6-13).

The State understands that the main benefit of the *Praticagem* is to contribute to the protection of marine environments, to avoid accidents at sea and on land, in addition, to defend the interests of the country (MORAES et al; 2013, p.14).

4. THE PRACTICES OF ENVIRONMENTAL, SOCIAL AND GOVERNANCE IN MARITIME TRANSPORT

Environmental, Social and Governance (ESG) is a project designed to evaluate not only market criteria such as profitability, security, competitiveness and resilience, but also to include environmental, social and corporate governance attributes. BELINKY, 2021, p.2.

This acronym originated from the recent concerns with global environmental issues, having been discussed in the business scenario. It's events, agendas, discussions, that have been bringing this subject up with a lot of relevance and highlighting it.

The ship is the most common means of transporting commodities between vessels worldwide, counting in all over 4,900 ports around the world that carry 90% of world trade according to the International Maritime Organization (IMO, 2023). In this way, for all the movements that take place daily in the world's ports, there is also the action of the Pilots.

The *Praticagem* of the State of São Paulo has implanted the best operational practices and management of environmental impacts, such as the use of rainwater (reuse), has increased the solar energy in the shipyard and has been replacing the mechanical motors of the speedboats with electronic motors that have lower levels of CO2 emission. (PRATICAGEM DO ESTADO DE SÃO PAULO, 2023). The application of ESG measures needs to be continuous and constantly improved due to the speed of change in today's world.

The *Praticagem* also implemented the C3OT system (Center for Coordination, Communication and Traffic Operations). Which are cameras strategically located along the entire harbor, state-of-the-art meteorological and oceanographic equipment, used for measuring height and wavelength, direction and intensity of sea currents and wind, tidal height variation and visibility. Allowing in real time the monitoring of the entire channel of the Port of Santos, ensuring even more agility and safety in the maneuvers of ships that are increasingly attending the port and that require redoubled care in the narrow and winding channel of Santos. (PRATICAGEM DO BRASIL, 2023).

With the implementation of ReDraft software, an innovative and pioneering system, it is possible to determine the maximum operational draft in real time. This

system identifies the minimum clearance between the ship's bottom and the seabed, as well as the exact point at which this clearance will occur along the ship's path through the channel. In addition, the ReDraft anticipates the risks the vessel may face when entering or leaving the port, taking into account current environmental conditions, such as oceanographic data obtained from tide gages, wave gages and anemometers. All this is done in strict compliance with the main national and international regulations, such as ABNT, PIANC and USAC (BOAS et al; 2022, p.204).

The risks that ships can pose to the marine environment include oil spills and inadequate waste disposal caused by leaks from cargo ships, particularly oil tankers. In addition, emissions of air pollutants such as sulfur oxides (SO_x), nitrogen oxides (NO_x) and carbon dioxide (CO₂), oil spill and inappropriate waste disposal can be found (SILVA et al; 2021, p.336).

Generally speaking, accidents are the consequences of failures in marine fauna and flora (BRANDÃO, 2012, p.7). Unexpected events directly or indirectly interfere with the health and safety of the surrounding population and have impacts on the environment.

5. METHODOLOGICAL PROCEDURES

The methodology of this article was developed from three pillars, aiming to identify the main factors that demonstrate the importance of the *Praticagem* in the safety of navigation and prevention of environmental risks in the Port of Santos.

The first axis refers to the search and validation of research with bibliographic data of published articles.

In addition, two separate questionnaires were drawn up, one of a qualitative and one of a quantitative nature. The first questionnaire was developed on the basis open questions, allowing the interviewees, who are employees of the *Praticagem* of Saints, greater freedom to answer and to talk about the theme in question. The second questionnaire was prepared with closed questions, in order to obtain more objective answers. This approach was adopted with the purpose of ensuring a more precise and direct analysis of the collected data.

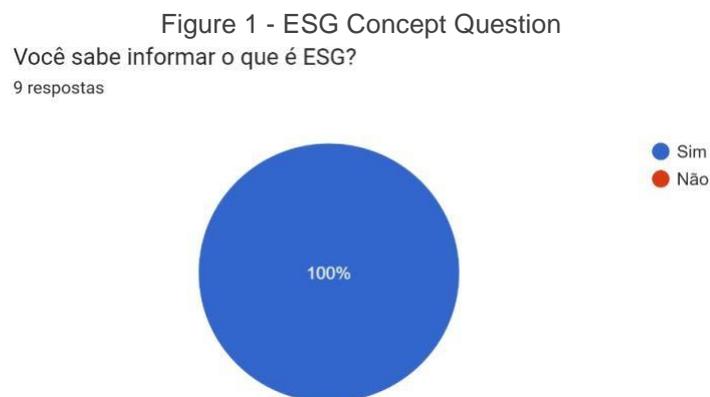
As the last pillar of this study, field research was conducted within the *Praticagem* of Saints. The members of this work had the opportunity to make a visit to

the access channel to Porto, accompanied by a craft Pilot from the institution itself. This visit aimed to deepen the understanding of the scenario studied and to obtain first hand information.

Finally, a comparison was made between the stages to discuss the main points of convergence that corroborate the problems of this study.

6. RESULTS

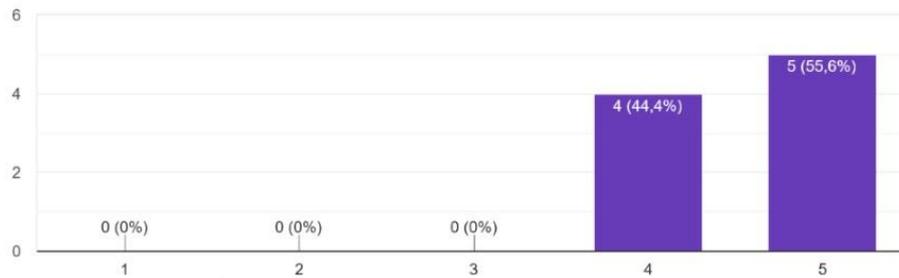
This chapter presents the results of an investigation in which nine employees of the *Praticagem* of Saints, among them the Pilots and the collaborators of the company, answered two questionnaires: one quantitative and the second qualitative, with the purpose of generating insights and answers that direct the understanding of the research question and the achievement of the objectives. The results of the quantitative questionnaire are presented in the form of graphs as shown in the figures below.



Source: Prepared by the authors 2023

According to the graph presented, it is noted that there was unanimity regarding the understanding of the concept of ESG among the employees of the *Praticagem* of Saints, since this understanding has been applied in daily life.

Figure 2 - Implementation of ESG measures
 Você acredita que a Praticagem se adequou aos métodos de ESG? De 1 (fraco) a 5 (forte).
 9 respostas

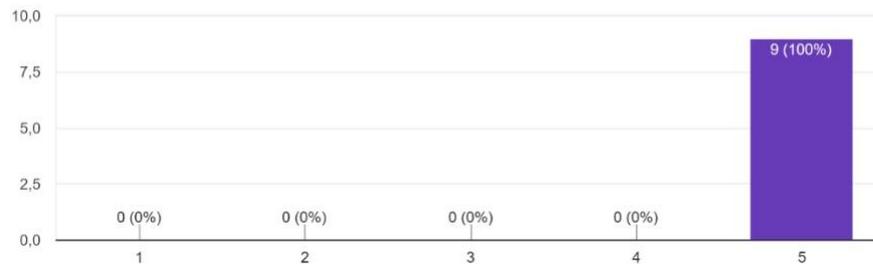


Source: Prepared by the authors 2023

It should be noted that out of the nine employees interviewed, the *Praticagem* was able to adapt considerably as to ESG methodologies, because five employees consider the maximum rating as to the company's efforts, and four said they were good.

Figure 3 - Environmental preservation within the service provided by the Pilot
 De 1 (fraco) a 5 (forte) - O quão essencial você acredita que é a preservação ambiental dentro do serviço prestado pelo Prático?

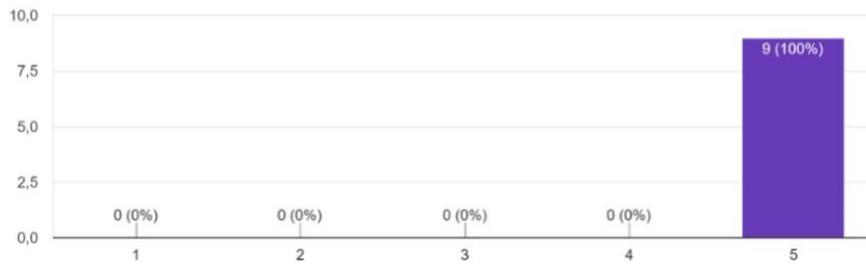
9 respostas



Source: Prepared by the authors 2023

The collaborators of the *Praticagem* of Saints recognize the importance of environmental preservation, this occurs as a reflection of the efforts that the Pilots of this city have in applying the ESG measures within the service, as was mentioned in chapter 2.3.

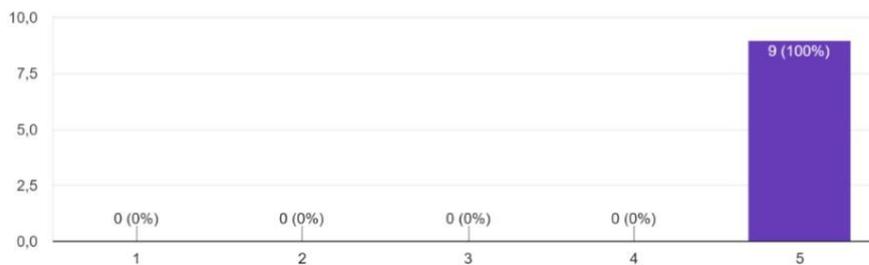
Figure 4 - ESG measures efficiently practiced by Pilots
 De 1 (fraco) a 5 (forte) - Você acredita que as medidas ESG são praticadas de forma eficiente pelos Práticos?
 9 respostas



Source: Prepared by the authors 2023

It is noted that the service provided by the *Praticagem* has a positive perception as to concern with the environment. This occurs because 100% of the interviewees responded with a maximum mark.

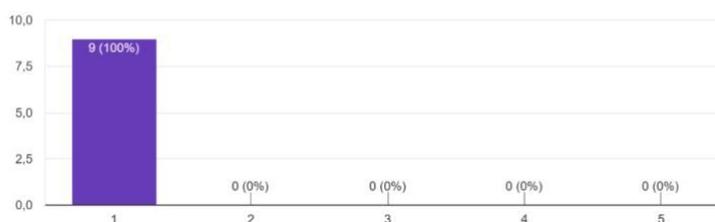
Figure 5 - Responsibility of the Pilot for Marine Life
 De 1 (fraco) a 5 (forte) - O quão responsável o prático é para saúde marinha?
 9 respostas



Source: Prepared by the authors 2023

From the results of the research, it can be seen that the Pilot has importance in marine life, since 100% of the interviewees confirmed it with a maximum mark.

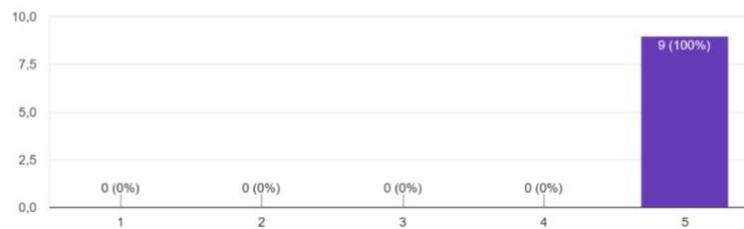
Figure 6 - Accidents by Pilots
 É provável que a quantidade de acidentes ocorra de maneira recorrente ou mais rara? Sendo 1 rara e 5 constante.
 9 respostas



Source: Prepared by the authors 2023

As the articles cited in this work point out, the Pilot has the responsibility of preventing accidents in port areas, preserving marine, environmental and human life. The results brought from this research reaffirm that this profession prevents unforeseen events in the operation of ships in Porto.

Figure 7 - *Praticagem* Safety
 O quão seguro você acredita que são as habilidades dos práticos na execução das manobras?
 Sendo 1 para não seguro e 5 para seguro.
 9 respostas



Source: Prepared by the authors 2023

The maneuvers are safety-related, and this question has been raised in order to highlight the importance of this profession in preventing port accidents. As a result, *Praticagem* officials have confirmed that the value of Pilots' skills makes life safer for the population residing in the port area and for fauna and flora.

The results obtained in the qualitative research were made through nine questions in which Pilots and *Praticagem* staff responded, thus selecting the most objective answers.

6.1 HOW ARE EMERGENCY PLANS DRAWN UP IN THE EVENT OF AN OPERATIONAL FAILURE?

All systems, sensors and equipment are dual in case an emergency occurs. In addition, there is a generator with a capacity of 120KVa to supply a power shortage. In the *Praticagem* activity, as it has a very high degree of readiness and unpredictability, there is no possibility of needing an "emergency plan". If there is an unforeseen event that a Pilot cannot perform at its scheduled scale, the following is immediately provided on the scale for automatic replacement. And in case any scheduled ship needs to cancel, nothing happens and the stopover remains waiting for the next confirmation.

6.2 WHAT POLICIES AND PRACTICES ARE APPLIED WITHIN THE ORGANIZATION TO PREVENT DAMAGE TO THE ENVIRONMENT?

Until the recent past, the *Praticagem* of São Paulo was certified by ISO 9002, having given up maintaining this certification by its own option, but all activities are carried out in such a way as to avoid or, at least, reduce to the maximum the possibility of damage, not only to the environment, but to the installations on land and human lives, involved or not in the activity. And we also have a practice of collecting rainwater for domestic use in the sectors where this is appropriate and applicable, supplying electricity by means of solar cells that are on the roof of the administrative headquarters and in the shipyard, and the vessels have control so that there is no emission of pollutant gases. In addition, we are changing the engines of these speedboats to electric ones, which are less polluting.

6.3 HOW CAN LACK OF MAINTENANCE AFFECT THE WORK OF THE PILOT?

- A failure of computers or communications systems in the Control Center (C3OT) could lead to serious accidents, as it would prevent traffic coordination, generating incalculable losses;
- A failure in the engines of the boats would reduce the transport logistics of the Pilots, generating delays and losses;
- A lack of maintenance of the sensors and vessels could indirectly affect the *Praticagem* activity.

That is why we follow strict routines for the maintenance of equipment and vessels.

6.4 HOW DO PILOTS DEAL WITH NAVIGATION CHALLENGES IN DIFFERENT WEATHER AND PORT CONDITIONS?

Besides the expertise generated by the constant execution of the maneuvers, the Pilots take courses in Brazil and abroad, aiming at the improvement of skills, adaptation to new technologies and training in emergency situations. Also practicing in maneuvering simulators. In addition, all the Pilots in activity in the Port of Santos

have already carried out more than one thousand maneuvers, acquiring experience to perform them in any climatic condition. But when bad weather occurs, the Pilot disembarks at a point of channel more or less sheltered, where the risk of life for their disembarkation occurs under more or less acceptable conditions, where there are fewer risks.

6.5 WHAT ARE THE MAIN CHALLENGES OF *PRATICAGEM* IN ENSURING SAFETY IN NAVIGATION?

The fact of dealing with different types of ships, with different levels of maintenance and crew proficiency, makes the Pilot have to have the maximum attention to the minimum details, identifying, not infrequently, before the ship's commander, situations that can turn into problems, acting in advance to avoid them. Finally, the constant maintenance of operational procedures to accommodate the ever larger ships, as well as the maintenance of the necessary resources (equipment and vessels).

6.6 HOW ARE TECHNOLOGY AND INNOVATION INFLUENCING *PRATICAGEM* AND IMPROVING NAVIGATION SAFETY?

Although maneuvering a ship is an activity that depends essentially on the personal skill of the person who carries it out, undoubtedly the improvement of the on-board equipment and the profusion of information generated and the disposition of the Pilot (tides, currents, meteorology, navigation software, etc.), have made the activity much safer. Because we can actually get the real-time positioning of the ships along the channel and the draft size.

6.7 IS THERE A PENALTY FOR A SHIP MISHANDLING?

When an accident occurs, an inquiry is conducted by the Local Representative of the Maritime Authority - in this case, the Port Authority. The result is forwarded to the Tribunal Marítimo, in Rio de Janeiro, despite the name, is an administrative and not judicial body.

Depending on the situation, those responsible may be punished with a fine, suspension or cancelation of the license, without prejudice to civil action. There have been cases of accidents involving ships, which have also been caused by the possible failure of one of the many complex shipboard systems.

7. FINAL CONSIDERATIONS

The service of the Pilot is of paramount importance for safety and environmental preservation according to the years according to the applied studies, moreover, as pointed out in this research, without the work of this professional the accident rate in the estuary would be high, bringing great impacts both on the economy and on environmental health. *Praticagem* plays a key role in the port context and is responsible for carrying out the first action as soon as vessels enter ports. However, when it comes to export operations, the *Praticagem* assumes responsibility for the proper parking of the vessels. This activity involves positioning vessels safely and strategically during the loading and departure process, ensuring the efficiency and safety of port operations.

Given that the *Praticagem* service prevents major accidents, as discussed in this article, it is estimated that the presence and action of Pilots during maneuvers reduces the likelihood of incidents compared to sailing without the Pilot's presence on board, proving the efficiency of their service. In times of difficult night monitoring, it can be seen that the absence of them results in an estimate of navigation failure that becomes unfeasible.

In terms of environmental preservation, the *Praticagem* has become part of the group of companies that are applying Environmental, Social and Governance (ESG) measures to reduce pollution in the world. It is worth mentioning, the initiatives regarding the environment had a national dimension from 2016 when Brazil signed the Paris Agreement, due to this, many companies started to adopt environmental preservation measures. As was the case with the *Praticagem* of the State of São Paulo.

It became the first in Brazil to implement the Environmental Management Program of the Via Green Institute (VGP), thus planning an inventory of greenhouse gas emissions, as well as adopting some measures in order to support the cause in question, such as: harnessing rainwater, solar energy in the shipyard and replacing

the mechanical engines of speedboats by electronic engines that manage to obtain lower CO2 emission rates.

This article presents arguments that substantiate and prove the effectiveness and efficiency of the Pilot in security issues and ESG measures adopted in the world, besides corroborating with facts and exploratory studies that have evidenced its performance as being positive for both themes exposed. That said, it is possible to conclude that the Pilot presents the quality of safety on vessels, in spite of a world totally globalized and robotic, the human factor in this context collaborates in order to add and not hinder in the preservation of nature and safety.

Ethical limitations have occurred due to the complexity of the subject and the reserved nature of the sector, which involves private information from participants. Those Limitations may have led members to fear sharing information that could affect their business.

Due to the complexity and lack of academic studies on the market structure of the *Praticagem*, further research is needed. Such research can provide a more comprehensive and accurate understanding of this market, including its economic impact in a region or country, considering factors such as job generation, cargo movement, and maritime sector development. Therefore, it is fundamental to invest in research that provides valuable insights into this complex and little explored area, contributing to a better understanding of its dynamics and effects.

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CHAPTER 12

TEMPORAL VARIATION OF ANDEAN WETLANDS USING GEOGRAPHIC INFORMATION TECHNOLOGY IN THE DISTRICT OF URANMARCA, APURÍMAC - PERU

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ABSTRACT: The general objective was to estimate the amount of wet surface of the wetlands and its variation in the years 2010 to 2023 of the Uranmarca District, using geographic information technologies and the specific objectives: a) Identify the available satellite information, which will allow the variation to be determined humidity of the surface of the wetlands of the District of Uranmarca, b) Analyze the spectral indices that help to improve the discrimination of the humid surface of the wetlands of the District of Uranmarca c) Quantify the variation of wet surface in the years 2010 to 2023 the wetlands of the Uranmarca District. The method used in the research is quantitative, the type of research is non-experimental and the level of explanatory research. The area of wetlands in the district of Uranmarca was determined, being 1570248.16 m² for the year 2013, 1783753.43 m² in 2017, 1478876.2 m² in 2020 and 1728497.94 m² for the year 2023. It is concluded that the variation in wet surface of the Andean wetland has suffered a decrease of 55255.49 m², for a period of 10 years between 2013-2023.

KEYWORD: andean bofedal, Uranmarca District, temporal variation, Apurímac region.

RESUMEN: El objetivo general fue Estimar la cantidad de superficie húmeda de los bofedales y su variación en los años 2010 hasta 2023 del Distrito de Uranmarca, utilizando tecnologías de información geográfica y los objetivos específicos: a) Identificar la información satelital disponible, que permitirán determinar la variación de humedad de la superficie de los bofedales del Distrito de Uranmarca, b) Analizar los índices espectrales que ayuden a mejorar discriminar la superficie húmeda que posee los bofedales del Distrito de Uranmarca c) Cuantificar la variación de superficie húmeda en los años 2010 hasta 2023 de los bofedales del Distrito de Uranmarca. El método utilizado en la investigación es cuantitativo, tipo de investigación es no experimental y el nivel de la investigación explicativa. Se determinó la superficie de bofedales del distrito de Uranmarca, siendo para el año 2013 de 1570248.16 m², 2017 de 1783753.43 m², 2020 de 1478876.2 m² y para el año 2023 de 1728497.94 m². Se concluye que la variación de superficie húmeda de bofedal andino ha sufrido una disminución de 55255.49 m², para un periodo de 10 años entre el 2013-2023.

PALABRA CLAVE: bofedal andino, Distrito de Uranmarca, variación temporal, región Apurímac.

1. INTRODUCTION

1.1 PROJECT DESCRIPTION

Water is a vital resource for all human activities, in the headwaters of the basin water resources are stored as a result of rainfall; forming the Andean wetlands. These must be preserved and protected in order to have this resource permanently, which allows to meet agricultural, livestock, human consumption, etc.

1.2 PROBLEM

1.2.1 Problem approach

The wetlands are the reserves of water resources at the head of the watersheds that need to be identified, measured and conserved in order to preserve the water resources of the district of Uranmarca.

Wetlands, in particular wetlands (peatlands, meadows) located on the banks of rivers and springs of grasslands and high mountain deserts, function as archipelagos of diversity. Climate change could lead to reduced water availability, salinization, reduced land area and increased carbon (especially CO₂) emissions in these ecosystems.(Herzog et al., 2012)Oh, yeah.

The research will determine the variation of the temporal humidity of the surface of wetlands using geographic information technologies of the district of Uranmarca. This will allow to identify and conserve this important resource of regulation of the water resource; which will benefit the peasant communities of Uranmarca, Tancayllo, Huancané, Antasco-Pariabamba, Santa Rosa de Manzanayoc-Uchuran and Culluni Izquierdo for their productive activities, population consumption, etc. It should also be noted that the wetlands fed to Rio Pomabamba and the Huancaray gorge that extends through the territory of the district of Uranmarca.

1.2.2 Formulation of the problem

a) Main problem

How will wetland surface moisture variation be determined in the period 2013 to 2023, using geographic information technologies in Uranmarca District?

b) Secondary problems

- What types of medium-resolution satellite images will determine the humidity variation of the wetlands of the Uranmarca District?
- How will the spectral indices applied to optical satellite imagery determine the humidity in the wetlands of the Uranmarca District?
- How will the variation of humidity be quantified from 2013 to 2023 in the wetlands of the Uranmarca District?

1.3 BACKGROUND

1.3.1 National Background

(Pauca-Tanco et al., 2020), determined for the period 1986-2016, the bofedal area of the Chalhuanca Annex presents an increase of 12 ha/year, where the highest growth rate (138.07%) was presented in the period 1991-2001. The average NDVI values show an increase for the evaluated period, and it was also established that the threshold value for determining wetlands in the area corresponds to 0.26. The climatic variables studied for the period evaluated, present an increase, being significant only the maximum and minimum temperature. Precipitation has been found to show an increase of 32 mm/dec, while the maximum and minimum temperature show an increase of 0.3 °C/dec and 0.6 °C/dec, respectively. Correlation and determination analyzes show a close relationship between the variables bofedal area-precipitation ($r=0.92$; $R^2=0.85$), NDVI|precipitation ($r=0.89$; $R^2=0.80$) and NDVI-bofedal area ($r=0.96$; $R^2=0.94$). On the other hand, the relationship between wetland area and temperature and NDVI|temperature were only significant, however, since the increase in precipitation is not statistically significant, a clear relationship can not be established, but probably, the increase in the water supply for wetlands during the dry season is due to a deglaciation process associated with the increase in temperature. It is still

necessary to study some complementary variables to establish a more consolidated causality relationship.

(Monge-Salazar et al., 2022), mention that the high-altitude wetlands of the Central Andes, known locally as *wetlands*, provide important ecosystem services, in particular carbon storage, forage provision and water regulation. Local communities have artificially expanded the woodlands by irrigating the surrounding grasslands to maximize areas for alpaca grazing. Despite their importance, the biophysical processes of both natural and artificial wetlands are still poorly studied, which hinders the development of adequate management and conservation strategies. The composition of vegetation, hydrological variables, groundwater chemistry, and soil characteristics of a natural and an artificial wetland at least 10 years old in southern Peru were analyzed and compared to understand their interrelationships and the consequences for the provision of ecosystem services. No statistically significant differences were found in soil, water and vegetation characteristics. Soil organic carbon (SOC), which was used as an indicator of carbon storage, negatively correlates with dissolved oxygen, pH and soil water temperature. In addition, the analysis of non-metric multidimensional scaling shows a positive relationship between the composition of the plant community, the COS content and the electrical conductivity of water. The results suggest a triple interaction between hydrological, soil and vegetation characteristics in the natural woodland, which is also valid for the artificial woodland. Plant cover of two of the most nutritious species for alpaca, *Lachemilla diplophylla* and *Lilaeopsis macloviana*, with 19 to 22 % crude protein, have weak or no correlation with environmental variables, suggesting that grazing might be obscuring these possible relationships. Given the great economic importance of alpaca breeding for local communities, artificial expansion of woodlands seems an effective strategy to improve their ecosystem services with minimal impact on the ecohydrological properties of woodlands.

(Chimner et al., 2019) They also mention that wetlands (called wetlands in the Andes of Peru) are abundant and important components of many mountain ecosystems around the world. They provide many benefits, including water storage, high-quality habitat, pastures, nutrient sinks and transformations, and carbon storage. The remote and rugged environment of mountain wetlands creates challenges for mapping, which usually leads to misclassifications and underestimates of the extent of

wetlands. Multiple sensor and multiple date radar and optical imaging (Landsat TM/PALSAR/RADARSAT-1/SRTM DEM-TPI) combined with field verification were used to map wetlands in Huascarán National Park, Peru. The wetlands were mapped in the main types of wetlands: 1) cushion plant peatlands, 2) cushion plant wet meadows and 3) grasses wet meadows with an overall accuracy of 92%. A fourth type of wetland (graminoid peatlands) was found but was too rare to map accurately, so it was combined with cushion peatlands to form a single class of peatlands. The total area of wetlands mapped in the National Park is 38,444 ha, which is 11% of the park area. Peatlands were the most abundant wetland type occupying 6.3% of the park, followed by wet grasses (3.5%) and wet cushion grasslands (1.3%). These maps will serve as a basis for better management, including restoration and estimates of the landscape's carbon stocks 5%) and humid padded meadows (1.3%).

(Roucoux et al., 2017), indicate that large intact areas of tropical peatlands are highly threatened globally by the expansion of commercial agriculture and other forms of economic development. Landscape-scale peatland conservation, with its hydrology intact, is of international conservation importance in order to preserve its distinctive biodiversity and ecosystem services and maintain its resilience to future environmental changes. We explore threats and opportunities to conserve the remaining tropical peatlands intact; therefore, we exclude the peatlands of Indonesia and Malaysia, where extensive deforestation, drainage and conversion to plantations mean that conservation in this region can protect only small fragments of the original ecosystem. We focus on a case study, the Pastaza-Marañón Foreland Basin (PMFB) in Peru, which is among the largest intact tropical peatland landscapes in the world and is representative of peatland vulnerability. The maintenance of critical hydrological conditions for carbon storage and the ecosystem function of peatlands is, in the PMFB, threatened mainly by the expansion of commercial agriculture linked to the new transport infrastructure that facilitates access to remote areas. Opportunities remain at the PMFB and elsewhere to develop alternative and more sustainable land-use practices. Although some of the peatlands in the PMFB are within existing legally protected areas, this protection does not include the most carbon-dense areas (domed pole forest). New carbon-based conservation instruments (e.g. REDD+, Green Climate Fund), market development for sustainable peatland products, transfer of land titles to local communities, and expansion of protected areas offer avenues for greater

protection of intact tropical peatlands in the Amazon and elsewhere, such as those in New Guinea and Central Africa, which remain, for the time being, beyond the frontier of commercial development.

(Aduato & Willems, 2016) In addition, they present preliminary results of the study of the evolution of forest ecosystems in the area of Pilpichaca, Huancavelica. These wetlands, together with the water bodies of the place, are part of the ecosystem in the headwaters of the Pisco and Pampas basins. The studies use images from the TM and OLI sensors on board Landsat satellites as the main input, which are processed in order to generate vegetation and humidity indices – two of the most relevant parameters to the ecosystems of interest. It also involves the evaluation of classification techniques, such as decision tree analysis, as tools for the discrimination of wetland/non-wetland areas, as well as the identification of existing wetland types (permanent and temporary). The process leads to the generation of thematic maps, about the location and extent of wetland types, as well as multi-year evolution. These are validated by high spatial resolution images and spectral analysis studies. The results show a permanent decrease in grassland areas.

Gutierrez (2018), in the research carried out in the Coata river basin, which is located between the provinces of Lampa, San Román and Puno, whose objective was to determine the degree of correlation between the spatial dynamics of the wetlands during the years from 1984 to 2016 and climate factors such as accumulated precipitation and maximum temperature. The methodology consisted of determining the surface extension of these wetlands using Standardized Difference Vegetation Index (NDVI) algorithms, using Landsat 5 and Landsat 8 satellite images, information was also collected on annual cumulative precipitation and annual maximum temperature, and the trend that these climatic factors present during the indicated years was analyzed, which resulted in a significant trend in the annual maximum temperature. Finally a multiple linear regression was performed and it was taken as a result, that the climate factor that most influences the behavior of the wetlands is the maximum temperature, because the correlation coefficient resulted ($R^2 = 0.46$) which means that there is a significant relationship. It is concluded that as the maximum annual temperature increases, the surface extension of the wetlands decreases or in some cases the wetlands disappear, which implies that, one of the factors in the behavior of the wetlands is climate change.

1.3.2 International Background

(Jara et al., 2019), through the results obtained with Random Forest it can be observed that the variables with greater importance that served for the quantification and identification of wetlands in the RPFCH are the EVI 2 index, with an importance of 37.72% for Landsat-8, while with Sentinel-2 the Red Edge index was the one that provided more information with 38.54%; however, as Landsat-8 does not have the Red Edge bands, a comparison with the information provided by this band could not be made.

Due to the difference in resolutions of 30×30 m of Landsat-8 and 10×10 m of Sentinel-2 and the 13 bands with which Sentinel-2 works for the quantification and identification of wedges, it is concluded that the results derived from Sentinel-2 (with an overall percentage of correct of 86.59%) were more accurate compared to the data obtained with Landsat-8 (with an overall percentage of correct of 77.90%).

Compared to Landsat-8 which shows the following percentages: 15.41% of the bofedal intervened, 24.36% of the bofedal conserved and 1.43% conserved, Sentinel-2 shows that 24% of the bofedal ecosystem is in the intervened category (12,818.69 ha), 12% is conserved (6,112.05 ha), while 3% is conserved (1,587.29 ha), giving a total of 20,518.03 ha of bofedales, that is 39 % of the total area of the Reserve. From the data generated in the present study, the forest ecosystem can be used sustainably, because the information provided from the different indices is scientifically relevant to generate management strategies, in order to prevent the deterioration of existing resources and, consequently, contribute to the quality of life of local inhabitants and the permanence of biodiversity.

Guerrero et al. (2022), presents a classification and evaluation of the geo-ecological and environmental functionality adapted to the high Andean wetlands in the province of Loja; a total of 279 wetlands are reported, classified in 163 semi-capped (mixed II-III); 52 wetlands water mirrors (I) and 64 wetlands capped grass or peatlands (IV), the latter being abundant in the páramos of Saraguro and Yacuambi (to the north), where more critical geo-ecological conditions are recorded, linked to unfavorable hydroclimatological and anthropogenic factors.

The progressive decline of the water mirror wetlands (I) and mixed semi-capped wetlands (II) directly affects the availability of effective water for the population.

However, semi-capped (III) and capped (IV) wetlands are critical as carbon sequesters and storages.

The Loja-Vilcabamba and Jimbura-Amaluza wetlands (to the south) have better geo-ecological and water quality conditions than the Saraguro and Yacuambi wetlands (to the north). The protection of high Andean wetlands is a priority as they directly or indirectly benefit the population through carbon storage, regulation of water cycles, freshwater conservation, pollutant purification and climate stabilization.

Environmental policies should be oriented to regulate and manage the occupation and use of territory in wetlands and adjacent areas, through territorial instruments such as special protection plans. These should consider forest restoration and the creation of protective zones in high river basins, to mitigate the negative impact of both the progressive advance of the agricultural frontier and the effects of climate change.

Valois et al. (2020), mention that the combination of ERT and GPR geophysical methods allows a better understanding of both the geological composition and geometry of the high-altitude peatlands. According to these results, and with the data extracted from witnesses, the studied woodland is composed of layers of unconsolidated saturated sediments with low clay content, such as sand beds, gravels and silts. Such layers are expected to be found to a depth of about 10 m, where a strong contrast of resistivity and EM velocity marks the boundary between the bottom of the alluvial fill and the top of a medium probably composed of rock court or weathered bedrock, inferred from the high resistivity and relatively high EM velocities.

By conducting longitudinal and transverse profiles and following the strong interface of resistivity and velocity, it was possible to define the geometry of the bofedal as a basin-shaped relief, with a thicker sedimentary infill downstream than upstream. The converging scree lobes form a barrier that defines the boundary downstream of the ridge. Together, these observations suggest that the woodland was formed by the closure of the valley by rocky slopes and the progressive deposition of alluvial deposits upstream.

The water storage capacity of this alluvial filling structure is estimated at 2000 mm per square meter of bofedal, resulting in a reservoir capacity comparable to the annual flow and actual evapotranspiration of peatlands at the basin scale. High-altitude peatlands (wetlands) are therefore important reservoirs of water that consume a

significant amount of water in arid environments, but are necessary to provide the essential ecological services of peat, soil, plant production and carbon accumulation. Thanks to their reservoir function and their low vertical permeability, wetlands can cushion the impact of droughts. Efforts to characterize the hydrological role and preserve these unique wetlands, critical to sustaining biodiversity and livestock grazing, must be a priority in the context of a changing climate.

1.4 RATIONALE AND IMPORTANCE

1.4.1 Justification

Water resources are very important for the physiological activities of man, as well as for his productive activities. The district of Uranmarca depends on water resources for the population and agricultural activity that constitutes the livelihood of the population.

It is therefore important to identify the woodlands of the district of Uranmarca, in order to preserve and protect them for the benefit of the population of the district.

The wetlands are threatened by various anthropic activities and by climate change.

These ecosystems are highly vulnerable due to intrinsic characteristics, such as the area it occupies, which is generally small, the slow process of formation and the high diversity of species. Additionally, their high dependence on water makes them vulnerable to variations in the water cycle, especially if one considers a decrease in precipitation and glacier melt.(Moya et al., 2015)

1.4.2 Importance

The research is important because it will allow to identify the wetlands, as well as temporal variation of humidity of the district of Uranmarca. This will allow us to know the volume of water available in time and at different times of the year such as avenues and drainage.

This will allow to propose strategies for the conservation of this resource, which regulates the availability of the water resource to meet the needs of the population of the district of Uranmarca as population use, productive activities, livestock, etc.

1.5 OBJECTIVES

1.5.1 General objective

To estimate the amount of wetland surface of the wetlands and their variation in the years 2013 to 2023 of the District of Uranmarca, using geographic information technologies.

1.5.2 Specific objectives

- Identify the available satellite information, which will allow to determine the variation of humidity of the surface of the wetlands of the District of Uranmarca
- Analyze the spectral indices that help to improve and discriminate the wet surface that has the wetlands of the District of Uranmarca
- To quantify the variation of wet surface in the years 2013 to 2023 of the bofedales of the District of Uranmarca.

1.5.3 Limitations of Research.

It should be carried out evaluation of edges in time of avenues with radar images, with the landsat images has not been able to carry out, because of the high cloudiness of the study area and because these images do not penetrate the cloudiness as if it does the radar images.

2. METHOD

2.1 METHODS OF INVESTIGATION

- The research is quantitative, since the variables are measured in quantities (km^2 , m^3).

- The type of research is non-experimental, since there is no control of variables.
- The level of explanatory research, as the reasons that cause the problem are sought.(Zamora et al., 2022)

2.2 POPULATION AND SAMPLE

- **The universe** is composed of the population of wetlands of the Peruvian territory. Specifically of the High Andean wetlands.
- **The sample** was chosen randomly and for convenience, which is located in the Uranmarca district, located in the Province of Chincheros, Apurímac region.
- **The space domain** that was considered is the district of Uranmarca.
- **Analysis Unit.** – The unit to be investigated is the wetlands using medium resolution satellite images in different years.
- **Temporary Space.** – The research was conducted in the years 2010 to 2023.

2.3 DATA COLLECTION TECHNIQUES OR INSTRUMENT

Satellite information will be collected as satellite images available on the servers of the Peruvian Space Agency; also basic digital cartographic information, thematic of the Ministry of the Environment, National Water Authority (ANA), Ministry of Transport and Communications, Geological, Mining and Metallurgical Institute (INGEMMET), Regional Government of Apurímac, Geological Service of the United States.

2.4 MATERIALS

2.4.1 Cartographic information

The cartographic information that will be used in the investigation are the national charts elaborated by the National Geographic Institute (I.G.N.) which have a scale of 1: 100 000. Leaves 28-o (Chincheros) covering the surface of the Uranmarca district have been identified.

2.4.2 Thematic information

Thematic maps developed by national institutions will be used, and are as follows:

- Ecological Map, prepared by the National Office for the Evaluation of Natural Resources (ONERN) in 1972 at scale 1: 1 000 000.
- Forest map of the Apurímac region, drawn up by the Apurímac regional government in 2003 at scale 1: 100 000.
- Map Current land use of the Apurímac region, prepared by the regional government of Apurímac in 2003 at scale 1: 100 000.
- Map of Life Zones of the Apurímac region, prepared by the Apurímac regional government in 2003 at scale 1: 100 000.

2.4.3 Space Images

- **Digital Model Elevation (D.E.M):** It will be used to determine the volume of water resources of the bofedales of the district of Uranmarca, for which a digital model of the ALOS PALSAR satellite terrain with a spatial resolution of 12.5 meters is used.
- **Landsat images:** Landsat images 8 and 9 will be used to determine the wetland surface of the Uranmarca district.
- **KompSat images:** Images from the Korean KompSat 3-3A satellite to identify the bofedales of the Uranmarca district and compare with images from another sensor.

2.4.4 Software

For the development of the research, geographic information systems software will be used, for the processing of vector information such as: ArcGIS Pro. Also, software will be used for satellite information processing for which Erdas Imagine and SCANEX will be used to process images and Microsoft Word for Office writing.

2.5 PROCEDURES

With the help of the GIS Software, the extensions of the woodlands are delimited within the thematic maps downloaded from the official sites of the corresponding entities.

2.6 SPECTRAL ANALYSIS

The relationship of the infrared, green and red field will allow us to determine the state of the humidity of the surface of the wetland, for this the upper values of “0.01” will be considered as surface with humidity, being the negative values surface without humidity.

2.7 SPATIAL ANALYSIS

With the quantification of the pixels with these values we proceed to classify them by ranges of values and convert them to polygons to quantify the area obtained within each analysis period.

3. RESULTS

3.1 IDENTIFY THE AVAILABLE SATELLITE INFORMATION, WHICH WILL ALLOW TO DETERMINE THE VARIATION OF HUMIDITY OF THE SURFACE OF THE WETLANDS OF THE DISTRICT OF URANMARCA

Landsat 8 and Landsat 9 imagery was collected for dry season from the US Geological Survey's <https://earthexplorer.usgs.gov/> (Earth Explorer), as detailed in Table 1.

Table 1. Landsat Satellite Images

<i>N°</i>	<i>Landsat image</i>	<i>% Cloudiness</i>	<i>Scene</i>
1	LC08_L2SP_005069_20130821_20200912_02_T1	23.62	5/69
2	LC08_L2SP_005069_20170613_20200903_02_T1	24.34	5/69
3	LC08_L2SP_005069_20200723_20200911_02_T1	17.72	5/69
4	LC09_L2SP_005069_20230724_20230802_02_T1	19.11	5/69

3.2 DIGITAL MAPPING OF THE DISTRICT OF URANMARCA

The location map, topography map of the district of Uranmarca was designed for this purpose, digital cartography was used in shape format at 1:100000 scale of the National Geographic Institute (IGN). The national chart used is sheet 28-o (Chincheros). The digital files in Shape generated are detailed below

Table 2. Digital Archives of the Uranmarca District.

Archive	Description	Topology	Scale	Format
Rios_Uranmarca.shp	Hydrography	Line	100,000	Shape
Curves_level_Uranmarca.shp	Level Curves	Line	100,000	Shape
Dimensions_Branch.shp	Land dimensions	Point	100,000	Shape
Islands_Ukraine.shp	Islands	Polygon	100,000	Shape
Txt_rios_Uranmarca.shp	Name of rivers	Line	100,000	Shape
Txt_Cerros_Uranmarca.shp	Name of hills	Line	100,000	Shape
Lagos_Uranmarca.shp	Gaps	Polygon	100,000	Shape
Signs_Uranmarca.shp	Signals	Point	100,000	Shape
Urban_Population_Uranmarca	Urban Area	Polygon	100,000	Shape

Note: Research Group

Digital files were also generated in shape format of thematic cartographic information, which are detailed in Table 3.

To define the sub-basins and micro-basins of the district of Uranmarca, water level and network curves were used, and water divides were defined. It was then validated with Landsat Satellite imagery.

Table 3. Thematic digital archives of the Uranmarca District.

Archive	Description	Topology	Scale	Format
District_Uranmarca.shp	District Limit	Polygon	100,000	Shape
Basins_Uranmarca.shp	Subbasins / Microbasins	Polygon	100,000	Shape
Bofedales_Uranmarca.shp	Bofedales	Polygon	100,000	Shape

The micro-basins and sub-basins of the district of Uranmarca were designed, which are fed by the bofedales that are located in its head of basins that is detailed in Table 4.

Table 4. Subbasins and Microbasins of the Uranmarca District.

Name	Area (km ²)	Perimeter (km)	Subbasin/Microbasin
<i>Interbasin</i>	31.26	38.07	Interbasin
<i>Ada. Pallac Huayjo</i>	17.89	20.01	Microbasin Qda. Pallac Huayjo
<i>Ada. Pomabamba</i>	108.79	51.75	Qda sub-basin. Pomabamba
<i>Quishuar Chaca River</i>	46.76	36.10	Micro-basin Rio Quishuar Chaca

3.3 ANALYSIS OF SPECTRAL INDICES TO DISCRIMINATE THE WET SURFACE OF THE WETLANDS OF THE URANMARCA DISTRICT

The different indices were analyzed to discriminate the wetland surface of wetlands of the district of Uranmarca, being the following:

The **Differential Normalized Vegetation Index (NDVI)**, provides us with information about the state of vigor of the crop. It is calculated as follows:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad \text{..... Equation 1}$$

Where:

NIR = near infrared light

RED = visible red light

The **Differential Index of Normalized Vegetation** was calculated with the Landsat satellite images collected from Table 1 and with the help of the Erdas Imagine software of the District of Uranmarca, where areas with vegetation were identified.

The **Standardized Water Differential Index (NDII)** allows us to identify water bodies and areas with moisture saturation:

$$NDII = \frac{(NIR - SWIR)}{(NIR + SWIR)} \quad \text{..... Equation 2}$$

Where:

NIR = Near Infrared

SWIR = near-infrared to short waves

Using the images in table 1, applying equation 2 in the **Erdas Imagine** software. The NDII of the district of Uranmarca was calculated, which allowed identifying areas with high humidity.

3.4 TO QUANTIFY THE VARIATION OF WET SURFACE IN THE YEARS 2013 TO 2023 OF THE BOFEDALES OF THE DISTRICT OF URANMARCA.

To quantify the wetland surface of wetlands, digital terrain model ALOS PALSAR with a spatial resolution of 12.5 meters was downloaded, which is detailed in Table 8.

Table 8. Digital model of the land

N°	ALOS PALSAR	DATE
1	AP_15944_FBS_F6910_RT1.dem	3/28/2015

With the information of the digital model of the terrain, the slope map, topographic position index of the study area was generated as shown in Figure N° 13, 14 and 15 respectively

With the inputs: digital model of the terrain, slope map, topographic position index and **Standardized Water Differential Index in raster data model, a mathematical model (equation 3 and figure 16) was designed with which** the wet surfaces of the Andean wetland were determined. For which map algebra was used in the model builder of ArcGis Pro, as detailed in table 9 and figures No. 2, 3, 4 and 5.

$$\text{Superficie de Bofedal} = f(\text{TPI} > 0, \text{dem} > 3000, \text{ndii} > 1, \text{pend} > 10) \dots \text{Equation 3}$$

Where:

TPI = topographic position index

NDII= **Standardized Differential Water Index**

Pend = slopes

Dem = digital land model

Figure 1. Mathematical model to determine wet surfaces of wetlands.

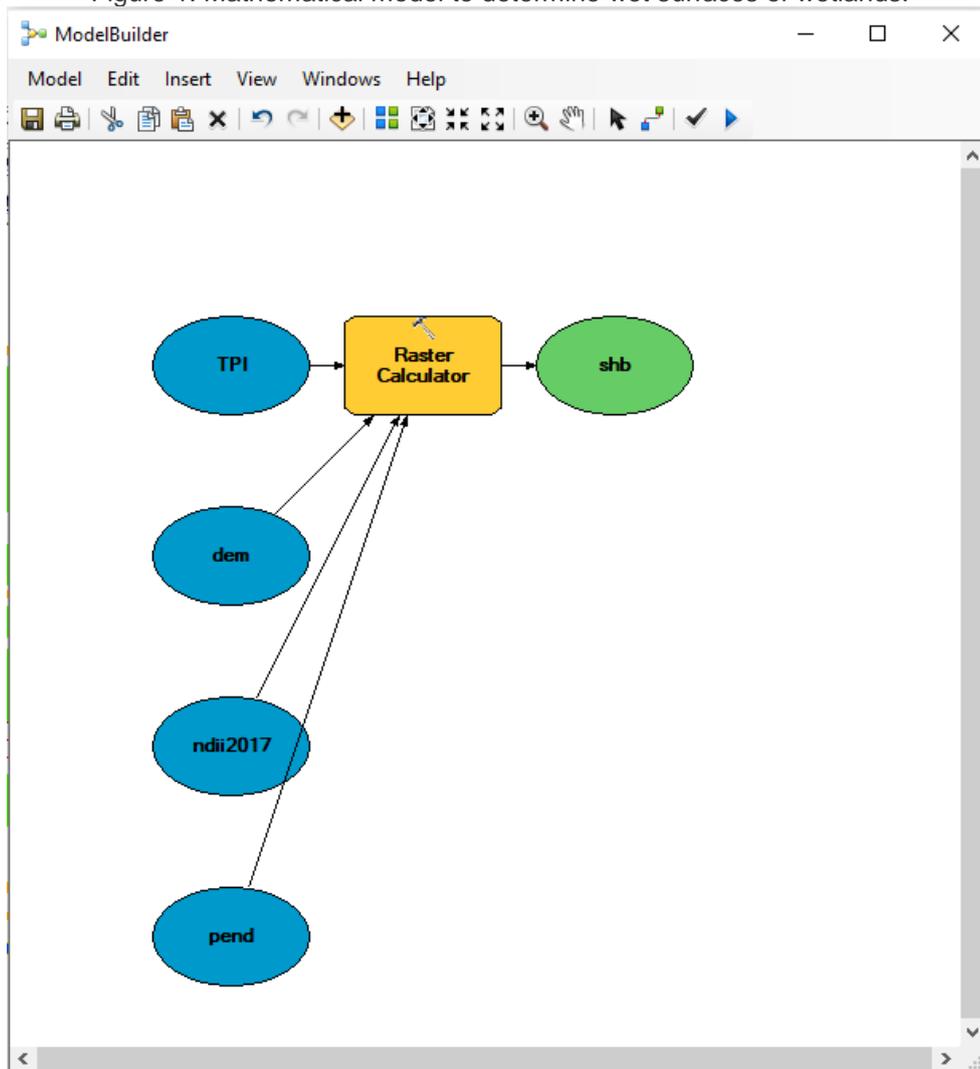


Table 9. Surface of wetlands in the district of Uranmarca

<i>N°</i>	<i>YEAR</i>	<i>N° BOFEDALES</i>	<i>AREA (m²)</i>
1	2013	24	1570248.16
2	2017	20	1783753.43
3	2020	22	1478876.20 %
4	2023	25	1728497.94

Figure 2. Bofedales 2013 surface map

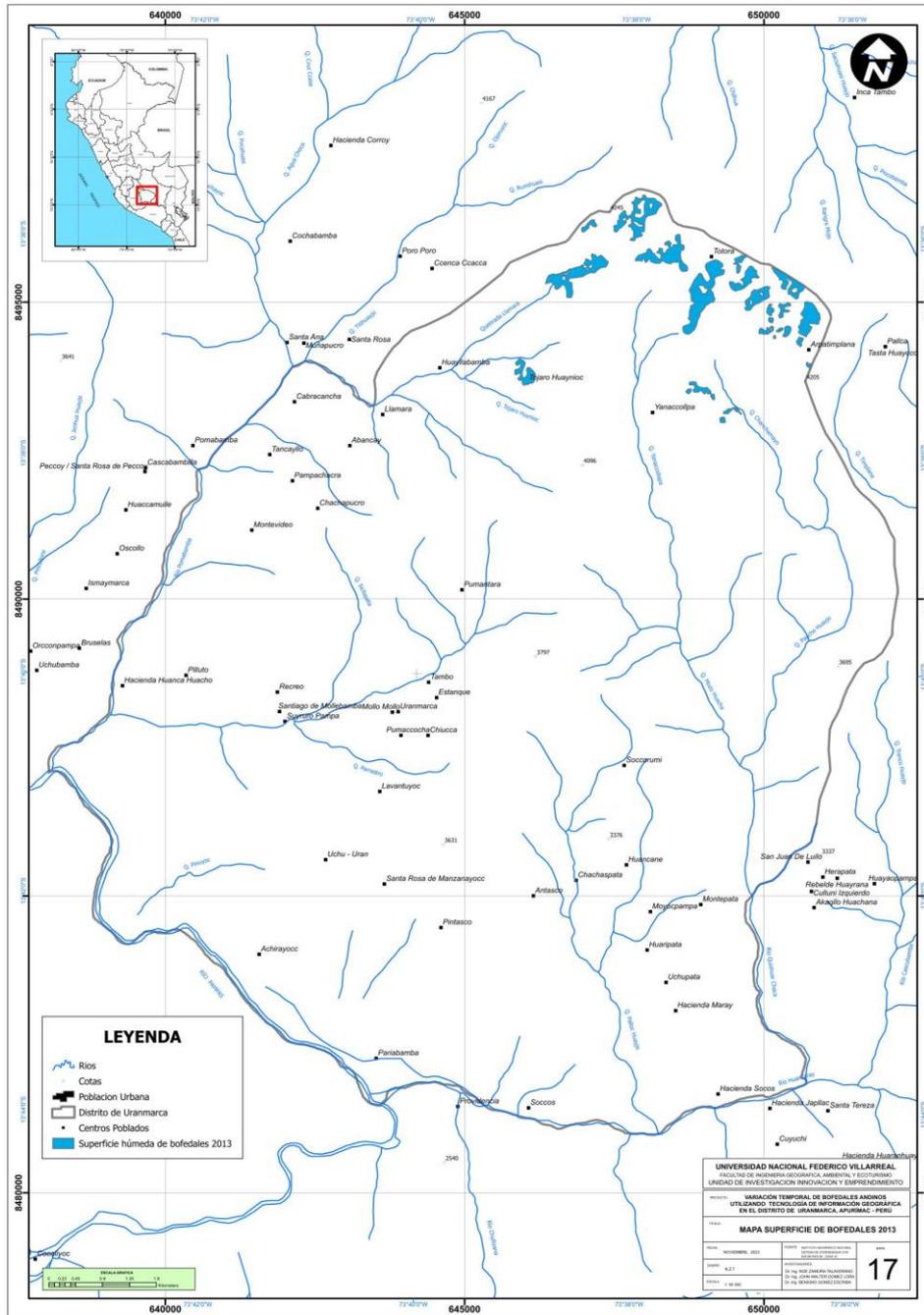


Figure 3. Bofedales 2017 surface map

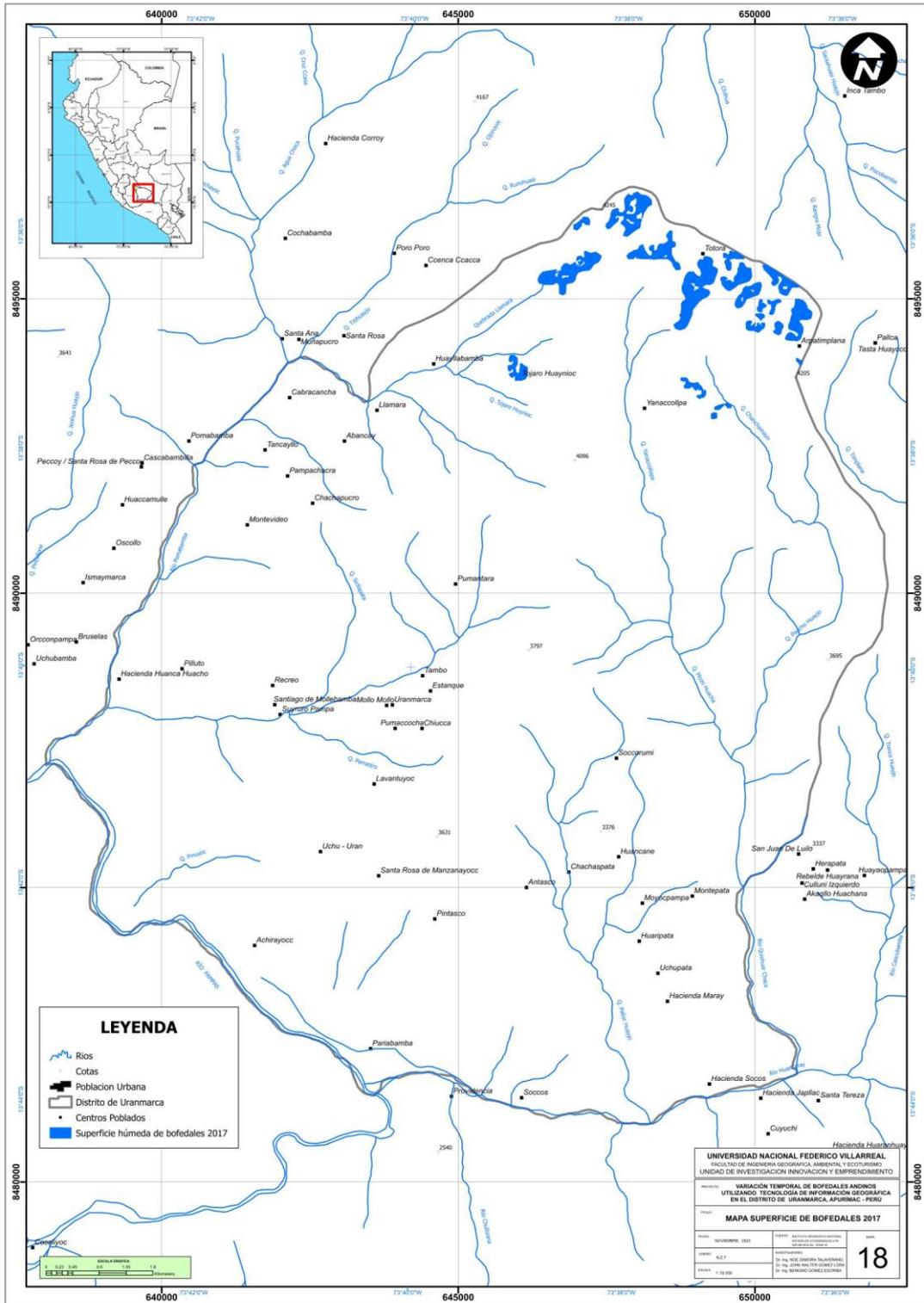


Figure 4. Bofedales 2020 surface map

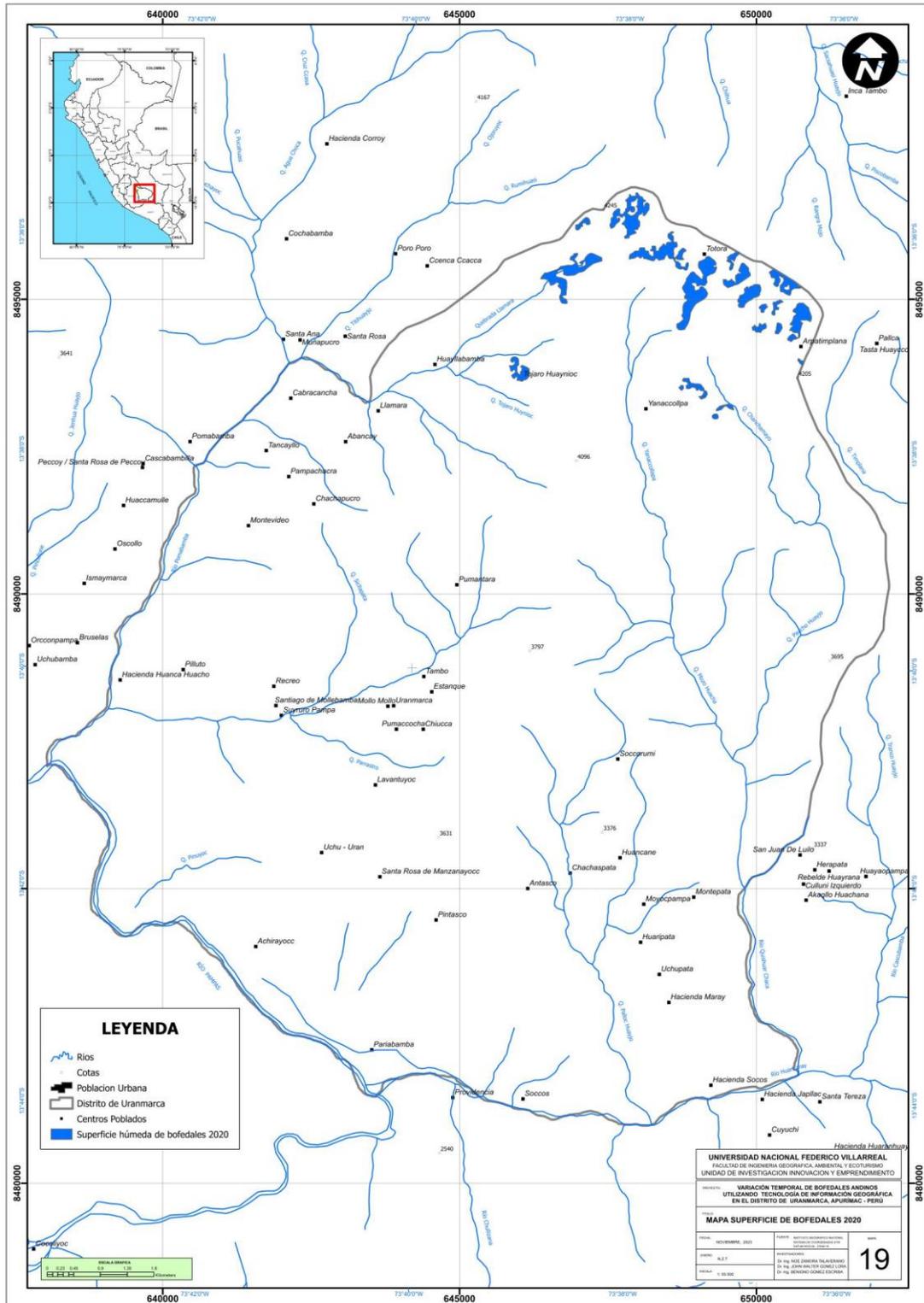
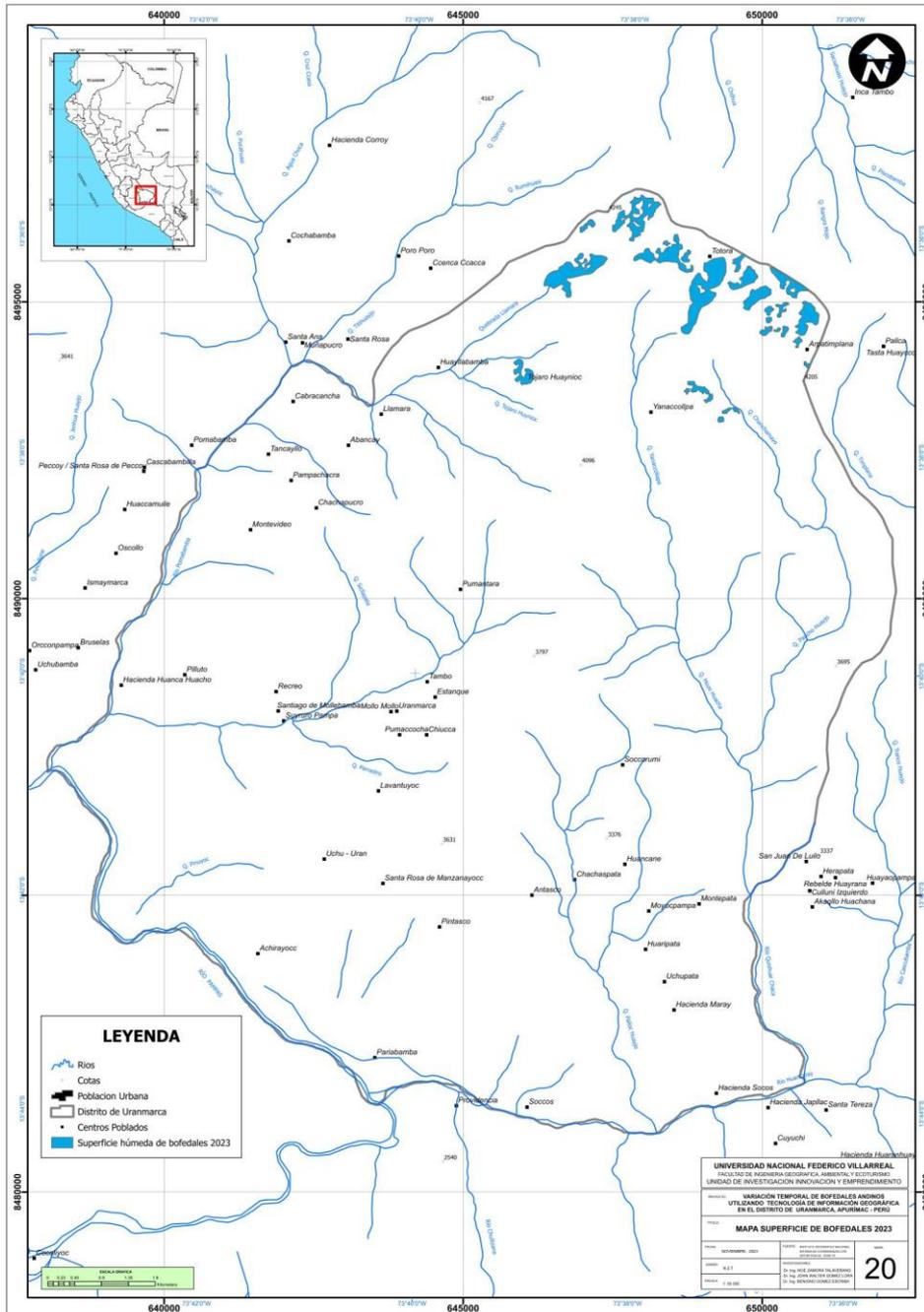


Figure 5. Bofedales 2023 surface map



4. DISCUSSION OF RESULTS

In the present investigation, the area of high Andean wetland of the Urubamba District was calculated from 2013 to 2023, with an analysis of 3-year time scenarios. On the way Adauto & Willems (2016) I use as main input landsat images of the TM and OLI sensors with which I determine the vegetation and humidity indexes.

(Guerrero et al., 2022), in the province of Loja determines 279 wetlands, in the present investigation in 2013 was determined 24 wetlands which have varied in terms of surface and number.

(Gutierrez, 2018) in his research in the Coata river basin he used the Normalized Difference Vegetation Index (NDVI) as a methodology, associated with meteorological variables such as annual cumulative precipitation and annual maximum temperature; he also used Landsat 5 and Landsat 8 satellite images. The research used Landsat 8 and Landsat 9 satellite images for the dry season. A mathematical model was designed, whose inputs were: digital model of the terrain, slope, topographic position index and humidity index. The result was adjusted with the Normalized Difference Vegetation Index to determine woodland moisture surface for the years 2013, 2017, 2020 and 2023.

Monge-Salazar et al., (2022) He also mentions that wetlands provide ecosystem services, carbon storage, forage provision and water regulation. In this research, the analyzed high Andean wetlands supply water resources to the Qda Microbasin. Pallac Huayjo, Subcuenca Ada. Pomabamba and Rio Quishuar Chaca Microwatershed. Uranmarca District. Which is used in population consumption, irrigation of agricultural crops and fruit mainly.

Pauca-Tanco et al. (2020) the wetland area of the Chalhuanca Annex for the period 1986-2016 has been increased by 12 ha/year. The wetland area of Uranmarca district has suffered a decrease of 55255.49 m², for a 10-year period between 2013-2023.

5. CONCLUSION

Landsat 8 and 9 satellite images were collected from the dry season in 2013, 2017, 2020 and 2023. Digital terrain models of the Uranmarca district were also collected, as well as topographic digital cartographic information.

The Standardized Water Differential Index (NDII), Standardized Vegetation Differential Index (NDVI) was used to determine wetland areas of the Uranmarca district.

The area of the bofedales of the district of Uranmarca was determined, being for the year 2013 of 1570248.16 m², 2017 of 1783753.43 m², 2020 of 1478876.2 m² and for the year 2023 of 1728497.94 m²

RECOMMENDATIONS

Install hydrometric sights in the wetlands of the Uranmarca district to determine the variation in the level of water resources.

Carry out topographic survey of the wetlands of the District of Uranmarca.

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CHAPTER 13

ESTIMATION OF GREENHOUSE GAS EMISSIONS AND PROPOSAL TO MITIGATE ENVIRONMENTAL IMPACTS GENERATED BY AN ELECTRICITY GENERATION ENTERPRISE: NATURAL GAS POWER PLANT

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RESUMO: O objetivo geral deste trabalho foi estimar as emissões de gases de efeito estufa (GEE) e propor estratégias de redução dos impactos ambientais para um empreendimento de geração de energia elétrica, a partir do uso de gás natural. A metodologia utilizada foi a GHG Protocol, personalizada para indústria de energia. Com o objetivo de analisar o comportamento da ferramenta, foram aplicados dados reais, referentes aos anos de 2016 e 2017, de uma Usina Termelétrica a gás natural situada no Rio Grande do Norte. Utilizou-se o método de neutralização de carbono como alternativa de mitigação dos impactos ambientais dos GEE, por meio da conversão destes em biomassa pela reação de fotossíntese. O bioma em estudo foi o da caatinga, considerando a localização da usina termelétrica. Obteve-se o resultado estimado de emissão de GEE no valor de 1.102.144,639 tCO₂e (CO₂ equivalente) e 1.138.256,986 tCO₂e, nos anos de 2016 e 2017, respectivamente. A partir do resultado de emissão dos GEE, estima-se que será necessário o plantio 188.939.079 e 195.129.754 árvores, nos anos de 2016 e 2017, respectivamente, para neutralizar os impactos ambientais da emissão de GEE. A quantidade elevada de árvores é justificada pelo tipo de bioma considerado neste estudo, uma vez que a Caatinga é formada por árvores de pequeno porte e elevado espaçamento, gerando assim a

necessidade de uma grande quantidade de mudas e aquisição de áreas extensas, para implantação da referida proposta.

PALAVRAS-CHAVE: mudanças climáticas, gases de efeito estufa, inventário de emissão, neutralização de carbono, GHG protocol.

ABSTRACT: The general objective of this work was to estimate greenhouse gas (GHG) emissions and to propose strategies to reduce environmental impacts for an electric power generation enterprise, using natural gas. The methodology used was the GHG Protocol, customized for the energy industry. In order to analyze the tool's behavior, real data were applied, referring to the years 2016 and 2017, of a natural gas thermoelectric plant located in Rio Grande do Norte. The carbon neutralization method was used as an alternative to mitigate the environmental impacts of GHGs, by converting them into biomass through photosynthesis reaction. The biome under study was the caatinga, considering the location of the thermoelectric plant. The estimated GHG emission result was obtained in the amount of 1,102,144.639 tCO₂e (CO₂ equivalent) and 1,138,256,986 tCO₂e, in the years 2016 and 2017, respectively. Based on the result of GHG emissions, it is estimated that 188,939,079 and 195,129,754 trees will be planted in 2016 and 2017, respectively, to neutralize the environmental impacts of GHG emissions. The high number of trees is justified by the type of biome considered in this study, since the Caatinga is formed by small trees and high spacing, thus generating the need for a large number of seedlings and the acquisition of extensive areas, for the implantation of the that proposal.

KEYWORDS: climate change, greenhouse gases, emission inventory, carbon neutralization.

1. INTRODUCTION

The exponential growth of the world's population prevailing mainly in the least developed countries, although it has been cooling down in the developed countries in recent decades, added to the effects of the pattern of development predominant in most countries since the post-war period, centered on the industrial production of intermediate goods, capital, durable and non-durable consumption and large-scale agrarian and urban growth, together with the socio-economic development of the modern world, has greatly accelerated the use of renewable and non-renewable natural resources, generating, among other effects, the exponential increase of the concentration of greenhouse gases (GHG) in the atmosphere (FRANCE, 2016).

According to Guimarães (2016), GHGs are compounds that accumulate in the specific layer of the atmosphere of the planet, contributing to the warming of the planet and forming what is called the greenhouse effect. This accumulation has been influencing the phenomenon of Climate Change, whose impact has been discussed with emphasis by the international scientific community.

The Intergovernmental Panel on Climate Change - IPCC, which is an organization created by the United Nations Environment Program to study phenomena related to climate change, confirms that human influence on the climate system is clear and growing, with impacts observed on all continents and oceans (RIBEIRO and SANTOS, 2016).

Several energy end-use sectors, such as transport, construction, buildings and agriculture are the main drivers of these changes, with industry contributing approximately one third of the world's carbon dioxide (CO₂) emissions related to energy (HENRIQUES JUNIOR, 2010).

In Brazil, according to the Institute of Energy and Environment - IEMA (2016:p.64), the energy sector presented the highest average annual growth rate in the period between 1990 and 2014, consequently its atmospheric emissions leapt from 189.7 million tons of carbon dioxide equivalent (CO₂e) to 479.1 million tons of CO₂ and, in the same period, surpassing the emissions of the livestock farming and consolidating itself as the most emitting sector, behind only the item Change of Land Use.

Drawing up a GHG Emissions Inventory is the first step for an organization to be able to contribute to combating climate change. This is an evaluation tool that is

made of a company, production sector, city, state or country in order to determine the sources of GHG emissions in the productive activities and the amount released into the atmosphere (MACIEL, 2016).

Based on the results of the inventory of GHG emissions, strategy, plans and targets can be established for the mitigation and management of greenhouse gas emissions, thus aiming to contribute to minimizing global warming. In addition, the development of GHG inventories also allows institutions to aim for new business opportunities in the so-called carbon market, created by the Kyoto Protocol, through the Clean Development Mechanism, involves raising resources for investments that generate emission reductions or carbon removal from the atmosphere, by issuing and purchasing Pollution Certificates or Carbon Credits, or even seeking processes that ensure energy and operational efficiency (FRANCE, 2016).

Climate change mitigation is the search for alternatives to eliminate or reduce GHG emissions in a given activity or enterprise. Action in mitigation tends to be less costly to remedy or have to adapt to the damage generated by GHGs (HENRIQUES JUNIOR, 2010).

Among the main measures to mitigate emissions and to stabilize GHG concentrations in the energy industry, are considered mainly the decrease in the use of fossil sources in the generation and use of energy, the adoption of renewable energy sources, carbon capture and storage and technological control of fugitive emissions (RIBEIRO and SANTOS, 2016). In all these measures, new technologies tend to have an important influence and should require a series of incentives to encourage their development, acquisition, implementation, diffusion and removal of barriers (FOSTER et.al., 2007).

Considering that the energy sector contributes a significant share in GHG emissions in Brazil and the world, measuring and organizing data on GHG emissions and studying this mitigation potential in the energy sector, will contribute to the search for solutions to the problem of global climate change, besides bringing other benefits, such as the reduction of air pollution, energy security, among others.

2. GHG PROTOCOL CORPORATE STANDARD

Among all the tools for carrying out existing greenhouse gas inventories, the GHG Protocol (*GHG Protocol Corporate Accounting and Reporting Standard*, GHGPCS) is the methodology most used worldwide by corporate and government entities for the purpose of understanding, quantifying and managing their emissions. Regarding enterprise inventories, the GHG Protocol sets out six key steps:

1. define the organizational limits of the inventory;
2. define the operational limits of the inventory;
3. select the calculation methodology and emission factors;
4. collect data;
5. Calculate emissions;
6. Prepare the GHG emissions report.

The methodology is compatible with ISO standards and the quantification methodologies of the Intergovernmental Panel on Climate Change (IPCC). In Brazil, its application is adapted to our needs and is an initiative of the Center for Sustainability Studies of the Getúlio Vargas Foundation (GVces), in partnership with the *World Resources Institute* (WRI), Ministry of the Environment (MMA), Brazilian Business Council for Sustainable Development (CEBDS) and the *World Business Council for Sustainable Development* (WBSCD) (BRAZILIAN PROGRAM GHG PROTOCOL, 2009).

During 2007, the WRI and GVces submitted a project to the British Government in order to develop the GHG Protocol Program in Brazil, considering the local peculiarities. The idea was based on establishing a culture of corporate inventories in the country, by means of the free transfer of the method and *know-how* for calculating the emissions.

The official launch of the Brazilian GHG Protocol Program was on May 12, 2008, in Brasilia. Two days later, a workshop was held for the 27 pioneering companies that would join the program - called founding members. These companies help to define, for example, the format of the trainings, the work plan and adaptations of tools to the Brazilian reality. In August of the same year, the founding members presented an initial scope of the Greenhouse Effect Inventory and received guidance on how to supplement the report in order to adapt it to the GHG Corporate Standard. In 2009, in

the first semester, there was the engagement of new companies, with the objective of presenting the first Brazilian inventories.

In 2010, the first disclosure of the 35 new corporate GHG inventories took place and the first Public Emissions Register in Brazil was launched at the Annual Event of the Brazilian GHG Protocol Program. In the year 2011, the number of inventories published and recognized at the Program Annual Event increased to 77. Also in this event, the public area of the Public Greenhouse Gas Emissions Registry and the publication of Verification Specifications (GHG PROTOCOL BRAZIL, 2014) was launched.

Inventory generation can be described in 6 steps:

2.1 STEP 1: SET ORGANIZATIONAL LIMITS

Establishing organizational limits implies choosing an approach for the mapping and consolidation of issues, which will allow the company to record and communicate its issues. Corporate ownership and control of the company should be considered, as detailed below:

Corporate participation approach: In this case, the emissions of a company are recorded according to its corporate participation in the operation, i.e. it reflects the percentage of the company's participation in the operation and therefore its share in the emissions division. In cases where this is not defined, its economic participation in the operation should be considered.

Operational control approach: It is one in which the company responds to 100% of the GHG emissions of the operations that it controls, but does not account for the emissions of operations that has no control, in spite of having some participation. It should be noted that operational control is verified when the company or one of its subsidiaries has full authority to introduce, implement or change its policies in the operation, that is, the company will account for 100% of the issues of these operations over which it has direct or indirect control.

According to the Brazilian GHG Protocol Program, participating companies must choose one of the two options below and apply it to all levels of their organizations:

- Prepare the report with GHG emissions information in two formats - one based on operational control and the other on corporate participation or;

- Report GHG emissions information based on operational control only and include a list of entities and operations in which there is a corporate stake without operational control. That list shall include the percentage of the company it holds with each listed entity.

2.2 STEP 2: SET THE OPERATIONAL LIMITS

It is determined by identifying the GHG emissions associated with the company's operations. They are classified as direct or indirect. Direct emissions are those from sources owned or controlled by the company. And indirect emissions are those that are the result of the company, however caused by sources that are owned or controlled by another non-subsidiary company.

To improve these definitions and better reflect inventory guidelines, defined **3 scopes** for GHG recording and reporting:

Scope 1: Direct GHG emissions

They are direct GHG emissions from sources owned or controlled by the company. The activities typically associated with emissions from this scope are:

- Generation of electricity, heat or steam from stationary sources such as boilers, furnaces and turbines;
- the processing or manufacture of chemicals and materials and the processing of such production waste;
- Transportation of materials, products, waste and collaborators, in vehicles of the organization, representing emissions from mobile sources;
- leakage of GHG emissions, whether intentional or unintentional, from own sources, such as GHG discharges in connection of equipment, lids, packaging and in tanks;

Importantly, CO₂ emissions from biomass combustion should not be included in Scope 1 but reported in the inventory. In addition, emissions that are not included in the Kyoto Protocol as CFCs and HCFCs will not be included in Scope 1 but may be reported separately.

Scope 2: Indirect GHG emissions from electricity

Accounts for emissions from the generation of electricity purchased (that which is purchased or brought into the physical region of the organization) or consumed by

the company. Therefore, in this scope are accounted the emissions that occur in the place where it is generated. For many companies, Scope 2 covers most emissions as well as the greatest opportunity to reduce them.

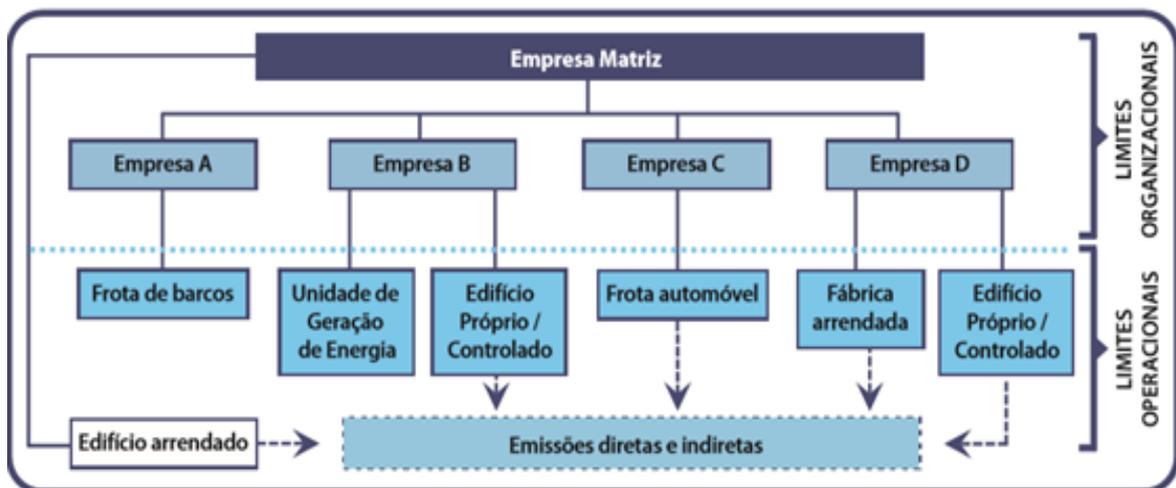
Scope 3: Other indirect GHG emissions

It addresses all other indirect emissions, that is, those arising from the activities of the enterprise that are produced in sources that are not owned or controlled by the enterprise or its subsidiaries. Activities commonly reported in Scope 3 (as long as not reported as direct issues) are:

- Extraction and production of purchased materials and fuels;
- Activities related to the transport of materials in vehicles other than the organization or purchased goods, purchased fuels, products sold, waste, business trips of employees, detachment of employees on the way to and from work;
- Activities related to electric energy consumption that are not included in Scope 2 (extraction, production and transport of fuels, for consumption in electricity production, purchase of electricity for resale, production of electricity consumed in a system);
- leased goods, franchises and outsourced activities;
- Use of Goods and Services Sold;
- Treatment of operational waste or products sold at the end of life.

Figure 1 shows the organizational and operational boundaries of a company.

Figure 1 - Organizational and Operational Limits of a Company



Source: Authors

Due to the difficulty of assertively defining standards for determining emission sources as belonging to Scope 3, some generic steps can be highlighted to facilitate this classification, such as:

- Describe the value chain - recording emissions along the entire chain can reveal opportunities for efficiency gains and cost savings. In addition, indirect emission reductions represent easier and less costly reductions compared to Scope 1;
- Determine which Scope 3 categories are relevant. Some criteria are: high percentage share of emissions from a given source in the company's Scope 3, emissions that can harm and expose the company's image, critical emissions considered by shareholders, financiers and *stakeholders*, emissions that have reduction potential;
- Identify partners along the value chain;
- Quantify Scope 3 emissions;
- Select the calculation methodology and emission factors.
- Collect data, where each company must survey its emission data according to its specifications and the GHG source. This step must respect the principle of scoping presented in the body of this work;
- Scope 1 emissions will be calculated in most cases on the basis of the quantity of commercial fuels purchased using published emission factors;
- Scope 2 emissions shall be assessed primarily by metrics obtained from electricity consumption and specific to the supplier, local network or other published emission factors;
- Scope 3 emissions shall be calculated from activity data, such as fuel utilization, flight miles, in addition to third-party published emission factors, prioritizing source or site-specific emission factors;
- Calculate emissions;
- Prepare the GHG emissions report. In this part it is important to plan ahead and develop the report from standardized communication sources and a consistent and pre-approved information base. Calculations can be centralized, where all sectors report their data to another sphere of the company or decentralized, where each sector performs the calculation directly and according to the regulated methods and report a sector inventory.

The Brazilian GHG Protocol Program offers some guidelines for preparing the report:

- a brief description of the emission sources and emission data for the six GHGs separately;
- a list and explanation of exclusions or inclusions;
- Definition of the base year and profile of emissions over time;
- the period assessed and the methodologies used for the calculation;
- Any trends shall be reported;
- progress towards previously set targets;
- Discussion of uncertainties in the reported data or in consumption and activities with recommendations on how such data can be improved;
- Description of events and changes that have impacted the published data.

For companies that register centrally, please also consider the following:

- Activity data on passenger freight transport;
- data from processing emission activities;
- Clear recording of all data to obtain the activity/fuel data;
- Local emission factors needed to transform fuel use or consumption into GHG emissions.

For companies that do decentralized registration, there are some additional guidelines to the guidelines:

- a description of the calculation methodology and any changes made to pre-existing methodologies relating to previous reporting periods;
- calculation ratio indicators;
- Details of any references to data used for calculations;
- Clear records of calculations made to obtain emission data should be kept for any future internal or external verification.

Reporting GHG reductions: Emission reductions can be quantified in the following categories:

- Corporate GHG reductions in the context of individual installations of a company or a group;
- Reduction of indirect emissions;
- Reductions based on credit offsets and projections;

- Project-based reductions.

It is important to stress that effective GHG management requires setting an emissions target, even if it is informative or voluntary. As companies create strategies that mitigate GHG emissions from their products and operations, GHG targets for the entire corporate structure become key elements of this joint effort, even when part of the company is subject to mandatory GHG limits.

Common guidelines for the establishment of an emissions target include:

- minimize and manage emission-related risks;
- Achieve cost reductions and stimulate innovation;
- Preparing the institution for future, more stringent regulations;
- Demonstrate leadership and responsibility for the environment;
- Participate in voluntary mitigation programs.

Base year selection: You must choose the base year of the inventory to be generated by specifying the reasons for choosing that particular year. The base year may be the current year or any other year for which emission data is available that can be verified according to the specifications of the Brazilian GHG Protocol Program.

Recalculation of base year emissions: Your base year emissions must be recalculated in cases of:

- Structural changes in the reporting organization that have a significant impact on base year emissions. A structural change involves the transfer of ownership or control of emission-generating activities or operations from one company to another. Structural changes include: mergers, acquisitions or divestments; outsourcing and incorporation of issuing activities and change of issuing activity within or outside the geographic limits of the program (Brazil);
- changes in the calculation methodology or an improvement in the accuracy of emission factors or activity data that result in a representative impact on base year emissions;
- Findings of material errors or accumulated errors that compromise the veracity of the published inventory;
- Demonstrate leadership and responsibility for the environment;
- Participate in voluntary mitigation programs.

Your base year emissions adjustments are made in the following situations:

- Acquisitions, incorporations, divestments or outsourcing of a fraction of the business that did not exist in the base year;
- Structural changes due to outsourcing when the entity;
- Findings of material errors and/or accumulated errors that compromise the veracity of the published inventory;
- structural changes due to incorporation, when the entity included indirect emissions associated with incorporation activities;
- Organic growth or decline, when it refers to increasing or decreasing production, product changes, and closing or opening of operating units controlled by the entity.

3. MATERIAL AND METHOD

This research characterized itself as a study of an applied nature, taking an exploratory and quantitative approach, as well as applying bibliographic and case study procedures.

The Greenhouse Gas Protocol - GHG Protocol tool was used in the preparation of the GHG inventory.

The present work was structured in the following stages:

- Customize the GHG Protocol tool for a power undertaking;
- Apply the tool by means of a case study of the Natural Gas Thermoelectric Plant located in Rio Grande do Norte;
- Draw up a proposal to mitigate the emissions of pollutants from this undertaking.

3.1 GHG PROTOCOL TOOL

The *GHG Protocol*, among the different existing methodologies for undertaking corporate GHG inventory, is the most widely used tool worldwide by companies and governments to understand, quantify and manage their emissions.

The *GHG Protocol* methodology is compatible with *International Organization for Standardization* (ISO) standards and IPCC quantification methodologies.

In this study, the *GHG Protocol* tool was used developed by the Getulio Vargas Foundation (FGV) and *World Resources Institute* (WRI), in its version 2018.1.4.

The *GHG Protocol* methodology (2008) sets out six steps for the development of corporate inventories: the definition of the organizational and operational limits of the inventory; the selection of the calculation methodology and emission factors; the collection of data from activities that emit GHG; the calculation of emissions; and the elaboration of the inventory of GHG emissions.

3.1.1 Organizational Limits

The companies' operations vary in their legal and organizational structures and include: wholly owned operations, *incorporated* and unincorporated *joint ventures*, subsidiaries and others. For GHG accounting purposes, the organizational boundaries, which depend on the structure of the company and the relationship with all parties involved.

When setting organizational limits, the company chooses an approach for consolidating GHG emissions and then applies this approach to record and report its GHG emissions.

The Brazilian Program of the *GHG Protocol* (2008) uses two approaches to consolidate organizational boundaries: operational control and corporate participation.

In this study, the inventory approach was used by means of operational control, considering that the Natural Gas Thermoelectric Plant is controlled by a single company. Thus, the organization will account for 100% of the GHG emissions of this undertaking under study.

3.1.1.1 Thermoelectric Plant

The UTE is a cogeneration thermoelectric power plant, with capacity to produce 340 MW of electricity and 600 t/h of water vapor, located in the rural area of the municipality of Alto do Rodrigues, in the central region of the state of Rio Grande do Norte. In this Study, we will consider the annual dispatch of 50% of generation capacity.

The UTE consists of two sets of natural gas turbines and heat recovery boilers. The turbines produce electricity using natural gas as fuel. The exhaust gases heat the water in the recovery boiler, producing steam, which is carried by a 28 km steam pipeline and injected into oil wells in the Alto do Rodrigues region.

For the supply of water for steam production, UTE has a water abstraction that uses water from the River Piranhas-Açu and an ETA that produces three types of water: filtered, drinkable and demineralized, the latter is used for the steam production process. The ETE receives the plant's liquid effluents and treats them for disposal in the Piranhas-Açu river in accordance with the specifications contained in Brazilian environmental legislation.

The 230 kV substation receives the energy produced by the turbogenerators and transmits it via a 30 km transmission line to the CHESF substation located in Açu city, where it is connected to the National Interconnected System.

3.1.2 Operational Limits

Operational limits involve identifying the emissions associated with their operations, classifying them as direct and indirect emissions and selecting the scope for accounting and inventory taking.

Direct emissions cover the consumption of fossil fuels within the enterprise by means of its own equipment and vehicles and indirect emissions are related to emissions resulting from the activities of the organization it is inventorying, but occurring in sources that belong to or are controlled by another organization.

Thus, to facilitate the understanding of direct and indirect sources, three scopes were defined for GHG recording and inventory, as presented in Table 01:

Table 1 - Characterization of scopes 01, 02 and 03 for Thermolectric Plant.

SCOPE TYPE	SOURCES	SOURCE DESCRIPTION
SCOPE 01 Direct Emissions	Fossil fuel burning	Emissions from fuel consumption in own equipment or leased by the undertaking to operate under its management
		Transport emissions with own or controlled vehicles.
	Fugitive emissions	Emissions from gas line depressurization activities, extinguisher recharge and refrigeration equipment maintenance.
SCOPE 02 Indirect emissions	Power purchased for unit operation	Acquisition of electrical energy for equipment operation
SCOPE 03 Other Indirect emissions	Destination of waste	Emissions from the transport, treatment or disposal of waste by third parties.

Source: Authors

3.1.3 Inventory Temporal Definition

Companies can undergo significant structural changes such as acquisitions, separations and mergers, which can alter the company's emission profile, making comparisons difficult over time. Thus, the temporal definition of the inventory is necessary for a better understanding of the organization's emission profile.

According to the verification specifications of the Brazilian *GHG Protocol* Program (2017), a GHG inventory should cover the entire calendar year period, that is, the accounting and quantification of emissions should cover the activities developed by the organization between January 1 and December 31.

The Rio Grande do Norte Natural Gas Thermal Power Plant has never conducted an inventory of GHG emissions. Thus, we sought to measure the air emissions of the last two years - 2016 and 2017, in order to have a comparative basis of recent data. It should be noted that the selected period was marked by water restriction due to the low rainfall recorded in the last five years in the Northeast region of Brazil.

3.1.4 Emission Factors

Activities with a potential polluter have an emission factor, which expresses how intensive the activity is in terms of GHG emissions, representing the volume of GHG emitted by a certain activity unit (FRANCE, 2016).

The emission factors used in the tool were based on the activities assessed in the process of generating electricity from the natural gas plant. The specific emission factors and their respective literature sources are provided by the *GHG Protocol* worksheet, which are compatible with the IPCC quantification methodology.

3.1.5 Calculation methodology

GHG emissions shall be calculated taking into account the emission factor of the activity under study, the intensity of which depends on the emitting source, as set out in the *GHG Protocol* tool. After the emission factors are surveyed, the information on raw material and services is sought. The calculations by type of issue are

established by different formulae. The inventory of emissions is the sum of all individual contributions of the gases emitted in each activity.

It should be noted that to allow for the comparison of the emissions of different sectors with different gases, the volumes of each gas and its potential contribution to global warming are converted into a common unit, the carbon equivalent: CO₂e, considering that each greenhouse gas has a different potential to contribute to global warming.

3.1.5.1 Sum of Emissions

The sum of the emissions was performed individually in relation to the type of scope. The calculation shall be carried out in accordance with equation 1.

$$Emiss\tilde{a}oTotal(tCO_2e) = Escopo01 + Escopo02 + Escopo03 \quad (1)$$

Where:

Scope 01 - Scope 01 emission sources (tCO₂e);

Scope 02 - Scope 02 emission sources (tCO₂e);

Scope 03 - Scope 03 emission sources (tCO₂e).

3.1.5.2 Reducing the effects of carbon neutralization GHG emissions

The neutralization or reduction of GHG emissions is the removal of CO₂ from the atmosphere and its conversion into biomass by photosynthesis reaction (OLIVEIRA et al, 2013). This reaction allows biomass to accumulate by absorbing CO₂ and releasing oxygen (O₂) into the atmosphere, fixing carbon in trees. Also, according to the same authors the number of trees to be planted to neutralize the CO₂ emitted in the period of one year can be calculated by equation 2.

$$N = [(Et \div Ff) \times 1,2] \quad (2)$$

Where:

N - number of trees to be planted;

Et - total quantity of GHG emitted by the UTE, in t CO₂e;

Ff - carbon fixation factor in biomass at the site of planting, in tCO₂/n^o of planted trees, considering a process of natural regeneration of forests and the traditional planting of native species for the recovery of degraded areas, in the Caatinga biome, totaling about 1,644 trees per hectare. Thus, the fixation factor adopted in this study was 0,007 tCO₂/ no of trees (SANTOS et.al, 2016);

1,2 = Compensation factor for possible seedling losses;

4. OUTCOME AND DISCUSSION

The GHG emission results of the thermoelectric plant under study obtained from the *Greenhouse Gas Protocol - GHG Protocol* tool for the years 2016 and 2017 will be described below. The GHG emissions calculated in this work are expressed in tons of carbon dioxide equivalent (tCO₂e).

4.1 TOTAL GHG EMISSIONS

From the GHG emission results obtained for each scope, one can calculate the overall GHG emission result generated by the natural gas-fired power plant in question. This overall result is the sum of the emissions of the three types of scopes considered in this study, addressing the total emissions in tons of carbon dioxide equivalent (tCO₂e). Table 2 illustrates the total estimated GHG emissions result in this study from the *GHG Protocol* tool, considering the 2016 and 2017 periods.

Table 2 - Total GHG emissions (tCO₂e) generated by the natural gas-fired power plant in 2016 and 2017.

Source	Total GHG emissions (tCO ₂ e)	
	2016	2017
Natural Gas Thermoelectric Plant	1 102 144 639	1 138 256 986

Source: Author (2018).

The figures obtained in the GHG emission inventories for the years 2016 and 2017 are consistent with the interruption of the downward behavior of GHG emissions generated by the economic crisis observed in 2015 and 2016 (year when emissions

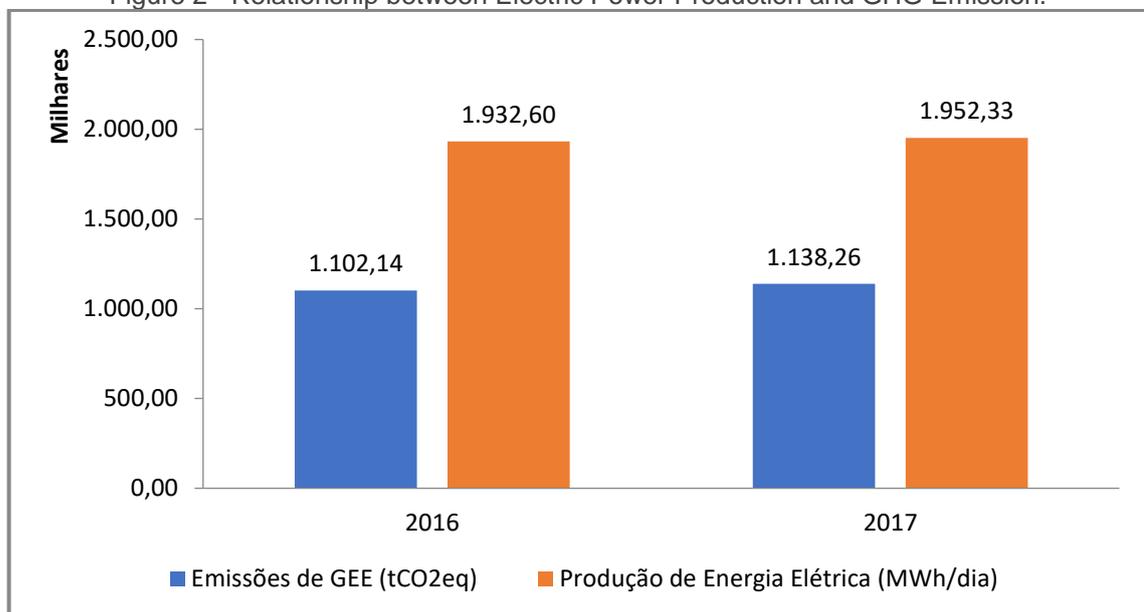
fell by 7%), as presented in the Brazilian GHG Emissions Summary Document (TASSO REZENDE DE AZEVEDO, 2018), with a growing trend observed comparing the results of the years 2016 and 2017.

Still according to data from Tasso Rezende de Azevedo (2018), despite Brazil's GHG emissions drop by approximately 2.3%, in 2017, the energy sector, more specifically the electric power generation sector, had a 7% increase in GHG emissions, due to a further fall in power generation in hydroelectric power stations, with consequent increase in fossil fuel thermoelectric generation.

There was an electricity production corresponding to 1,932,602,424 MWh/day and 1,952,333,610 MWh/day, in 2016 and 2017, respectively, as shown in Figure 2.

Relating GHG emissions to electrical energy production, it is observed that there was the emission of g CO₂e/kWh corresponding to 570.3g CO₂e/kWh and 589.0g CO₂e/kWh, which is below the world average of open cycle natural gas plants equivalent to 717 gCO₂e/kWh, but within the global range ranging from 487 to 962g CO₂e/kWh (BAUER et.al, 2018).

Figure 2 - Relationship between Electric Power Production and GHG Emission.



Source: Author (2018).

According to Bauer et. al. (2018), the average GHG emission per electric power generation is above the range for natural gas plants per combined cycle ranging from 400 to 460 g CO₂e/kWh, which is explained by the fact that plants per combined cycle

have a higher efficiency rate in energy use, around 49 to 53%, which shows that plant cycle closure can be an alternative to reducing GHG emissions.

From the Graph, it can also be observed that as the production of electrical energy grows, the generation of GHG emissions increases, due to the greater consumption of natural gas, for the operation of the thermoelectric power plant.

4.2 NEUTRALIZATION OF TOTAL GHG EMISSIONS

Considering equation 2 and the values obtained in the GHG emission inventories for the years 2016 and 2017, we estimate the quantitative of trees of the Caatinga biome, where the natural gas thermoelectric plant in question is located, as shown in Table 3 below:

Table 3 - Total trees required to neutralize GHG emissions.

Year	Total GHG emissions (tCO ₂ e)	Number of trees
2016	1 102 144 639	188 939 079
2017	1 138 256 986	195 129 754

Source: Author (2018).

The high number of trees needed to neutralize the GHG emissions generated by the natural gas thermal power plant in question in the years 2016 and 2017 is observed. This result is justified by the type of biome considered in this study, since the Caatinga is formed by trees of small size and high spacing.

If the thermoelectric power plant in question were located in the Atlantic Rainforest biome, we would have the result of 8,588,139 and 8,869,534 trees for the GHG emission results of the years 2016 and 2017, respectively, considering the carbon fixation factor in biomass at the planting site of 0.154 tCO₂/ # of trees (OLIVEIRA, 2013).

The difference represents a 95% reduction in the number of trees. According to Santos et. AL (2016), studies of carbon storage in Caatinga trees are reduced to the present, however, in comparison to studies in other Brazilian biomes, it can be said that vegetation has low carbon storage capacity.

Faced with this result, the alternative of reducing the effects of GHG emission by neutralizing carbon becomes quite costly, considering the costs of acquiring native plants and acquiring extensive land for planting the number of trees estimated here.

5. CONCLUSION

It was found that anthropic actions are the main cause of the current global warming. This is due to the increase in the concentration of GHG coming from human activities, which implies an increase in the capacity of the atmosphere to retain heat, and consequently an increase in the temperature of the planet.

In this vision, one of the main anthropic activities that are related to the gradual increase of GHG emissions is the burning of fossil fuels, in particular in the use of energy production. The energy sector subject to this work - including fuel and electric energy production and consumption - represents, according to the Climate Observatory (SEEG, 2018) the third largest source of gross GHG emissions in Brazil.

The use of the *Greenhouse Gas Protocol* tool - *GHG Protocol*, in the case study of this work - Simple Cycle Natural Gas Thermal Power Plant located in Rio Grande do Norte, allowed to estimate GHG emissions in the order of 1,102,144,639 tCO₂e and 1,138,256,986 tCO₂e in the years 2016 and 2017, respectively.

Comparing the results obtained in the case study of this work with the results of other thermal power plants, it was found that thermoelectric power plants with a combined cycle show a lower emission of greenhouse gases, around 60%, even in cases where the installed power of the power plant is greater, making it possible to infer that the closing of the cycle of production of electrical energy is an alternative to be considered as a mitigating measure of atmospheric emissions.

Another alternative considered in this work was to neutralize GHG emissions by planting trees. Considering the result of GHG emissions in the years 2016 and 2017, there was the estimate of trees in the Caatinga biome, where the natural gas thermoelectric plant in question is located, around 188,939,079 and 195,129,754, respectively.

The high number of trees needed to neutralize the GHG emissions generated by the natural gas thermal power plant in question in the years 2016 and 2017 is

observed. This result is justified by the type of biome considered in this study, since the Caatinga is formed by trees of small size and high spacing.

Faced with this result, the alternative of reducing the effects of GHG emission by neutralizing carbon becomes quite costly, considering the costs of acquiring native plants and acquiring extensive land for planting the number of trees estimated here.

It is necessary to deepen the study on the technical and financial feasibility of closing the power generation cycle of the plant in question, in search of the abatement of GHG emissions and energy efficiency, in line with the National Energy Efficiency Plan of the Brazilian Industry.

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CHAPTER 14

NITROGEN, PHOSPHORUS AND POTASSIUM RETENTION FROM HYDROGEL RESIDUARY WATER

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ABSTRACT: Pig farming is an intense activity in the western region of Paraná, generating a significant amount of waste, which concerns both the environmental and public health. In most properties it is common to dispose of liquid and solid waste directly to the soil during the off-season, as a complement to mineral fertilization and water reuse in agriculture. Thus, the objective of this work was to evaluate the possible retention and subsequent release in the soil of Nitrogen, Phosphorus and Potassium from organic and mineral fertilization by hydrogel in columns of unchanged soil. For this, four treatments were evaluated (80 m³ ha⁻¹ of swine wastewater (ARS); 80 m³ ha⁻¹ of wastewater with 0.5% hydrochloride polymer for planting; 80 m³ ha⁻¹ of wastewater with 0.5% hydrochloride polymer from a disposable diaper and NPK

mineral fertilizer (ADM)) at five times (1, 11, 21, 41 and 81 days after treatment application) at two depths (0-10 and 10-20 cm). A completely randomized experimental design (DIC) was used, totaling 66 soil columns. When analyzing differences between NPK at depths, taking into account all treatments and Nitrogen, phosphorus and potassium concentrations differ significantly, appearing in larger amounts in the surface layer. In the analysis of the different treatments applied in the superficial layer, it was possible to see that the nitrogen in the ARS presented in higher concentrations than in the ROM and in the control, and it could be observed that the treatments that used ARS presented significant difference in relation to the control. For Phosphorus, the significant difference in concentrations stood out only in the application of ARS, therefore, did not show significant difference in concentrations in other treatments. Potassium, in turn, showed no significant difference between treatments. In the comparison of the second depth, it was possible to verify for Nitrogen that the ARS treatment presented in higher concentrations than in the ADM and Witness treatments. It can also be observed that all treatments presented significant difference for nitrogen in relation to the control. The treatments that used hydroretent polymers showed no significant difference with the treatment in which ADM was applied. For Phosphorus and Potassium, the difference was not significant between treatments. It can then be concluded that the hydrochloride polymers evaluated did not show significant benefit at study doses and times.

KEYWORDS: agricultural reuse, hydrochloride polymer, organic fertilization.

RESUMO: A suinocultura é uma atividade intensa na região oeste do Paraná, gerando um volume de dejetos considerado significativo, o que preocupa tanto no âmbito ambiental, quanto na saúde pública. Na maioria das propriedades é comum destinar os dejetos líquidos e sólidos diretamente ao solo no período de entressafra, como forma de complemento à adubação mineral e reuso de água na agricultura. Desta forma, o objetivo deste trabalho foi avaliar a possível retenção e posterior liberação no solo de Nitrogênio, Fósforo e Potássio provenientes de adubação orgânica e mineral pelo hidrogel em colunas de solo inalterado. Para isto, foram avaliados quatro tratamentos ($80 \text{ m}^3 \text{ ha}^{-1}$ de água residuária de suinocultura (ARS); $80 \text{ m}^3 \text{ ha}^{-1}$ de água residuária com 0,5% de polímero hidrotentor para plantio; $80 \text{ m}^3 \text{ ha}^{-1}$ de água residuária com 0,5% de polímero hidrotentor proveniente de fralda descartável; e adubação mineral NPK (ADM)), em cinco tempos (1, 11, 21, 41 e 81 dias após a aplicação dos tratamentos), em duas profundidades (0-10 e 10-20 cm). Utilizou-se delineamento experimental inteiramente casualizado (DIC), totalizando 66 colunas de solo. Ao serem analisadas as diferenças entre NPK nas profundidades, levando-se em consideração todos os tratamentos e tempos, constatou-se que as concentrações de Nitrogênio, Fósforo e Potássio se diferem significativamente, aparecendo em maiores quantidades na camada superficial. Na análise dos diferentes tratamentos aplicados na camada superficial, foi possível visualizar que o Nitrogênio na ARS se apresentou em maiores concentrações que na ADM e na Testemunha, podendo ainda ser observado que os tratamentos que utilizaram ARS apresentaram diferença significativa em relação à testemunha. Para o Fósforo, a diferença significativa nas concentrações destacou-se somente na aplicação de ARS, conseqüentemente, não apresentou diferença significativa de concentrações nos outros tratamentos. O Potássio, por sua vez, não apresentou nenhuma diferença significativa entre tratamentos. Na comparação da segunda profundidade, foi possível verificar para

Nitrogênio que o tratamento com ARS apresentou-se em maiores concentrações que nos tratamentos com ADM e Testemunha. Pode-se ainda observar que todos os tratamentos apresentaram diferença significativa para Nitrogênio em relação à testemunha. Os tratamentos que utilizaram polímeros hidroretentores não apresentaram diferença significativa com o tratamento no qual foi aplicada ADM. Tanto para o Fósforo, quanto para o Potássio, a diferença não foi significativa entre tratamentos. Pode concluir-se então que os polímeros hidroretentores avaliados não apresentaram benefício significativo nas doses e tempos do estudo.

PALAVRAS-CHAVE: reúso agrícola, polímero hidroretentor, adubação orgânica.

1. INTRODUCTION

The pig industry is a widespread activity throughout the Brazilian territory, being the third largest producer and the fourth largest exporter of pork. Most of the production is concentrated in the south of the country, totaling 61.4%, with the state of Paraná responsible for 17% of the national production (ABIPECS, 2012). This concentration is due to the strong integration policy promoted by various local agro-industries.

Concentrated and on a large scale, pig farming produces a large quantity of pig waste water (ARS). It is often released to the soil as a source of organic fertilization and to help meet the water demand of crops, a routine practice that is often the only source of nutrients available to the crop, thus alleviating production costs and raising the profit of rural properties (MAGGI *et al.*, 2011). However, this organic fertilization with ARS is being carried out without considering agronomic or environmental criteria, being used only as a supplementary fertilizer to the mineral fertilizer. Even the ARS considered as a source of nutrients, it is considered an unbalanced source of fertilizer.

In the south of Brazil, pig farming is an agricultural activity developed, most often in small farms, where there is intense cultivation of the soil due to good climatic conditions. These characteristics also make possible applications of ARS, usually made with mechanized assembly (tractor + liquid manure distributor), to the soil in short periods of the year, thus providing recurrent applications and in high doses, which favors the accumulation of nutrients in the soil and, consequently, transfer to the aquatic environment, potentiating diffuse pollution of surface waters and, reflecting the degradation of water quality and life of the population (DIETER, 2014).

At high rates over the same areas, the ARS provide an accumulation of elements present in the soil, such as phosphorus (CAOVILLA *et al.*, 2010), nitrogen (SAMPAIO *et al.*, 2010a), heavy metals (SMANHOTTO *et al.*, 2010) favoring their transfer to the aquatic environment, via surface runoff (CERETTA *et al.*, 2010) or percolation (MAGGI *et al.*, 2011; SAMPAIO

The accumulation of these elements in the first layers of the soil is enhanced when the soil is managed in a no-till system, because there is no soil movement. In this way, fertilized agricultural soils have a great potential for transferring nutrients to the aquatic environment by surface runoff. However, this transfer is related to several factors such as source of fertilization (BERTOL *et al.*, 2010; SAMPAIO *et al.*, 2010a)

precipitation intensity (BERTOL *et al.*, 2010) and time between ARS application and first precipitation occurred (SHIGAKI, 2007; SHIGAKI, *et al.* 2006). The short period between the application of ARS and rainfall causes an increase in nutrient losses (ALLEN E MALLARINO, 2008), probably due to increased runoff (BERTOL *et al.*, 2007) as a consequence of surface sealing caused by ARS.

In the storage of pig waste in manure trees, the essentially anaerobic environment is predominant, which is why the accumulation of N in the form of ammonium occurs, since the oxidation of this form of N until nitrate depends on the presence of O₂ (SCHMIDT, 1982). Considering that 40 to 70% of the total N of pig waste is in ammoniacal form, the speed with which the ammoniacal N of the waste is nitrified, after its application in the field, will condition the amount of NO₃⁻ in the soil. If the rate of nitrification is high, the levels of N in the form of nitrate will increase rapidly, often at a time when the demand for N by the crops is still small. Depending on the intensity and amount of rainfall in this period, significant N losses may occur via NO₃ leaching (AITA *et al.*, 2007).

According to Maggi *et al.* (2011) the mobility of phosphorus in soil is very small, hence percolation losses in agricultural soils are considered negligible, and as a result low concentrations of the element in percolate are observed. Ceretta *et al.* (2003) also found that the phosphorus content available in the soil increased considerably with the application of ARS over time. However, Smanhotto (2008) states that the phosphorus contained in the manure diffuses more slowly in the soil than that contained in commercial fertilizers, observing that the vertical movement of organic phosphorus is lower than that of mineral phosphorus. However, Hesketh and Brookes (2000) point out that in quantities that exceed the demand of the crop, successive applications of manure can cause the movement of phosphorus in the soil profile, caused by the decrease in the capacity of soil adsorption, besides the possibility of movement in the phosphorus profile in organic form.

Ceretta *et al.* (2003) reported that potassium is present in ARS in mineral, soluble form and, due to this, its residual effect is short. They also state that plants with a high absorption rate of this element decrease their potential losses in the system. However, it is a mobile element in the soil and is subject to leaching, which is greater the more expressive the presence in anion solution, with lower adsorption capacity

(MAGGI *et al.*, 2011). According to Bertol *et al.* (2010) potassium has low reactivity with soil and greater mobility may occur.

Hydrogel is a petroleum-derived product, being synthetic and presenting physicochemical properties capable of water retention (AZEVEDO *et al.*, 2002). These synthetic polymers, initially developed in the 1960s, are recommended as soil conditioners in agricultural use, as they improve both the physical and chemical properties of soils, reduce the number of irrigations and nutrient losses, resulting in lower costs in crop development (SAAD *et al.*, 2009).

Talheimer *et al.* (2010) further state that this product has been used to reduce leaching and percolation losses. Mendonça *et al.* (2013) add that, in agriculture, this product has been used more frequently, in forestry, fruit growing and as a constituent of substrates for seedling production. In addition, the use of hydrogel in nurseries as a substitute for supplementary irrigation has already yielded results in the production of seedlings with the same quality as irrigated seedlings (Marques *et al.*, 2013).

The present study aims to evaluate the possible retention and subsequent release in the soil of nitrogen, phosphorus and potassium from organic and mineral fertilization by the hydroretainer polymer.

2. METHODOLOGY

2.1 LOCATION AND CHARACTERIZATION OF THE EXPERIMENTAL AREA

The experiment was conducted in a laboratory from September to November 2015, at the Federal University of Paraná - Sector Palotina, with soil coming from an area under no-till system, located in the municipality of Nova Santa Rosa, whose geographical location is at 24°27'23.21" latitude South and 53°53'07.51" longitude West, and altitude of 348 meters. With an average annual precipitation of 1642 mm, the climate is of the humid subtropical type (Cfa), presenting average temperature of 22°C and UR of air on average of 76% (IAPAR, 2012). The soil is classified as Eutroferric Red Latosol (Embrapa, 2012).

The area has been used for agriculture since 1956, with mechanization beginning in 1969 still under conventional planting system, having started the no-till system in mid-1985, with last soil revolution, dated by the owner around 1995. The

history of recent years is of succession soybean crop and corn crop, with some wheat crops in the intervals of time, but this was not carried out every year.

2.2 EXPERIMENTAL DESIGN

Four treatments were evaluated: T1: application of 80 m³ ha⁻¹ of wastewater from a pig's maternity hospital; T2: application of 80 m³ ha⁻¹ of wastewater together with 0.5% hydroretainer polymer for planting, from Hortaviva Seeds; T3: application of 80 m³ ha⁻¹ of wastewater with 0.5% hydroretainer polymer from disposable diaper; T4: application of mineral fertilizer NPK, as recommended by Embrapa, 11 92 kg ha

Levels of nitrogen (ammonium and nitrate), phosphorus and potassium in the soil were evaluated at five moments. At each moment, three repetitions of each treatment were evaluated, with three witnesses at the beginning and at the end of the experiment, totaling 66 experimental units (soil columns) chosen randomly for the study.

2.3 INSTALLATION OF THE UNDEFORMED SOIL COLUMN EXPERIMENT

2.3.1 Collection of unformed soil columns

The columns, 20 centimeters high and 10 centimeters in diameter, were collected in soil managed under the direct sowing system. The collection of these soil columns was carried out through PVC pipes, with 30 cm of height and internal diameter of 10 cm. For this, the soil was subjected to a pre-watering, with the subsequent introduction of the pipes in the vertical direction, being necessary the use of a sledgehammer, and sequent external waterings, for later, the level of eight centimeters, was used hydraulic jack under a tractor (FIGURE 1). The control of the depth was done by placing a mark 20 cm high on the tubes.

Figure 1. Use of hydraulic jack and tractor for insertion of columns to the ground.



Source: Authors

In order to facilitate the introduction of PVC pipes into the soil, some procedures were adopted: before the introduction of the pipes into the soil, the soil strip intended for the collection of the columns was saturated with water. This saturation of the soil with water was carried out with the aim of leaving it in the consistency of fluidity, thus facilitating the introduction of the tube and preserving the structure of the collected soil, since while the soil is in this consistency, the formation of cracks in the interior of the column is avoided by the effect of a possible friction with the inner wall during the descent of the latter to the interior of the soil.

The removal of the pipes from the inside of the ground was carried out manually with the help of a shovel, to avoid deformation of the soil inside the pipe. To complete the collection of the columns, the soil that was adhered to the outer wall of the PVC tube was removed, as well as the excess soil in the lower part of the tube, causing it to be in the same plane as the lower end of the tube. In order to prevent the soil column from moving downwards, a 10 cm diameter PVC CAP with carpet and crushed stones was placed at the bottom end, which was properly fitted into the tube, and pierced for subsequent leaching (FIGURE 2).

Figure 2. Fill cap with pebble (a) and carpet (b).



Source: Authors

2.3.2 Installation of the columns in the laboratory

The columns were installed in a trestle, properly constructed to allocate them in the laboratory, in order to sustain them in their original position in the soil, besides facilitating the methodological procedures, as Figure 3.

Figure 3. Easel for allocation of the soil columns.



Source: Authors

2.4 TREATMENT APPLICATIONS AND RAIN SIMULATION

The treatments were applied simulating the natural conditions in the soil. In this way, two centimeters were removed from the surface layer of the soil and the treatments applied, with the subsequent relocation of the soil.

2.4.1 Wastewater from pig farming

The use of $80 \text{ m}^3 \text{ ha}^{-1}$ of wastewater was based on the maximum amounts tested by Ceretta *et al.* (2010) Basso *et al.* (2004) and Aita *et al.* (2007).

Both in the treatment using only ARS, and in the treatments with the addition of hydrogel, this was applied at a depth of two centimeters, with subsequent covering.

The ARS used was collected directly from a settling pond of a piglet-producing unit with a retention time of approximately 120 days. The nutritional characteristics of this ARS are described in Table 1.

Table 1. Quantities of nitrogen, phosphorus and potassium in pig waste water.

	Total N mg L⁻¹	NH₄⁺ NO₃ mg kg⁻¹	NH₄⁺ mg kg⁻¹	PARAGRAPH₃ P mg dm⁻³	K	
ARS sample 1	1953	493.1	493.1	0.0	434.3	452.1
ARS sample 2	2,042	518.3	518.3	0.0	466.3	428.2
Medium	1997.5	505.7	505.7	0.0	450.3	440.15

Source: Authors

2.4.2 Fertilizer application

The application of mineral fertilizer was arranged at a depth of two centimeters, using 192 kg ha⁻¹, in the 08-20-20 formulation, according to Embrapa's recommendation.

2.4.3 Application of hydroretainer polymer

The amount of hydroretainer polymer used was based on the manufacturer's recommendation, 5 grams L⁻¹. The use of disposable diaper was decided from the observation of better swelling compared to the swelling capacity of commercial hydrogel when in contact with ARS, which was lower than the performance demonstrated when in contact with water. This is possibly due to the high concentration of salts in ARS.

2.4.4 Precipitation intensity simulation

The simulation of rainfall intensity was carried out manually on the surface of the soil, with slides of distilled water, in accordance with the average of the rainfall of the region in the months of September, October and November, the period in which the experiment was carried out.

Thus, a quantity of 117 mL was distributed to each column of the experiment for eight days in September (05, 08, 09, 14, 17, 24, 25 and 28), 126 mL for 11 days (01, 05, 07, 14, 16, 20, 21, 22, 23, 27 and 29) in October, and 130 mL for seven days in October (day 03, 04, 06, 12, 17, 18, and 20), as shown in Table 2

Table 2. Historical average rainfall of the IAPAR season in the municipality of Palotina, in the months of September, October and November.

Month	Total	Rainy days	Volume	Volume
	Mm		L m ⁻²	L column ⁻¹
September	134.5	9	14.94	0.117
October	176.8	11	16.07	0.126
November	165.2	10	16.52	0.130

Source: Instituto Agronômico do Paraná (IAPAR). Climate maps of the state of Paraná. Londrina: IAPAR, 2012.

2.5 MATERIAL COLLECTION

The collection of the soil was divided into five intervals, on days 1, 11, 21, 41 and 81 after the application of the treatments, in such a way as to cover the carrying out of the crop, compatible with the nutritional requirements of a possible crop. On days one and 81 soil columns were also collected that received only precipitation. These served as a witness.

For the collection, a ten-centimeter layer was removed from the column, and afterwards the rest. Stored in different containers for later analysis of the 0-10 and 10-20 centimeters of soil. The samples were stored in a freezer until the end of the 81 days, so that they were all analyzed together.

2.6 LABORATORY TESTS

For the nitrogen analyzes, the samples were sieved, still wet, for the best homogenization. The analyzes were carried out on the basis of the extraction of exchangeable ammonium and nitrate, in a process based on steam distillation, by which the quantification of N takes place by titration, according to Embrapa (2009).

For the Phosphorus and Potassium analyzes, the samples were dried in the air, and subsequently ground for better homogenization and for finer soil (2mm sieve). Subsequently, the aliquots were subjected to a solubilization of these elements, carried out by the extraction solution of Mehlich 1 according to Embrapa (2009).

The results of Phosphorus were obtained by reading the intensity of the color of the phosphomolybdic complex, by reading a spectrophotometer with a wavelength of 660 nm, according to Embrapa (2009).

Potassium was determined by the direct method using a flame photometer, also according to Embrapa (2009).

For the amounts of Nitrogen the results were expressed in mg kg^{-1} of soil, while for the data of Phosphorus and Potassium they were expressed in mg dm^{-3} of soil.

2.7 STATISTICAL ANALYZES

After tabulation analyzes of the data obtained, a descriptive analysis of the data was performed, with verification of the normality of the errors and the results submitted to the analysis of variance with comparison of averages by Tukey at the level of 5% significance, with subsequent evaluation through line graph.

3 RESULTS AND DISCUSSION

When the depths (0-10 and 10-20 cm) were analyzed, taking into consideration all treatments and times, it was found that the concentrations of Nitrogen, Phosphorus and Potassium differ significantly in the depths studied, presenting in greater quantities in the surface layer, as shown in Table 3.

Table 3. Comparison between depths for nitrogen(n), phosphorus(p) and potassium(k).

Depth (cm)	N	P	K
	mg kg^{-1}		mg dm^{-3}
0-10	28.9a	31.4th	207.4a
10-20	8.4b	7.6b	83.0b

Different lower case letters in the columns differ according to Tukey's test at the 5% significance level.

Source: Authors

According to Soares and Restle (2002), the speed and quantity of mineral nitrogen that is lost by leaching are controlled mainly by the texture, structure, porosity, rainfall pattern, water retention capacity and soil cations, presence and type of vegetation cover and method of application of the fertilizer. Bertolini *et al.* (2000) state that the lower drag of nitrate to lower soil is a consequence of the higher water storage capacity of clay soils, which reduces the percolation of water by the profile. Sangoi *et al.* (2003) further express that in addition to texture, organic matter content can also interfere with nitrate leaching, as there is a higher availability of nitrogen due to the decomposition of organic matter, especially when the area is not being cultivated.

As for phosphorus, Heathwaite *et al.* (2000) conclude that the mobility of this element in the soil is very small compared to NO_3 , and the losses from vertical

movement on farmable land are almost not considerable. For Ceretta *et al.* (2005), low phosphorus mobility is a possible cause of the low concentrations of phosphorus available in the lower layers, and it can be adsorbed by soil particles and the remaining precipitate. Tomé Jr (1997) states that the available phosphorus content tends to decrease with depth, keeping up with the organic matter content of the soil.

Potassium, whether available from straw, or added via potassium fertilization, can be intensely leached in the soil profile, but depends on the amount of rain, the amount of nutrient applied and the soil texture (ROSOLEM *et al.*, 2006). As for Doblinski *et al.* (2007), which state that high levels of potassium in the most superficial layers of the soil occurred depending on the dosage used in the treatment, since potassium, as well as phosphorus, also shows fixation, in smaller quantity, but mainly through adsorption in the soil exchange complex.

In the analysis of the different treatments applied in the most superficial layer (0 to 10 centimeters), it was possible to visualize that the Nitrogen in the ARS showed itself in greater concentrations than in the ADM and in the Control. It can also be observed that all treatments using ARS showed significant difference in relation to control. When comparing the treatments that used ARS, none of them showed any significant difference between them. For Phosphorus, only the application of ARS was highlighted, consequently, it did not show significant differences in concentrations in the other treatments. Potassium, in turn, did not show any significant difference between treatments, showing that this nutrient may have varied over time, but not between treatments. Such significance can be observed in Table 4.

Table 4. Comparative of nitrogen, phosphorus and potassium between treatments at depth 0-10 cm.

Nutrient	Control	ARS	ARS+G1	ARS+G2	WMD
N (mg kg⁻¹)	1.0C	42.8A	37.8AB	34.0AB	12.3BC
P (mg dm⁻³)	21.9B	41.6A	29.2B	28.7B	29.8B
K (mg dm⁻³)	201.6th	227.2A	198.6A	207.3A	198.8A

Equal capital letters in the line do not differ according to Tukey's test at the 5% significance level. ARS: pig waste water (80 m³ ha⁻¹). ARS+G1 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer polymer for planting). ARS+G2 (80 m³ ha⁻¹ of ARS + 0,315 g diaper hydrogel). ADM (mineral fertilizer in formulation 08-20-20, in a quantity of 192 kg ha⁻¹ to soil).

Source: Authors

Doblinski *et al* (2007), in their studies, concluded that mobility in the soil profile was higher for potassium, followed by nitrogen and phosphorus.

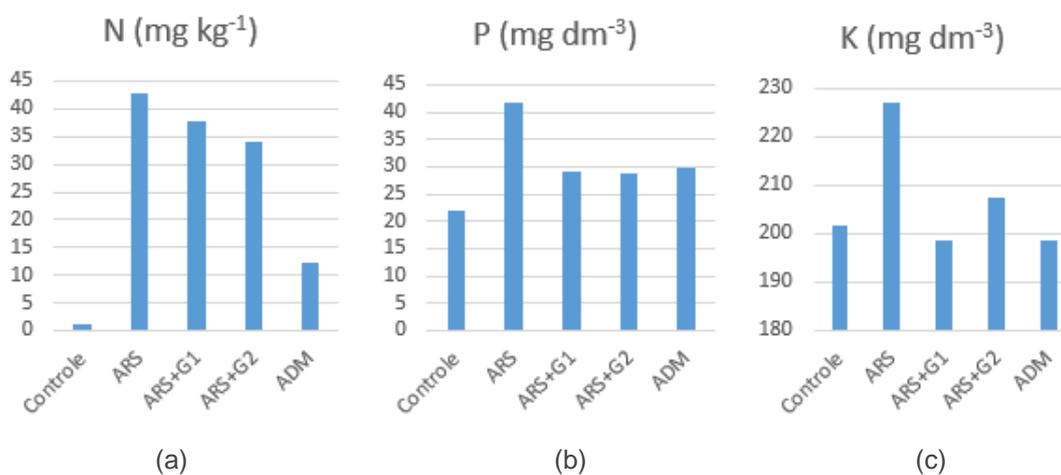
Because it is repelled by soil particles, which generally have a negative net electrical charge, the nitrate remains free in the solution. Consequently, the quantity present in the arable layer of the soil, which is not used by the plants, is subject to leaching (DYNIA *et al.*, 2006).

As well as Ceretta *et al.* (2003), the phosphorus content available in the soil increased with the application of pig waste over time. In studies conducted by Queiroz *et al.* (2004), it was possible to verify that Phosphorus and Potassium accumulated in the soil. Bertol *et al.* (2010) for their part, they showed that soil that received liquid pig manure provides greater susceptibility of the soil to phosphorus loss, compared to the soil that receives formulated with NPK, resulting in a transfer of phosphorus to the soil of higher environmental risk than if this transfer was made by an inorganic source.

For potassium Ceretta *et al.* (2003) reported that this element is found in the dung entirely in mineral, soluble form and therefore its residual effect is very short.

The differences observed between treatments in the statistical analysis can be better visualized in Figure 4.

Figure 4. Nitrogen (a), phosphorus (b) and potassium (c) concentrations in the topsoil



Source: Authors

In the statistical comparison of the second depth (10 to 20 cm), it was possible to verify for Nitrogen, as well as in the upper layer, the treatment with ARS was presented in higher concentrations than in the ADM and in the Control. It can also be observed that the treatments presented significant difference in relation to the control. When comparing the treatments that used ARS, none of them showed any significant difference between them. However, the treatments using hydroretainer polymers did

not show significant difference with the treatment in which ADM was applied. For both Phosphorus and Potassium, the difference was not significant between treatments. Such behavior can be seen in Table 5.

Table 2. Comparative of nitrogen, phosphorus and potassium between treatments in depth 10-20 cm.

Nutrient	Control	ARS	ARS+G1	ARS+G2	WMD
N (mg kg⁻¹)	0.3C	12.9A	9.1AB	9.2AB	5.8B
P (mg dm⁻³)	6.8A	7.7A	6.2A	8.5A	8.4th
K (mg dm⁻³)	75.2A	83.7A	79.7A	81.0A	90.8th

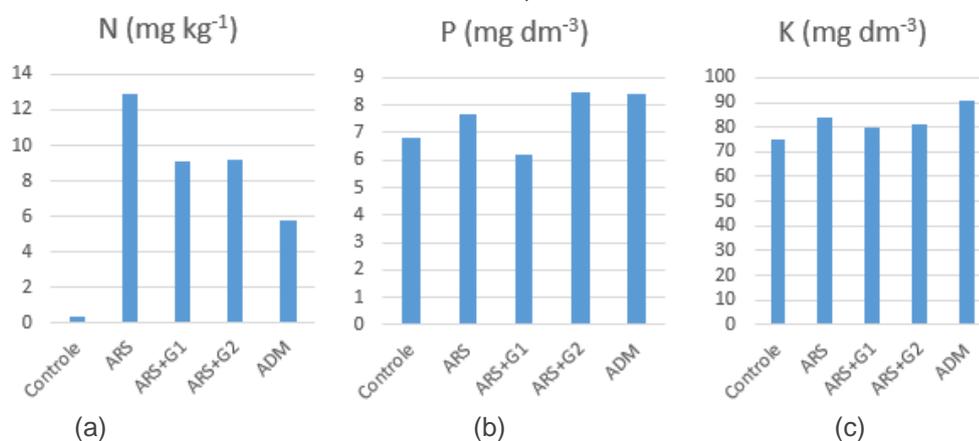
Equal capital letters in the line do not differ according to Tukey's test at the 5% significance level. ARS: pig waste water (80 m³ ha⁻¹). ARS+G1 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer polymer for planting). ARS+G2 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer diaper polymer). ADM (mineral fertilizer in formulation 08-20-20, in a quantity of 192 kg ha⁻¹ to soil).

Source: Authors

As evaluated by Silva (2005), potassium did not show any significant difference, further stating that with manure fertilization the soil was positively affected with levels up to 50 cm deep. Bertol *et al.* (2004) emphasized that potassium, in addition to being more soluble and mobile in soil than phosphorus, is easily leached since it is found in higher concentrations in soil. They also pointed out that even though potassium exhibits mobility in the soil profile, soil conservationist preparation has contributed to increase its concentration on the surface, as a result, transport by water from the flood increases.

Nitrogen, Phosphorus and Potassium concentrations in the soil in the second layer can be seen in Figure 5.

Figure 5. Nitrogen (a), phosphorus (b) and potassium (c) concentrations in the second soil layer (10-20 cm)



Source: Authors

Table 6 presents the statistical analysis of nitrogen concentrations in depth from 0 to 10 cm, comparing treatments and times. The Control did not present a significant

difference between the first and the last day of collection. However, it differed significantly from other treatments, being different on the first day and similar to treatment with ARS+G1 on the last day. In the columns that received ARS, the first three samples showed significant differences among themselves, differentiating still, from days 41 and 81 after application, which resembled each other, having little amount of N in the soil. Treatment with ARS and hydroretainer polymer for planting (ARS+G1) showed a difference in the amount of Nitrogen from day 21, not having a significant difference at day 41 and different from the last day of collection. The last day of collection, in turn, resembles the 41st. In the treatment with ARS and diaper hydroretainer polymer (ARS+G2) showed higher amounts of nitrogen in the first three collections after application, being significantly different among each other, while in the last two days of evaluation, nitrogen presented values not significantly different. In the treatment in which soil MMD was assessed, it was found that except on the first day, all other times did not show any significant difference.

When comparing the times, at the first day of the test, only the tests containing hydroretainer polymers (G1 and G2) did not show any significant difference between each other, the other tests being statistically different. On the second day of collection only the WMD treatments showed significant difference, and all those who used ARS showed large quantities of the nutrient, a result that resembles the third evaluation period (21 DAA). At 41 days after application, the ARS, ARS+G2 and ADM treatments showed no significantly different results, differing from the ARS+G1 treatment. However, this is significantly similar to ARS and ADM treatments. On the last day of the evaluation, it was possible to verify that the control was statistically similar to the ARS+G1 treatment, which in turn is significantly similar to the other treatments. These features can be better visualized in Table 6.

Table 3. Comparative nitrogen in mg kg⁻¹ between times in depth 0-10 cm.

Treatment	1 DAY	11 DAY	21 DAY	41DAY	81 DAY
Control	1.1Ad	-	-	-	0.9Ab
ARS	89.2Aa	58.9Ba	39.5Ca	13.6Dab	12.9Da
ARS+G1	68.1Ab	61.5Aa	33.9Ba	18.8BCa	6.5Cab
ARS+G2	63.0Ab	49.7Ba	38.5Ca	10.0Db	8.8Da
WMD	20.4Ac	10.7Bb	8.2Bb	13.1Bab	9.2Ba

Uppercase letters in the line compare times in each treatment. Lowercase letters in the column compare treatments at each time. DAA: Days after application. ARS: pig waste water (80 m³ ha⁻¹). ARS+G1 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer polymer for planting). ARS+G2 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer diaper polymer). ADM (mineral fertilizer in formulation 08-20-20, in a quantity of 192 kg ha⁻¹ to soil).

Source: Authors

In the second depth, it was possible to verify in the control a small quantity of nitrogen, there being no significant difference between the first and the last day of collection. In the soil columns where ARS was applied, nitrogen was present in greater quantities in the first four samples, being statistically different only in the last time evaluated in the experiment. Treatment with ARS and hydroretainer polymer for planting showed no significant difference between the times studied, with Nitrogen being in low concentrations. When the treatment with ARS and the polymer from disposable diaper was evaluated, it was possible to verify that there was an increase of Nitrogen in the time, and higher concentrations were observed for times 41 and 81 DAA. The studies that received mineral fertilization showed significant similarity in the first, third and fourth collections, being different from the second, which still showed difference in the last time evaluated, as shown in Table 7.

Also according to Table 7, it is possible to verify that in the first period of the experiment, the treatment with ARS directly to the soil showed higher concentrations of Nitrogen, being statistically different from the other treatments, which with the exception of the control did not show significant differences among themselves. The control also significantly resembled treatment with hydroretainer polymer (G1). In the second evaluation period, it was found that only the treatment with ARS presented significant difference, and the other treatments were similar to each other, with concentrations lower than the first. At 21 AAD no treatment was significantly differentiated. At day 41 after application, treatment with higher-concentration ARS and lower-concentration ADM differ significantly from each other, but not from other treatments, all with similar ARS, and those with ADM-like polymers (G1 and G2). In the last time evaluated in the experiment, the three treatments that used ARS also resembled each other, but only the treatment with the polymer (G1) showed no significant difference to the control and to the ADM.

Table 4. Comparative nitrogen in mg kg⁻¹ between times in depth 10-20 cm.

Treatment	1 DAY	11 DAY	21 DAY	41DAY	81 DAY
Control	0.5Ac	-	-	-	0.0Ac
ARS	10.4ABa	17.2Aa	13.7ABa	16.5Aa	6.9Bab
ARS+G1 (mg kg ⁻¹)	4.6Abc	11.3Ab	12.2Aa	12.8Aab	4.7Abc
ARS+G2	5.2Cb	11.2ABb	7.3BCa	11.8Aab	10.6Aab
WMD	6.2Bab	9.7Ab	5.6Ba	7.1Bb	0.3Cc

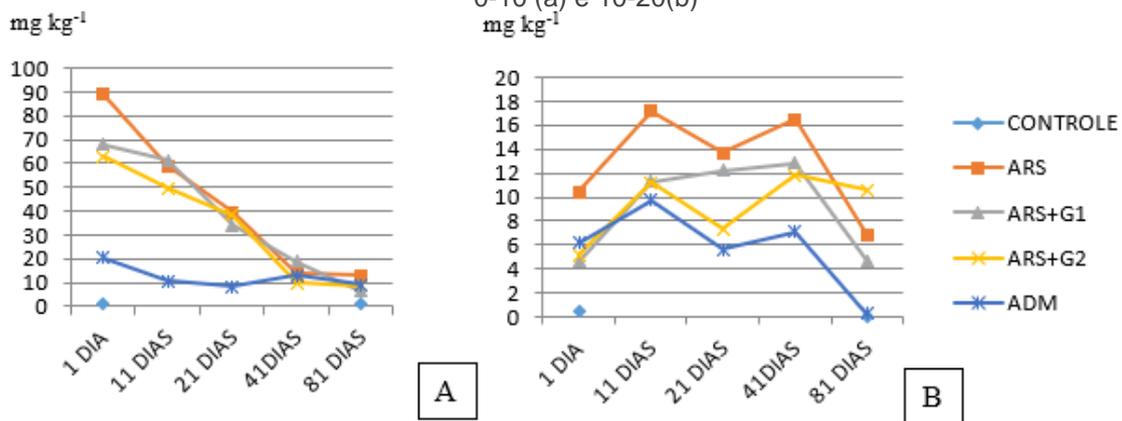
Uppercase letters in the line compare times in each treatment. Lowercase letters in the column compare treatments at each time. DAA: Days after application. ARS: pig waste water (80 m³ ha⁻¹). ARS+G1 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer polymer for planting). ARS+G2 (80 m³ ha⁻¹ of ARS + 0,315 g hydroretainer diaper polymer). ADM (mineral fertilizer in formulation 08-20-20, in a quantity of 192 kg ha⁻¹ to soil).

Source: Authors

For Luchese (2015), the nitric form is the one that predominates in aerated soils, and after approximately five days almost all the ammoniacal nitrogen that is released in the medium becomes nitric, the values can vary according to the conditions of oxy-reduction of the medium. He adds that this case may have been influenced by the fact that some columns were drained or soaked. He also states that the reference values of nitrate and ammonia in the soil vary a lot and are going to be directly related to some more controlled or momentary factors, so they are evaluated only for research, and one must take into consideration some questions, how much material was applied, how many days after the analysis was applied, the humidity maintained in the system, since all these factors have a brutal influence on the availability of Nitrogen.

Nitrogen concentrations in the soil columns and at each treatment and time can be better visualized in Figure 6.

Figure 6. Concentrações de nitrogênio em mg kg^{-1} nos diferentes tratamentos e tempos na cama de 0-10 (a) e 10-20(b)



Source: Authors

In the evaluations of phosphorus in the first layer of the soil, it was possible to identify that the control did not show any significant difference between the first and the last collection time. Treatment with ARS applied directly to the soil did not show a significant difference in the first three times evaluated, from which it showed a slight increase in concentration. In the columns that received ARS with the hydroretainer polymer (G1) it was not possible to identify any significant difference over the studied time, while in those that received ARS with the diaper polymer (G2) it was observed that the first, second and fifth collection times did not differ statistically, having presented different result only for 21DAA with lower concentration. The soil columns

that received only WMD did not show statistical difference for 1, 21, 41 and 81DAA, and was observed, lower concentration for 11DAA.

When evaluating the study times for the first phosphorus depth, ARS treatment was found to have a significant difference for times 1, 11 and 21 AAD with values higher than other treatments. For times 41 and 81DAA all treatments did not show significant statistical difference between them.

Table 5. Comparative phosphorus in mg dm^{-3} between times at depth 0-10 cm.

Treatment	1 DAY	11 DAY	21 DAY	41DAY	81 DAY
Control	18.7Ab				25.1Aa
ARS	53.7Aa	41.7Aa	46.8Aa	27.2Ba	38.5ABa
ARS+G1	27.4Ab	27.2Ab	29.7Aab	35.9Aa	25.9Aa
ARS+G2	30.8ABCb	36.7Aab	19.6Cb	22.0BCa	34.5ABa
WMD	26.3ABb	23.4Bb	28.0ABb	40.9Aa	30.4ABa

Uppercase letters in the line compare times in each treatment. Lowercase letters in the column compare treatments at each time. DAA: Days after application. ARS: pig waste water ($80 \text{ m}^3 \text{ ha}^{-1}$). ARS+G1 ($80 \text{ m}^3 \text{ ha}^{-1}$ of ARS + 0,315 g hydroretainer polymer for planting). ARS+G2 ($80 \text{ m}^3 \text{ ha}^{-1}$ of ARS + 0,315 g hydroretainer diaper polymer). ADM (mineral fertilizer in formulation 08-20-20, in a quantity of 192 kg ha^{-1} to soil).

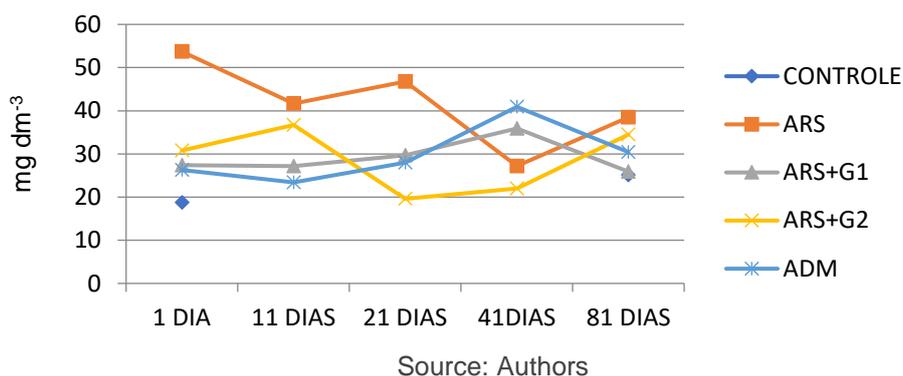
Source: Authors

According to Luchese (2015), even if high, values above 18 mg dm^{-3} for phosphorus are within acceptable limits for the region, since they belong to a region whose soils have between 40 and 60% clay.

In studies conducted by Bertol *et al.* (2010) It is clear that soil receiving liquid pig manure is more susceptible to phosphorus loss than soil receiving NPK formulations and it may also be noted that the transfer of phosphorus to soil via liquid pig manure poses a higher environmental risk than if this transfer was made by an inorganic source.

Phosphorus concentrations in the first layer can be more easily observed in Figure 7.

Figure 7. Phosphorus concentrations in mg dm^{-3} in the different treatments and times in the 0-10 cm layer.



Since the potassium levels did not show significant differences between treatments in the two layers, the statistical analysis of the times was not performed, as well as for phosphorus, which in the 10-20 cm layer did not show significant statistical difference for the results of all treatments.

4. CONCLUSION

In view of the aspects evaluated, it was possible to identify different concentrations of the three nutrients (Nitrogen, Phosphorus and Potassium) at the two depths under study, observing that all treatments and times presented greater quantities in the surface layer.

It can also be observed that in the surface layer of the soil the treatments with hydroretainer polymer showed similar behavior to that with ARS applied directly to the soil for Nitrogen, with higher values between the application and the 21DAA compared to ADM and the Control.

For Phosphorus, the treatments with hydroretainer polymers were similar to the application of ADM, with concentrations below that of the ARS direct to the soil. In the 10-20 cm layer it was possible to verify that for Nitrogen the ARS presented higher values, while for Phosphorus the values did not present significant statistical difference.

For Potassium, no significant statistical difference was observed between the treatments at each depth. Thus, it can be concluded that the evaluated hydroretainer polymers did not present significant benefit in the doses and study times.

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CHAPTER 15

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE DIGITAL TRANSFORMATION OF COMPANIES: RESHAPING BUSINESS PROCESSES AND DECISION-MAKING

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ABSTRACT: Technology and information are essential for strategic decisions in companies and public agencies. Organizational models improve performance, aligning objectives with business. Artificial intelligence (AI) based on algorithms and mathematical models revolutionizes industries and generates major digital transformation in companies. AI is applicable in various segments and relationships, such as healthcare, finance, and transportation, optimizing processes, increasing efficiency, and creating new models of agreements and producing satisfaction for the end customer, generating value and productivity. Companies such as Bradesco, Tesla, IBM, Ethos Asset Manager, among others, use AI to improve customer service and analyze large volumes of data to assist in strategic decisions. Adaptations are necessary to integrate AI and overcome challenges, such as the application of regulatory standards, ethical challenges, and the automation of processes, minimizing employment and human labor. AI drives collaboration, innovation, and competitiveness.

KEYWORDS: Artificial Intelligence, productivity, business, digital transformation.

RESUMO: A tecnologia e a informação são essenciais para decisões estratégicas em empresas e órgãos públicos. Modelos organizacionais melhoram o desempenho, alinhando objetivos aos negócios. A inteligência artificial (IA) baseada em algoritmos e modelos matemáticos revoluciona indústrias e gera grande transformação digital nas companhias. A IA é aplicável em vários segmentos e relações, como saúde, finanças e transporte, otimizando processos, aumentando eficiência e criando novos modelos de atividades e produzindo a satisfação ao cliente final gerando valor e produtividade. Empresas como Bradesco, Tesla, IBM, Ethos Asset Manager, entre outras, usam IA para melhorar o atendimento ao cliente e a análise de grandes volumes de dados para

auxiliar em decisões estratégicas. Adaptações são necessárias para integrar a IA e a superar desafios, como aplicação de normas regulamentadoras, desafios éticos e a automação de processos minimizando o emprego e o trabalho humano. A IA impulsiona a colaboração, inovação e a competitividade.

PALAVRAS-CHAVE: Inteligência Artificial, produtividade, negócios, transformação digital.

1. INTRODUCTION

Technology and information, nowadays, are essential for taking the strategic directions, mainly of the large companies and public bodies, where the development of organizational models to improve business performance is in implementing strategy and in turn, passes through the understanding of the right to decide and align the objectives of the organization. (ANDRADE, 2020).

Artificial intelligence (AI) is described as a revolution built on algorithms and mathematical models, often inspired by the structure and functioning of the human brain (SCHMIDT, 2023).

On the other hand, industries are embracing holistic business models, with complete redesign of products and services aimed at closer interaction with suppliers, partners and consumers. (EBERT; DUARTE, 2018).

AI can be applied in various market and industry segments, such as health, finance, manufacturing, transportation, among others (ELIAS,2023) and the digital revolution has changed business processes and the way companies deliver value to their customers, changing people's behavior and society (AGUIAR; COUTINHO, 2019).

Soon, we can see that new technologies are revolutionizing the way companies are seeing their business and adapting to win new business, improvements in their quality to the search and conquest of new challenges beyond segmentation to consolidate their strategic niche.

By imputing known data and setting the desired output option, it is possible to include a computational algorithm that implies training a network that allows automated analysis at a level that dispenses with great human effort.

So this work will seek to foster the idea of the digital transformation of businesses and what artificial intelligence (AI) can help in this regard.

The problems, hypotheses, objective, justification and methodology will be explained at the next session, in order to give the reader a clear notion of the study.

2. PROBLEM, HYPOTHESES, OBJECTIVE, JUSTIFICATION AND METHODOLOGY

The central point that the present seeks to answer is the problem to be solved, aiming at a direction of research, facilitating the analysis of the results and reaching a credibility.

The main **problem** that this article will look into is what the impact of Artificial Intelligence (AI) is on the relationships and competitiveness of companies, and how it is influencing processes, business models and decision-making.

On the other hand, the purpose of the investigation is the objective. Directing, organizing, and clearly facilitating study evaluation.

The **overall objective** seeks an analysis of the effect of implementing AI solutions on process optimization, increasing operational efficiency, and generating new business models in different industry sectors and as **secondary objectives**, studying real-world cases of companies that have implemented AI solutions and their results achieved.

Thus, provisional propositions that seek to answer a question of the research are called hypotheses, aiming to direct the research, to facilitate the interpretation of the results, and to contribute to the advance of knowledge.

As **hypotheses** one has as milestones: a) the implementation of AI is directly correlated with optimizing business processes, reducing running time and operating costs; b) the implementation of AI is associated with creating new business models, driving innovation and competitive differentiation; c) the impact varies, depending on the industry, being more significant in high-volume sectors of data and complex processes; d) the organizational culture is a determining factor for the successful implementation of AI solutions.

Thus, the relevance and importance of knowledge can be demonstrated by the justifications, aiming to demonstrate the magnitude, support and orientation of the study.

Therefore, **justifications would be undertaken** if: a) automation of tasks and data-driven decision making, provided by AI, can significantly improve the efficiency of processes and companies adopting this technology tend to have better productivity and quality of products and services. b) AI enables the identification of patterns and

anomalies in data, optimizing resource allocation and strategic decision-making, enabling the development of new business models. c) sectors such as finance, manufacturing and health, whose businesses generate high volumes of data and complex processes can be benefited and optimized with the implementation of AI d) and the culture of organizations can play a decisive role in implementation of new technologies, such as change resistance and AI ignorance can hinder eventual deployments.

In this sense, the methodology can be summarized as the "path to discovery", being a roadmap to be followed to achieve the proposed goal, aiming to propose methods and techniques to collect, analyze and interpret the data.

As **a methodology**, development is based on the form of bibliographic and documentary research with the analysis of *survey* results already carried out by specialized bodies and through the study of cases of companies that have already implemented AI in their business through a qualitative analysis. The companies studied will be based on these observations not limited to their business, developing a culture as comprehensive as possible. This is the way to look at various market segments with the intention of seeing the scope of the use of AI and its most diverse results. The stages of the search begin in the identification and survey of international organisms for researching technology and the study of their respective analyzes. The limitation of own research is imposed in time and territorial scope, however, in the already existing literary study, it fills this gap, since there are institutions in constant guidance on the theme and in direct contact with entrepreneurs and new sciences, at the world level, as will be demonstrated in the work.

3. WHAT IS ARTIFICIAL INTELLIGENCE (AI) AND DIGITAL TRANSFORMATION

In this context, it is necessary to define what AI and digital transformation is, so that then, one has basic parameters of its applicability within a business.

Erokhin (2019) defines AI as a computational algorithm that can produce actions that only man can perform, such as image recognition, sound, decision making, and other activities.

In turn, artificial neural networks (ANN) can be defined as a computer system that can simulate the structure of a brain system (KOUZIOKAS, 2023). The implication

of neural networks is closely linked to AI, as AI depends on AI in creating a neural structure for data analysis and delivery of an expected result.

From another perspective, digital transformation is a disruptive technology that increases productivity, value creation and social welfare (EBERT, DUARTE, 2018). According to Rabelo (2020) digital transformation is a process of change of mentality of companies that start using technology to make their business more modern and competitive, improving performance market reach and expanding technological advances in the world.

AI dates back to the 1950s where names like Marvin Minsky, John McCarthy and Hebert Simon had an ambitious idea of recreating human intelligence in a machine (LEE, 2019). However, the first recognized work on AI dates back to Warren McCulloch and Walter Pitts in 1943 (RUSSEL; NORVIG, 2010).

Alan Turing (1950), working with other scientists, devised a machine¹ capable of decoding German-encrypted messages in World War II, an invention that culminated in the recognition of information crucial to Allied victories and the defeat of Nazi Germany, culminating in a practical application of the use of an automated machine for analyzing a large volume of data (decryption).

Chandrasekaran (2010) launches the concept of paradigmatic confusion in AI in which he describes that there is no broad agreement on the essential nature or formal basis of intelligence and the proper theoretical framework for it, conceptualizing AI as "information processing in representations".

The study has been outlined by several scientists since 1943 to the present day with the invention, by four different groups, of *back-propagation* learning and the adoption in 1987 of AI as a scientific method (RUSSEL; NORVIG, 2010).

The term industry 4.0 comes closely associated with the issue of digital transformation in which the McKinsey Global Institute identifies as the age of "cyber-physical systems" with the integration of cloud computing, networks, mobile devices, Internet of Things (*Internet of Thing* - IoT), AI, robotics, cybersecurity and 3D printing (PICCAROZZI; AQUILANI; GATTI, 2018). The authors add that the digital transformation, through the use of the term "industry 4.0" comes from Germany around 2011.

¹ The cryptographic machine used by the Germans was called "the riddle" and Turing's original one was called "the bomb".

In this sense, it can be understood that the digital transformation is a change of processes and strategic management of its products and services, with the use of technology, aiming to create differentials, foster better processes and methods to increase competitiveness and quality, as well as, the use of AI is closely linked to this process (COSSIO; SOUZA, 2023).

4. IMPACT OF AI ON BUSINESS PROCESSES

One of the great uses of AI and task automation and repetitive process optimization. With the use of machine learning, it is possible to replace human operative force with machines endowed with artificial neural mechanisms, seeking the improvement of the processes.

Incorporating technologies such as advanced robotics and intelligent systems, companies can automate repetitive tasks, reduce operating costs and increase production (OLIVEIRA; SANTOS; FERREIRA, 2024).

Bradesco Bank's BIA, IA is a personal assistant for customers, able to make transfers and payments using voice identification, able to answer about 300 thousand questions/month with 95% accuracy. (THE WEATHER, 2023).

In another focus, with the advent of *Big Data*, i.e. the processing of large volumes of data, machine learning has helped companies to extract accurate and detailed information from their business needs automatically (DAVENPORT; HARRIS, 2017).

The use of AI to analyze the data and assist in making more assertive decisions is an evolution, because it aims to eliminate the subjective character of human analysis and allows a more judicious character according to the selected standards.

An example of this is the American company Ethos Asset Manager whose purpose is to assist in trading assets, based on the analysis of a 100-year history of quotes, trends, news, financial reports and other information for decision to sell or incorporate certain assets for decision making of its clients (EXAME, 2023).

Another example cited by Exame magazine (2023) is the case of QINV, a company specialized in cryptocurrencies, which uses AI and *machine learning* to help clients who have little experience in investments to make the best option according to their applicator profile.

5. IMPACT OF AI ON CUSTOMER EXPERIENCE

AI, in turn, can, through standards and customer profiles, offer services, customized products and services.

Cuponeria, a company created in 2011 that promotes the culture of loyalty through the issuance of customized coupons to customers, which predicts, based on previous purchases the consumption profile and issues personalized suggestions according to the personal criteria of its users, thus increasing the viability of sales (TERRA, 2023).

From another point of view, virtual assistants and *chatbots* enable personalized customer service experience. A virtual assistant is software that performs actions requested by means of voice command, such as Apple's Siri, Amazon's Alexa (2024) and Google (2024) Assistant (ARAÚJO, 2021), in new perspective, according to Oracle (2024) *chatbot* is a computer program that simulates human conversations, being able to be written or spoken, allowing interaction with digital devices.

An example application is ChatClass, which develops English teaching through *chatbots*, enhancing the efficiency of real-time learning by integrating with instant messaging systems and social networks such as WhatsApp and Instagram (TERRA, 2023).

The identification of mood and voice, as well as the use of natural language processing (NLP) helps to personalize and deliver the best integration to the consumer, Minds Digital, is an example. Founded in 2017, it uses voice biometrics to identify and prevent fraud in Brazil, with a high level of confidence and agility in the authentication of people, recognizing voice in just 1 second and, with this, helped to prevent more than R\$50 million in bank fraud (TERRA, 2023).

6. CULTURAL AND ORGANIZATIONAL ADAPTATION

According to Elias (2023) the technological progress on organizational behavior is characterized by the competing forces of automation and increased tasks of workers, even in strictly defined occupations.

Organizational behavior investigates the impact of individuals, groups and structures and their behaviors within institutions, aiming to use this knowledge to improve corporate efficiency (ROBBINS, 2009).

The redesign of functions, adaptability and rehabilitation of the workforce, as well as the employment of new technologies, and the study of the impact on workers and their respective workplaces, has generated debates on employability and underutilization of human labor, which has caused great resistance in the deployment of new technologies, including AI (ELIAS, 2023).

Adaptations of new processes, shortage of skilled labor, lack of investment, lack of strategies to serve customers, adaptation to new digital platforms (BABER; OJALA; MARTINEZ, 2019) in addition to culture coordination, skills management and capacity development to align business strategies, detect, model and capture opportunities and seek to understand which aspects of culture and processes should maintain or modify, are other points to be challenged in organizational culture (HEAVIN; POWER, 2018).

Elias (2023) suggests a few points for integration between AI and human teams for a more prepared digital transformation, namely: a) associating the creativity, empathy and skills of human critical thinking with machine automation and b) assisting the processing of large volumes of data and performing repetitive tasks, saving human effort. Kon (2020) suggests that AI can provide *data-driven insights* where humans can provide context and skills in decision making.

Elias (2023) continues in his study that with the evolution of technology, the roles and needs of people in the workforce can change and with this, moving to new skills and certain jobs will require new knowledge and more advanced techniques.

7. IMPACT OF AI ON INNOVATION AND COMPETITIVENESS

According to Segura (2018), AI can be a great opportunity for collaboration and innovation through the deployment of cognitive solutions and ways of thinking about

customer relationship and service, having a focus in areas such as marketing, sales, online services, supply chain, development, human resources, training and others.

Ossamu (2021) highlights an example of an interactive manual for Toyota Sienna vehicles, which is no longer printed, but rather an interactive application and virtual assistant using Google Cloud technology, including through voice activation, as a way to replace the manual on paper.

AI in turn elevates companies to another level of competitiveness, both by creating value and increasing the productivity of their employees through consumer experience and in forecasting and problem solving (RODRIGUES; ANDRADE, 2021)

Continued Rodrigues and Andrade (2021) that competitiveness involves everything from automation of simple tasks, increases and optimization of production, and, up to aid in decision making, being that in 70% of the analyzes, generated competitive advantages, somehow, the companies studied.

Challenges in the adoption of AI by institutions, according to Elias (2023), are focused on the volume of computational power, lack of trust of customers and collaborators, limited human knowledge, deficiency in privacy and data security, ethical problems and assignment of responsibilities, as well as human work adaptability skills.

Borges (2023) indicates positive aspects such as a) performing tasks more accurately, b) writing sophisticated texts, c) assisting in language translation and recognizing contexts and feelings, d) as well as overcoming intensive computational limitations and intellectual and creative abilities of human beings, are just a few examples.

8. CHALLENGES AND LIMITATIONS OF AI IN THE DIGITAL TRANSFORMATION

The deployment of AI, in turn, encounters obstacles regarding the ethics and privacy of individuals and organizations. Accountability for irregular action is another issue that has been causing much discussion. The application of standards involving ethics, transparency, governance and privacy is already a concern in the Brazilian judicial system (NATIONAL COUNCIL OF JUSTICE, 2020).

Some negative effects can be highlighted as: a) loss of jobs through automation, loss of personal identity, use for undesirable and malicious purposes, absence of

accountability for misuse and, in an extreme situation, the very commitment of the human race (RUSSELL; NORVIG, 2010).

Impartiality is also another factor that makes the latter or free of human subjectivism, such as for example, the curriculum selection and the implementation in employment recruitment, where impartial selection for interviews is a positive factor, ensuring the best quality and cultural adequacy of the company (ATANAZIO; SILVA; FORMIGONI; NOVAIS, 2021) (BLUMEN; CEPellos, 2023).

According to research by Fabri, *et al* (2022) one of the main advantages of the use of AI is that (39.4%) companies wanted to reduce their operating costs, but lack of investment and high implementation costs (49.5%) is a preponderant factor, besides lack of knowledge of personnel (34.9%), lack of knowledge of technology (22%) and, finally, lack of technical preparation (19.3%) are challenges encountered.

9. COMPARATIVE CASE STUDY

Google (2024) Assistant and Amazon (2024) Alexa are examples of applying voice recognition AI to automate tasks in your ² personal *gadget*. Such equipment is small sound boxes, coupled via a network, which allow the user to interact by voice, transforming this interaction into commands and so the system adopts the desired pretension, like playing music, seeing a calendar, advising time and climate, among others.

Microsoft Copilot (2024) uses the integration with Dall-E 3 (OPEN-IA, 2024), from AI-Pro.org, to create unique images according to what is requested, where, through a *command prompt*³, allowing exclusivity and creativity in generating unique designs that can be used for various purposes.

Boston Dynamic (2024), a company located in the municipality of Waltham in the state of Massachusetts, founded by Marc Railbert, has been developing robots since 1992 and today, implements AI in his machines for a variety of other functions, such as assisting in inspections, monitoring in hazardous environments, transporting heavy and bulky loads, automating and moving objects, among countless others.

² Portable electronic device for specific purposes

³ Currently commands issued for AI to perform some activity are called *prompts*

Tesla (2024) Autopilot is the use of AI and with actuator devices and sensors, allowing vehicles to move between streets and cities without human intervention and driving, allowing the use of 100% autonomous automotive steering. Entrepreneurs and engineers Martin Eberhard and Marc Tarpinning, founders of the business, in 2003 was eventually acquired by Elon Musk. Its product portfolio is electric vehicles, solar power generation equipment and electric charging station.

Siemens (2024) has developed an AI-enabled automation system that enables a standardization of its customers' products along with improved scalability and reliability. With the employment of machine learning and complex data analysis, a practical case was the deployment and control in managing and rearing fish, avoiding overfeeding, improving water quality and optimizing marine breeding.

IBM (2024) through its Watson supercomputer enables the analysis of a *company's supply chain* and allows it to predict network problems and mitigate functional and operational disruptions, optimizing deliveries, reducing costs and enabling greater customer satisfaction.

With the information above, we can develop a comparative framework for innovation, competitive modeling and applications (Table 01).

Table 1 - Competitive modeling and innovation comparison.

Company(ies)	Business	Returns TRUE on success or FALSE on failure.	Results	Differential/ Innovation
Google / Amazon	Personal <i>gadget</i>	Gadget as personal assistant/laser	Use of AI for voice recognition and decision making for actions.	The use of AI is already a reality in the recognition of images and voice, but innovation lies in the perfecting of techniques for decision making and human interactions.
Microsoft Copilot/Dalle-E	Imaging and Imaging	Tool for image development and creation.	Use of AI for image creation and development.	
Tesla autopilot	Automotive	Automation of automotive driving	Use of AI for environmental analysis and decision-making.	High-volume data analysis, mainly of sensors and actuators in the industrial field is a reality. And the management of productive processes has been employed in a frequent manner, particularly in large companies. The innovation is in the pursuit of business needs and meet them through the implementation of AI and task automation.
Siemens	Process and production management	Customer service for scalability, optimization and reliability of production processes	Use of AI for data analysis and process improvements.	
IBM	Supply chain (<i>Supply chain</i>)	Process analysis and management.	Application of AI in case management and analysis.	

Source: Authors (2024).

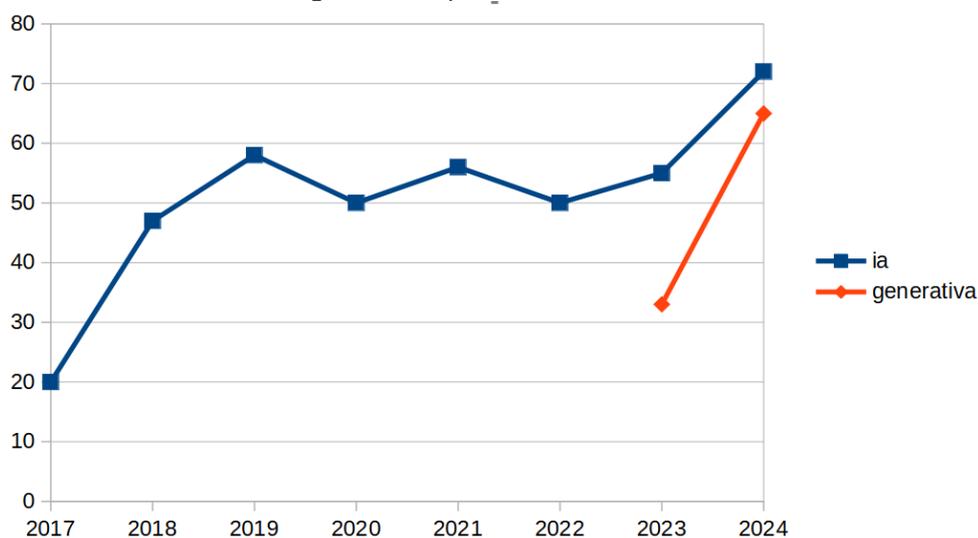
10. RESULTS AND DISCUSSIONS

According to a study conducted by Bean and Davenport (2024), in a questionnaire formulated for data executives and AI leadership, some conclusions can be observed:

- 87.9% of participants indicated importance in data analysis investments and these are priorities;
- 62.3% promoted that generative AI are as one of the main organizational prevalences;
- 89,6 % reported that investments in generative AI increased;
- 79.4% demonstrated that generative AIs should be centered and directed by the *Chief Data and Analytics Officer*;
- Only 15.9% of respondents stated that industry has done enough to address data and ethics in AI, i.e. this issue is very incipient in the business environment.

The study further demonstrated that: a) the largest volume of investment is due to leading and robust companies in the market; b) the use of data and analysis with expectation of delivery of commercial value; c) generative AI has the technological potential to transform a generation; d) the positions of data and analysis leadership is necessary, requiring its sedimentation; e) the deployment of AI in traditional business processes depend on behavioral change, organizational culture, time and commitment; f) safeguarding and data governance and AI are essential, but still very preambular.

Figure 1: Adoption of AI worldwide.



Source: Hanselman and Seiler (2024), adapted by the authors.

Hanselman and Sailer (2024) in another worldwide survey indicated that in the year 2023, 65% of companies are using generative AI regularly in their businesses, double the growth compared to 10 months ago survey (figure 1, orange chart) and in another focus, companies' adoption of AI has been increasing (figure 1, blue chart).

For the authors, this means a disruption in the industry over the next few years, predicting that about 75% will use generative AI in their business outright.

Espel *et al* (2020) carried out a comparative study of the main cost reduction indicators with AI deployment and other smart methodologies, not only cost reduction but process optimization, income gain and time optimization are observed (Table 02).

Table 2: Indirect cut of your costs with technology implementation.

Business Area	Technology Used	Observed indirect costs	Analysis	Results	Patterns/Differential
Shopping, medical technology company	Data Analysis, IA	Third-party expenses	Narrow view of expenditures; Segmented expenditures; Fragmented IT; Data on vendors with errors	Harmonization of data and use of AI. Comparison of prices and specifications. Renegotiation of contracts. Cost savings of 5-10%	Standards: Use of AI for high-volume data analysis. Differential: Use of information for contract renegotiation.
Global Technology Company.	AI	Receivables (CR), collection costs. Work smarter	Reduction of receivables balance; more problematic receivables analysis.	Predictive model, billing learning. Costs fell by 15% (in the process) and the CR balance increased by 7%. Income increased	Standards: Use of AI for information prediction. Differential: Cost analysis, revenue increase and income in general.
Energy Company. Acquisitions	Analyzing data with AI	Indirect purchases; maintenance, repair and operations (MRO) expenses	Analyzing transactions with raw materials, parts, and services = cost cutting	They paid 20% more for the same parts; Analysis of different scenarios; Reduction of 5 to 15% of costs.	Standards: High-volume analysis of specific information. Differential: Cost reduction in purchasing processes.
Vehicle Manufacturer, Production Management	Data visualization with AI, automate processes, and work smarter.	Personnel costs associated with technical planning and reporting	Production planning costs and <i>ramp-up</i> increased. Non-standard silos. Inefficiency in the overall development of the project.	Click prototype (production monitoring and planning). Minimum viable product. User test additional functionality. Planning and reporting time decreased by 30%.	Standards: the use of AI in improving production processes. Differential: Prototype creation for end-user analysis and support for new functionality.

Source: Espel *et al* (2020), adapted by the authors.

11. CONCLUSION

In this sense, we can demonstrate that the implementation of AI within companies has and will have great prominence in the transformation of their business, and that, effectively, the use of this technology creates a new level in competitiveness and profitability, significantly improving processes and models of their activities, besides it greatly assists the role of managers, with a fundamental role in the near future, the driving by the directors of data and analysis, as a strategic summit.

The main objective of the work was achieved, highlighting real-world cases in the demonstration of process optimization, operational efficiency and generation of new business models in various market segments, both industrial, commercial and service delivery.

It has been found that company managers are realizing that AI deployment facilitates multiple fields in various niche markets, mainly high-volume data analysis, guidance and facilitation in strategic decisions, quality improvements and processes, and minimizing and mitigating human effort in complex and repetitive tasks.

In addition, AI's employment favored improved profits, reduced spending, and provided more transparent, personalized, and satisfactory management of inventory and sales, products, and services to the end customer.

In the field of hypotheses, it has been confirmed that the use of AI, when well implemented, optimizes production and services, drives innovation and differentiation in the market segment, effectively assists in decision making mainly when it involves complex analysis and, the organizational culture must be reviewed to act in this new form of technological enterprise, breaking down barriers and human paradigms in the implementation and evolution of AI, in various fields and business segments of the most diverse possible.

The use of AI in predictive analysis of production processes, high data density studies, use in image analysis, sounds, sensors and actuators, scenario analysis with standardization of outputs and as differentials of the findings, the AI implantation differential is limited to human need and creativity.

As future expansions to the theme, it is suggested: a) the analysis of the impact of automations and *re-skilling*⁴ of AI for new work, skills and future occupations and b) further analysis for the employment of ethics and legal milestones for large scale application of AI, in addition to, c) detailed study in various areas of human activities such as health, education, finance, administration, among others.

A comparative study of the evolution of the employment of AI in regions or countries, at the international level, or even nationally, becomes an interesting topic for future research.

With all of this, the work sought to demonstrate, in the literary review and bibliography that the implementation of AI generates not only benefits to companies and businesses, but also, greatly improves the organization's prominence in its business niche, originating evidence to competitors and suppliers and, mainly, adding value to its customers with better and personalized products.

⁴ Process people acquire or improve skills to meet new market demands.

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