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Factor analysis as a tool for building the sustainable development index of river basins in Rondônia, Western Amazon

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***Abstract*— *Objective: to build a sustainable development index for the river basins of Rondônia, using factor analysis as an analytical model. Method: factor analysis was used as a tool for building environmental, economic, social and institutional performance indexes. The classification scale of Hair et al [16] adapted was adopted to express the results achieved by each hydrographic basin. Results: The set of sustainable performance indexes for the river basins of the Mamoré river (0.527) was considered a regular index; the Madeira River (0.388, a bad index); the Guaporé River (0.287, a bad index); the Machado river (0.256, bad index) and the Roosevelt river (0.177, terrible index). In addition, there was a drop in the indexes 10 years after the initial year of the survey, showing that, in terms of sustainable development, there was no improvement in Rondônia in the geographical context of the river basins. Conclusions: the factor analysis demonstrated efficiency as a multivariate statistical method in the construction of sustainable development indexes for the river basins of Rondônia. River basin management is still very ineffective, despite being regulated by state law. It is highly recommended to institutionalize regional public policies in the form of a River Basin Master Plan for Rondônia.*

***Keywords*— Hydrographic basins. Factor analysis. Sustainable development. Rondônia. Western Amazon.**

I. INTRODUCTION

The world development process has brought about a cultural and economic change on a global level and that such change, in general, has contributed, to a greater or lesser degree, to the worsening of the planet's environmental conditions [1]. However, it took some time for humanity to realize that the actions carried out in one particular territory ended up aggravating the environmental situation in another, resulting in a socio-environmental and economic burden to the detriment of the prosperity bonuses achieved by the territories originating from predatory actions that, normally, exercised the hegemonic role of industrial control.

From the political-institutional point of view, results of international agreements, the situation began to be formally discussed, among the stakes holders, when the first World Conference on Environment and Development (CMMAD), held in Sweden, in the city Stockholm in 1972. However, the world, even so, still did not know how to solve, in practice, the equilibrium equation between "environment and development", thus increasing the degree of complexity to carry out concrete actions in search of a model alternative development.

The Brundtland report, the main guiding document of the II CMMAD, which took place in Rio de Janeiro, in 1992, brought the famous definition of what would be this new model called "sustainable development", which, in fact, would be very close to the concept of "ecodevelopment" brought by Maurice Strong a year after I CMMAD, leading authors like Ignacy Sachs to recognize them as synonyms [2]. However, one of the major issues that emerge regarding the sustainable development paradigm, in the field of praxis, concerns its viability. This practical dilemma still persists today. And in this temporal trajectory, the self-reinforcing characteristics end up dictating the rules of the game in society, within a conception of space and power relationship, and, thus, influencing institutional performances, based on their historical constraints, as pointed out in the institutionalist theory of Douglass North [3].

Thus, this work is part of a contribution to the discussion on methodologies applied to studies from the perspective of environmental management, in order to serve as a practical instrument of analysis, with the objective of assisting decision making and, with that, planning, under the regional focus, however, within the concept of endogenous development, mainly in peripheral regions such as the Western Amazon.

In view of the above, the spatial cut at the level of hydrographic basins in the State of Rondônia was adopted as a central element of analysis, due to its role of importance for strategic planning and environmental management. In this context, the objective of the study was to build a sustainable development index for river basins in Rondônia, using factor analysis as an analytical model.

II. THE QUESTION OF WATERS AND THE RONDÔNIA HYDROGRAPHIC BASINS

The growing demand for water has aggravated water problems in many parts of the world. As a consequence, it is observed, more frequently, the increase in the statistics of completely dry rivers and / or streams and other sources totally unsuitable for human consumption, be they superficial or underground. Therefore, much of the water extracted for human activities, from whatever source, has been used in a very ineffective way [4].

Decree No. 24,643 of 1934 (Water Code) already regulated the use of water in Brazilian territory. Although it is recognized that the Water Code established a very advanced policy for the time, its regulation was limited to aspects related to the development of the electricity sector, leaving aside multiple uses and protection of water quality [5].

In the 1980s, with the institution of the National Environment Policy (PNMA), Brazil started to have a legal framework for dealing with environmental issues, which contributed to boost the formulation of new rules related to water management [6].

The Federal Constitution of Brazil, promulgated in 1988, played an important role in the management of water resources, because it defined waters as goods of common use and changed the dominance of the waters of the national territory, previously defined by the Water Code of 1934 [7]. Article 21, item XIX of the Federal Constitution of Brazil gives the Union the competence to institute a National Water Resources Management System and define criteria for granting the right to use it.

According to Setti et al [4], water resource management, in a broad sense, is the way in which it is intended to equate and resolve issues of relative scarcity of water resources, as well as to make the appropriate use, aiming at the optimization of resources for the benefit of society. Lanna [8] conceptualizes Water Resources Management as an analytical and creative activity focused on the formulation of principles, the preparation of normative documents, the structuring of management systems and decision-making, the ultimate goal of which is to promote the inventory, use, control and protection of water resources.

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Law no. 9,433, of January 8, 1997, instituted in Brazil the National Water Resources Policy (PNRH) and the National Water Resources Management System, which, according to article 1º, presents the following grounds: a) the management of water resources must always provide for the multiple use of water; b) the hydrographic basin is the territorial unit for implementing the National Water Resources Policy and performance of the National Water Resources Management System; c) the management of water resources must be decentralized and count on the participation of the Government, users and communities.

One of PNRH's guidelines is to adapt water resources management to the physical, biotic, demographic, economic, social and cultural diversity of the different regions of the country, the integration of water resource management with environmental management, and the articulation of water resources planning with that of the user sectors and with regional, state and national planning.

In the context of the State of Rondônia, Complementary Law No. 255, of January 25, 2002, is in effect, which "institutes the State Policy for Water Resources of the State of Rondônia and creates the Management System and the Water Resources Fund for the State of Rondônia and other measures".

By CNRH Resolution No. 32, of October 15, 2003, the Brazilian territory was divided into 12 Hydrographic Regions, as follows: Amazon, Western Northeast Atlantic, Eastern Northeast Atlantic, Parnaíba, Tocantins-Araguaia, São Francisco, East Atlantic, Southeast Atlantic, South Atlantic, Paraná, Uruguay, Paraguay. With regard to Rondônia, the State is inserted in the Amazon Hydrographic Region, with its territory divided into 7 hydrographic basins, which are those of the Guaporé River, Mamoré River, the Abunã River, the Madeira River, the Jamari River, the Machado River and the Roosevelt River.

Considering a hydrographic basin as a planning unit for the implementation and / or management of water resources requires addressing all elements of its landscape and not just water, in addition to adopting an approach that integrates environmental, social, economic and political aspects and the inclusion of environmental quality objectives for obtaining an increase in production potential with the minimum of environmental impacts and risks [9]; [10].

Santos [11] states that water management, from hydrographic basins, denotes:

> "The close links between waters, other natural resources and human activities. In general, integrated management and river basin management plans aimed at resources associated with water, are broader and more effective when they add measures for soil conservation, vegetation and fauna remnants and with the control of rural and urban activities".

The hydrographic basin as a planning unit, therefore, is already accepted worldwide, since it constitutes a natural system well delimited geographically, where phenomena and interactions can be integrated a priori by input and output, thus hydrographic basins can be treated as geographical units, where natural resources are integrated. It also constitutes a spatial unit that is easy to recognize and characterize, considering that there is no land area, however small, that does not integrate with a hydrographic basin and, when the central problem is water, the solution must be closely linked its handling and maintenance [11]; [12].

In this sense Guerra [13] reports that the hydrographic basins integrate a joint view of the behavior of the natural conditions and of the human activities developed in them, since significant changes in any part of the basin can generate changes, effects and / or impacts downstream and in the outgoing energy flows (discharge, solid and dissolved charges), among other consequences.

From the point of view of planning and managing regional development, river basins are presented as objects of study with an integrated and unified view of planning, enabling approaches and studies from the most diverse perspectives [14].

For Magalhães Jr [15] the hydrographic basin as a management and planning unit, results from the complex interaction between the parts and the whole. The adoption of the hydrographic basin as a delimitation of the system to be managed has advantages and disadvantages. The advantage is that the drainage network of a basin consists of a preferential path in most of the cause-effect relationships, especially when dealing with the water environment. The disadvantages are that the municipal and state limits do not always respect the basin's dividers.

According to Guerra [13], river basin management plans in Brazil have mostly addressed only the aspect of the use of water resources (irrigation or sanitation or energy generation), causing problems of a social, environmental, economic nature, political and cultural. This is because these plans are not always related to sustainable development, since the environmental capacity to support development always has a limit, from which all other aspects will inevitably be affected.

It is, therefore, within this focus that the present work was structured, using instruments of multifactorial analysis, to contribute to the discussions on the necessary means for decision-making in watershed areas in Brazil and, more specifically, in the Amazon.

III. PROPOSAL FOR AN ANALYTICAL MODEL

The proposal under study aims to establish a parameter for quantitative analysis involving issues inherent to environmental, economic, social, political-institutional parameters, capable of generating the index of sustainable development in river basins. For this purpose, factor analysis was used as a mechanism for building performance indices for each parameter studied.

Factor analysis is a generic name given to a class of multivariate statistical methods whose main purpose is to define the underlying structure in a data matrix. In general terms, factor analysis addresses the problem of analyzing the structure of the interrelations (correlations) between a large number of variables, defining a set of common latent dimensions, called factors. With factor analysis, the researcher can first identify the separate dimensions of the structure and then determine the degree to which each variable is explained by each dimension. Once these dimensions and the explanation of each variable are determined, the two main uses of factor analysis - summary and data reduction - can be achieved. When summarizing the data, factor analysis obtains latent dimensions that, when interpreted and understood, describe the data in a much smaller number of concepts than the original individual variables. Data reduction can be achieved by calculating scores for each latent dimension and replacing the original variables with the same ones [16]. Santana [17]; Santana [18]; Santana [19]; Santana [20] and Cavalcante [21] are other important works that corroborate with Hair et al [16].

For the analysis of such parameters, the municipalities were grouped by hydrographic basins, based on the distribution adopted by SEDAM - Rondônia State Secretariat for Environmental Development [22], as shown in table 1. It is also noteworthy that the Abunã River basin was not included in this work, since there are no municipalities in its coverage area.

Table 1: Distribution of river basins by municipalities in Rondônia.

Watersheds	Counties
Guaporé River	Costa Marques, São Francisco do Guaporé, Seringueiras, São Miguel do Guaporé, Alta Floresta d'Oeste, Alto Alegre de Parecis, Corumbiara, Cerejeira, Cabixi, Colorado do Oeste, Pimenteiras do Oeste
Mamoré River	Guajará-Mirim
Madeira River	Nova Mamoré, Porto Velho
Jamari River	Candeias do Jamari, Itapuã do Oeste, Alto Paraíso, Rio Crespo, Ariquemes, Monte Negro, Buritis, Campo Novo de Rondônia, Cacaulândia
Machado River	Cujubim, Machadinho do Oeste, Vale do Anari, Theobroma, Ouro Preto do Oeste, Governador Jorge Teixeira, Vale do Paraíso, Jaru, Teixeiropolis, Ji-Paraná, Nova União, Mirante da Serra, Urupá, Presidente Médici, Alvorada do Oeste, Cacoal, Castanheira, Espigão do Oeste, Pimenta Bueno, Chupinguaia, São Felipe do Oeste, Vilhena, Primavera de Rondônia, Rolim de Moura, Novo Horizonte do Oeste, Parecis, Nova Brasilândia, Santa Luzia D'Oeste
Roosevelt River	Ministro Andreazza

Source: Own elaboration, based on data from SEDAM.

3.1 Analytical model

A model of factor analysis can be presented in the matrix form as in Dillon; Goldstein [23]:

$$X = \alpha F + \varepsilon \qquad (1)$$

Then,

X = is the p-dimensional vector transposed from observable variables, denoted by $X = (x1, x2,..., xp)$;

F = is the q-dimensional vector transposed from non-observable variables or latent variables called common factors, denoted by $F = (f1, f2,..., fq)$, where q < P;

ε = is the p-dimensional vector transposed from random variables or unique factors, denoted by ε = (e1, e2,..., ep);

α = is the array (p, q) of unknown constants, called factorials loads.

According to Gama et al [24]; Santana [20], in the factorial analysis model it is assumed that specific factors are orthogonal, among themselves, with all common factors. Normally, E (ε) = E (F) = 0 and Cov (ε, F) = 0.

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According to the authors, the initial structure used to determine the array of factorials loads, in general, may not provide a significant pattern of variable loads, so it is not definitive. This initial structure can be done by several methods of rotation of the factors, as Dillon and Goldstein [23]; Johnson and Wichern [25]. It was used the VARIMAX method of orthogonal rotation of the factors for this study.

The VARIMAX method is a process where the reference axes of the factors are rotated around the source until some other position is reached. The objective is to redistribute the variance of the first factors to others and to achieve a simpler and more theoretically significant factorial [16]; [18]; [20]; [24]; [26].

The choice of factors was carried out through the technique of latent root. So, the array of factorials loads, which measures the correlation between the common factors and observable variables, is determined by means of the correlation matrix, as Dillon and Goldstein [23].

For the determination of sustainable development indexes, the matrix of factor scores estimated by the factorial basis orthogonal rotation process was adopted, as pointed out by Santana [19]. The factor score, by definition, places each observation in the space of common factors. For each factor *fj*, the i-th factor score extracted factorial score is defined by *F*Ij, expressed as follows [23]:

$$F_{IJ} = b_1 x_{i1} + b_2 x_{i2} + b_p x_{ip} \qquad (2)$$

Then:

b_i = are the estimated regression coefficients for the *n* Common factorials scores;

x_{Ij} = Are the *n* Observations of *p* Observable variables.

$i = 1,2,...,n.$

$j = 1,2,...,p.$

To arrive at the equation that represents the Performance Index, Gama et al [24]; Santana [20], show the evolutionary sequence of formulas from the previous equation. It turns out that even if the variable FIj is not observable it can be estimated through the factorial analysis techniques, using the matrix of observations of the vector x of observable variables. In factorial notation, equation 2 becomes:

$$F_{(n,q)} = X_{(n,q)} b_{(p,q)} \qquad (3)$$

In Equation 3, *F* is the matrix of the estimated regression from the *n* Factorials scores and it can be affected by both the magnitude and the measurement units of the variables *x*. To work around this kind of problem, replace the variable *x* by the standard variable *w*, given the ratio of the deviation around the average and the standard deviation of *x*, as follows:

$$\frac{x_i - \bar{x}}{S_x}$$

With these values, Equation 3 is modified making equation 4 possible, then:

$$F_{(n,q)} = w_{(n,q)} \beta_{(p,q)} \qquad (4)$$

Based on equation 4, the beta weights matrix (β) with *q* standardized regression coefficients, replaces *b*, given that the variables are standardized on both sides of the equation. Pre-multiplying both sides of equation 4 by the value $\frac{1}{n}$ ***w'***, in which *n* Is the number of observations and *W* is the transposed matrix of *w'*, it makes it possible to reach the following equation:

$$\frac{1}{n} w'_{(p,n)} F_{(n,q)} = \frac{1}{n} w'_{(p,n)} w_{(n,p)} \beta_{(p,q)} = R_{(p,p)} \beta_{(p,q)} \qquad (5)$$

The Matrix $\frac{1}{n}$ ***w'w***, therefore is the matrix of intercorrelated variables or correlation matrix among the observations of the matrix *x*, designated by R. The Matrix $\frac{1}{k} w' F$ It represents the correlation between the factorials scores and the factors themselves, denoted by Λ. With this, rewriting the equation 5, one must:

$$\Lambda_{(p,q)} = R_{(p,p)} \beta_{(p,q)} \qquad (6)$$

If the matrix R is non-singular, one can pre-multiply both sides of equation 6 by the inverse of R, obtaining:

$$\beta = R^{-1} \Lambda \qquad (7)$$

Substituting the β vector into equation 4, we obtain the factorial score associated with each observation, as follows:

$$F_{(n,q)} = w_{(n,p)} R^{-1}_{(p,p)} \Lambda_{(p,q)} \qquad (8)$$

In this way, the main formula of the Performance Index (I.D.) is arrived at, where the ID is defined as a linear combination of these factor scores and the proportion of the variance explained by each factor in relation to the common variance. The mathematical expression is now represented by the following formula:

$$ID_i = \sum_{j=1}^{q} \left(\frac{\lambda_j}{\sum_j \lambda_j} F P_{ij} \right) \qquad (9)$$

Then:

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i = 1,2,..., n.

λ = is the variance explained by each factor;

$\sum \lambda$ = is the total sum of the variance explained by the set of common factors.

The factorial score was standardized (FP) to obtain positive values from the original scores and allow the hierarchy of the municipalities since the values of the performance index are between zero and one. The formula that allows this hierarchy can be seen by the following equation:

$$FP_i = \left(\frac{F_i - F_{min}}{F_{\max} - F_{\min}}\right)$$

It can be seen that F_{min} e F_{max} are the maximum and minimum values observed for the factor scores associated with the parameters observed by municipalities in Rondônia, framed in the level of hydrographic basins, for a period of 10 years. Thus, it is based on this understanding that it was possible to determine the performance indices adopted by this research.

3.2 Tests of adequacy of the factorial method to the mass of data

According to Gama et al [24]; Santana [20], the two main tests with the objective of assessing the adequacy of the method to the mass concern, first, the Bartlett sphericity test, which has the property of evaluating the general significance of the correlation matrix, that is, it tests the null hypothesis that the correlation matrix is an identity matrix. In addition to the Bartlett test, the Kaiser-Meyer-Olkin (KMO) test is also widely used and is based on the principle that the inverse of the correlation matrix approaches the diagonal matrix, in this case, it seeks to compare the correlations between the observable variables. Thus, both methods were used by this research as techniques for assessing the adequacy of the method to the surveyed database.

According to Dillon; Goldstein [23]; Reis [26]; Mingoti [27]; Gama et al [24]; Santana [20] the mathematical formulas of these tests can be seen by the following equations:

$$KMO = \frac{\sum_i \sum_j r_{ij}^2}{\sum_i \sum_j r_{ij}^2 + \sum_i \sum_j a_{ij}^2} \quad (10)$$

Like this,

r_{ij} = is the sample correlation coefficient between variables xi and xj;

a_{ij} = is the partial correlation coefficient between the same variables that is simultaneously an estimate of the correlations between the factors, eliminating the effect of the other variables.

According to Hair et al [16], the a_{ij} should assume values close to zero, since it is assumed that the factors are orthogonal to each other. Thus, according to this same author, values of this test below 0.50 are unacceptable.

Bartlett's sphericity test tests the null hypothesis that the variables are independent, against the alternative hypothesis that the variables are correlated with each other. That is, H_0: R = 1 or H_0: $\lambda_1 = \lambda_2 = \ldots = \lambda_P$, which allows us to arrive at the following mathematical formula:

$$X^2 = -\left[n - 1 - \frac{1}{6}(2p+5)\right].\square|R| \text{ ou}$$

$$X^2 = -\left[n - 1 - \frac{1}{6}(2p+5)\right].\sum_{j=1}^{p} In\ \lambda$$

(11)

Where,

$|R|$ = is the determinant of the sample correlation matrix;

λ = is the variance explained by each factor;

n = is the number of observations;

p = is the number of variables.

The statistic has an asymptomatic distribution of x2 with $[0{,}5\,p(p-1)]$ degrees of freedom. The Bartlett test is the most common method applied to test the homogeneity of variances [28].

3.3 Analysis tool

The SPSS program, version 17, was used as an analysis tool, which enabled the application of mathematical knowledge and allowed the construction of performance indices based on each parameter analyzed: environmental, economic, social and political-institutional.

3.4 Levels of scale

The classification adopted by the research to express the results achieved by the river basins in Rondônia is described in table 2.

Table 2: Scale of analysis adopted by the research.

Scale	Description	Color representation
0.000 a 0.200	Terrible	
0.201 a 0.400	Bad	
0.401 a 0.600	Regular	
0.601 a 0.800	Good	
0.801 a 1.000	Great	

Source: Own elaboration based on the classification model of Hair et al [16].

3.5 Indicators raised by the survey

The model was built based on the following indices: environmental, economic, social and political institutional. The combination of these four indexes resulted in the sustainable development index, as indicated in the methodology (methodological script). The indicators raised and the respective research sources, which were part of the analysis of this work, are listed in tables 3, 4, 5 and 6, below.

Table 3: Environmental Index Indicators

Indicators	Source
Deforestation	INPEhttp://www.dpi.inpe.br/prodesdigital/prodesmunicipal.php
Percentage of the area of the municipality occupied by Conservation Units	ICMBio SEDAM
Percentage of the area of the municipality occupied by Indigenous Lands	SEDAM

Source: Own elaboration.

Table 4: Economic Index Indicators

Indicators	Source
Gross domestic product per capita	IBGE (Demographic census)
Number of cattle	IBGE (Municipal Livestock Research)
Rice production (% in relation to the State)	IBGE (Municipal agricultural production)
Coffee production (% in relation to the State)	IBGE (Municipal agricultural production)
Value of Pará nut production (R$ thousand)	IBGE (Production of plant extraction and forestry)
Value of non-processed wood production (R$ thousand)	IBGE (Production of plant extraction and forestry)
Cocoa production (% in relation to the State)	IBGE (Municipal agricultural production)

Source: Own elaboration.

Table 5: Social Index Indicators

Indicators	Source
Households with access to water (%)	IBGE (Demographic census)
Households with access to sewage (%)	IBGE (Demographic census)
Households with access to electricity (%)	IBGE (Demographic census)
Number of Health Units (per thousand inhabitants)	DATASUS
No. of hospital beds (per thousand inhabitants)	DATASUS
No. of doctors (per thousand inhabitants)	Atlas of Human Development in Brazil DATASUS
Illiteracy rate	IBGE (Demographic census)
Average household income per capita	IBGE (Demographic census)
Gini index of household income per capita	IBGE (Demographic census)
Proportion of people with low income	IBGE (Demographic census)
• % population with income <1/2 MW	IBGE (Demographic census)
•% population with income <1/4 MW	IBGE (Demographic census)
Proportion of children in a low income household situation	IBGE (Demographic census)
•% children income gift <½ SM	IBGE (Demographic census)
•% children income gift <¼ SM	IBGE (Demographic census)
Unemployment rate 16a and +	IBGE (Demographic

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	census)
Child labor rate	IBGE (Demographic census)

Source: Own elaboration.

Table 6: Institutional Political Index Indicators

Indicators	Source
Collection capacity	
• Per capita budget revenue	Own preparation based on data from IPEADATA, STN / FINBRA
• % own revenue	Own preparation based on data from IPEADATA, STN / FINBRA
Investment capacity	
• investment expense per capita	Own preparation based on data from IPEADATA, STN / FINBRA
• investment expense over realized expense	Own preparation based on data from IPEADATA, STN / FINBRA
Per capita expenses by function (R$)	
• Education and culture	Own preparation based on data from IPEADATA, STN / FINBRA
• Health and sanitation	Own preparation based on data from IPEADATA, STN / FINBRA
No. of municipal councils	IBGE (Profile of Brazilian municipalities)

Source: Own elaboration.

3.6 Methodological roadmap

Next, the steps taken in this work will be described, which were considered essential for the consolidation of the process of construction of sustainable development indexes due to the object of the present study.

Table 7: Methodological Roadmap

Phases	Description
1	Classification of municipalities in the State of Rondônia by hydrographic basins.
2	Survey of official data for each municipality framed by hydrographic basins.
3	Preparation of an Excel spreadsheet with the available data according to the structure recommended by steps 1 and 2.
4	Use the SPSS tool, through factor analysis, based on the Varimax method.
5	Observe the data adequacy criteria for factor analysis.
6	Determine the performance indexes by municipalities aggregated by river basins.
7	Using the average performance indexes of the municipalities, determine the indexes for each parameter for each hydrographic basin.
8	Using the average of the parameters, determine the index of sustainable development by hydrographic basins.

Source: Own elaboration.

IV. ANALYSIS OF THE SUSTAINABLE DEVELOPMENT INDEX AT HYDROGRAPHIC BASIN LEVELS IN THE STATE OF RONDÔNIA

Next, the results achieved by the present study will be presented, aiming to demonstrate the scope of the model and the possibilities of analysis, due to the proposed methodological instrument, as a suggestion of a scientific criterion for decision making involving the theme of environmental management, at hydrographic basins.

Figures 1A and 1B below show the environmental management indexes for river basins in Rondônia. Based on this parameter, the hydrographic basin of the Mamoré River was the one that presented the best results, reaching the maximum level of performance (performance index of 1,000 in the base year of the survey and 1,000, ten years later, according to the scale adopted). This hydrographic basin concentrates the highest percentages and areas of environmental preservation in Rondônia.

The opposite, however, was observed in the watershed of the Roosevelt River (index 0.000 in the first year and 0.000, ten years later). The hydrographic basin of the Madeira River (performance indexes 0.411 and 0.288, respectively in the first survey and ten years later) had a 19.9% drop in performance from the base year to a decade later, in the same way as the hydrographic basins of the Guaporé River (index of 0.291 and 0.206, respectively, in the first year and ten years later) fell by 29.2%, in the Machado River (index of 0.411 and 0.288, respectively), with a drop of 26.4% and in the Jamari River (index of 0.126 and 0.071, respectively in the first year and ten years later), with a drop in performance of 43.65%.

The environmental performance index of the first stage of the survey showed the following results: Mamoré river basin (1,000 considered an great index), Guaporé river basin 0.291 (bad index), Madeira river basin 0.411 (regular index), river basin Machado 0.125 (terrible index), Jamari river basin 0.126 (terrible index) and Roosevelt river basin 0.000 (terrible index).

Ten years later, the environmental performance index showed the following results: Mamoré river basin (1,000 considered an great index), Guaporé river basin 0.206 (bad index), Madeira river basin 0.288 (bad index), Machado river basin 0.092 (terrible index), Jamari River Basin 0.071 (terrible index) and Roosevelt River Basin 0.000 (terrible index). (Table 8).

Table 8: Environmental Management Index by river basins in Rondônia.

Hydrographic basin	Index (Reference year)	Index 10 years later
Guaporé River	0.291	0.206
Mamoré River	1.000	1.000
Madeira River	0.411	0.288
Jamari River	0.126	0.071
Machado River	0.125	0.092
Roosevelt River	0.000	0.000

Source: Own elaboration.

In the first phase of the survey, rates of economic performance were very low, without exception. The indices appear in the following decreasing order and classified according to the scale adopted in the research. Madeira River Basin 0.288 (bad index), Rio Machado Basin 0.256 (bad index), Rio Guaporé Basin 0.241 (bad index), Rio Jamari Basin 0.193 (terrible index), Rio Roosevelt Basin 0.182 (terrible index) and Mamoré River Basin with 0.163 (terrible index) completes the scenario of the economic performance conditions of the river basins of Rondônia.

Ten years later, the situation for economic performance index rates is as follows: Rio Mamoré Basin 0.437 (regular index), Rio Madeira Basin 0.333 (bad index), Rio Guaporé Basin 0.246 (bad index), Rio Basin Jamari 0.222 (bad index), Roosevelt River Basin 0.189 (terrible index) and Machado River Basin 0.183 (terrible index).

As for the economic aspect (figures 2A and 2B), the hydrographic basin of the Mamoré River presented the highest growth in the analyzed period (168.1%), reaching the highest index (0.437), followed by the hydrographic basins of the Madeira River (0.333), of Guaporé River (0.246), the Jamari River (0.223) and the Roosevelt River (0.189). It is inferred, therefore, that the Free Trade Area legally established in the municipality of Guajará-Mirim, located in the referred hydrographic basin, contributed to this index. Despite this, there has been no consolidation of a local development process in the region.

The municipality of Guajará-Mirim is projected as a strategic collection point for the State, which places it as an important economic zone in Rondônia. However, with reservations about the current management model implemented to consolidate the sector, which prevents the resources from the tax incentives in the free trade zone of Guajará-Mirim from returning in full as investments for the region (figures 2A and 2B).

In the same way, it can be inferred that the performance achieved by the hydrographic basin of the Madeira River has been influenced by the major infrastructure works in progress in the region, for example, the Hydroelectric Plants (UHE's) of Jirau and Santo Antônio, both located on the Madeira River. In addition, the strong process of "cattle raising" in the municipalities within the aforementioned hydrographic basin also demonstrates an influence on the performance of the economic index. (Table 9).

Table 9: Economic index by hydrographic basins in Rondônia.

Hydrographic basin	Index (Reference year)	Index 10 years later
Guaporé River	0.241	0.246
Mamoré River	0.163	0.437
Madeira River	0.288	0.333
Jamari River	0.193	0.223
Machado River	0.256	0.183
Roosevelt River	0.182	0.189

Source: Own elaboration.

The social performance indexes in the first stage of the research were as follows: Mamoré River Basin 0.706 (good index), Madeira River Basin 0.561 (regular index), Machado River Basin 0.476 (regular index), Guaporé River Basin 0.457 (regular index), Jamari River Basin 0.439 (regular index) and Roosevelt River Basin 0.329 (bad index). Ten years later, the social performance indexes were: Madeira River Basin 0.502 (regular index), Mamoré River Basin 0.489 (regular index), Machado River Basin 0.381 (bad index), Jamari River Basin 0.367 (bad index) , Guaporé River Basin 0.338 (bad index) and Roosevelt River Basin 0.295 (bad index).

With regard to the social parameter (figures 3A and 3B), it was found that all the studied hydrographic basins presented negative performances in the analyzed period, with emphasis on the Mamoré River which reached a decrease of -30.73%, followed by the Guaporé river (-26.04%), Machado River (-19.96%), Jamari River (-16.40%), Madeira River (-10.52%) and Roosevelt River (-10.33%).

The results demonstrate that, in general, the trajectory of public policies did not result in improvements in the quality of life of the population, which, in a way, reveals that Rondônia presented rates of economic growth in the period, however, without due monitoring in social performance, thereby affecting one of the main accounting mechanisms for "development", that is, indicating that the State has grown, but has not developed to the same degree from the perspective of river basins. (Table 10).

Table 10: Social index by river basins in Rondônia.

Hydrographic basin	Index (Reference year)	Index 10 years later
Guaporé River	0.457	0.338
Mamoré River	0.706	0.489
Madeira River	0.561	0.502
Jamari River	0.439	0.367
Machado River	0.476	0.381
Roosevelt River	0.329	0.295

Source: Own elaboration.

The indices of institutional political performance in the first stage of the research do not differ much from the other performance indices. The Jamari River Basin had a 0.415 index (regular index), followed by the Machado River Basin 0.423 (regular index), the Roosevelt River Basin 0.424 (regular index), the Guaporé River Basin 0.398 (bad index), the Madeira River Basin 0.339 (bad index) and Mamoré River Basin 0.319 (bad index).

Ten years later, the institutional political performance indexes were: Madeira River Basin 0.502 (regular index), Jamari River Basin 0.364 (bad index), Guaporé River Basin 0.311 (bad index), Machado River Basin 0.334 (bad index), Roosevelt River Basin 0.263 (bad index), Madeira River Basin 0.229 (bad index) and Mamoré River Basin 0.184 (terrible index).

The political-institutional parameter (figures 4A and 4B), the last one observed by the research, revealed a situation that is also worrying. From the perspective of hydrographic basin analysis, the political-institutional aspects did not bring the necessary strength capable of leveraging a level of identity of public policies linked to the local reality, in Rondônia. The absence of this characteristic ends up weakening the aspects inherent to governance and weakening local power, the main armor for the consolidation of a trajectory of economic prosperity, as pointed out by Putnam [29]. In Rondônia, it is considered to be the root cause of regional inequality [30]; [31]; [32].

Thus, according to figure 4, the largest losses were, in decreasing order, verified in the basin of the river Mamoré with -42.32%, followed by the basins of the rivers Roosevelt (-37.97%), Madeira (-32.45 %), Machado (-22.69%), Jamari (-12.29%) and Guaporé (-9.29%). (Tabela 11).

Table 11: Political-institutional index by river basins in Rondônia.

Hydrographic basin	Index (Reference year)	Index 10 years later
Guaporé River	0.398	0.361
Mamoré River	0.319	0.184
Madeira River	0.339	0.229
Jamari River	0.415	0.364
Machado River	0.432	0.334
Roosevelt River	0.424	0.263

Source: Own elaboration.

In this way, the sustainable development index of the hydrographic basins of Rondônia is reached (figure 5A and 5B). It was verified that the hydrographic basins reached the following indices: basin of the river Mamoré (index 0.527), river Madeira (index 0.388), river Guaporé (index 0.287), river Jamari (index 0.256), River Machado (0.256) and river Roosevelt (index 0.177). All of them showed a decrease in the performance index in the analyzed period, in the following proportions -3.65%, -15.5%, -17.29%, -12.63%, -23.29% and 20.08%, respectively. (Table 12).

Therefore, it was evident that in terms of sustainable development there was no improvement in Rondônia within the geographic context of river basins, which confirms the research carried out by Cavalcante [21]; Cavalcante; Góes [30]; [31]; Cavalcante; Alves [32]; Cavalcante; Góes [33]; Cavalcante; Silva [34] on the "conservation and development" trade-off in Rondônia.

Table 12: Index of sustainable development by river basins in Rondônia.

https://dx.doi.org/10.22161/ijaers.77.26 ISSN: 2349-6495(P) | 2456-1908(O)

Hydrographic basin	Index (Reference year)	Index 10 years later
Guaporé River	0.347	0.287
Mamoré River	0.547	0.527
Madeira River	0.400	0.338
Jamari River	0.293	0.256
Machado River	0.322	0.247
Roosevelt River	0.234	0.187

Source: Own elaboration.

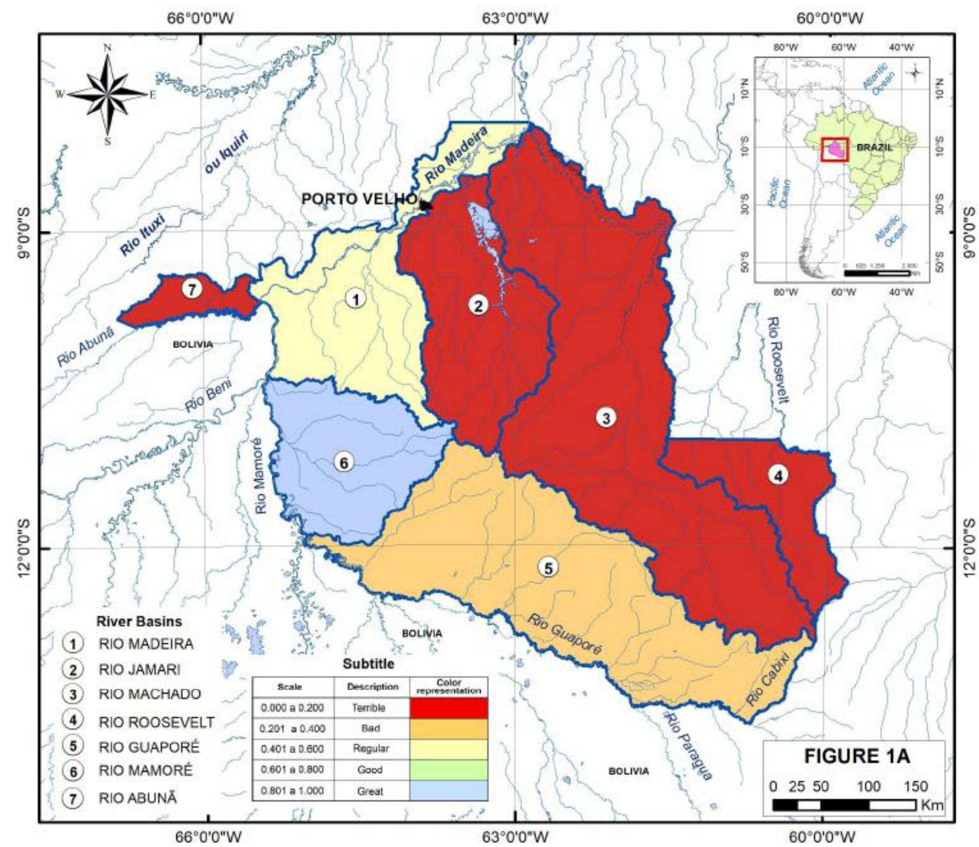

Fig.1A: environmenta management index for river basins in rondônia, in the reference year.

https://dx.doi.org/10.22161/ijaers.77.26 ISSN: 2349-6495(P) | 2456-1908(O)

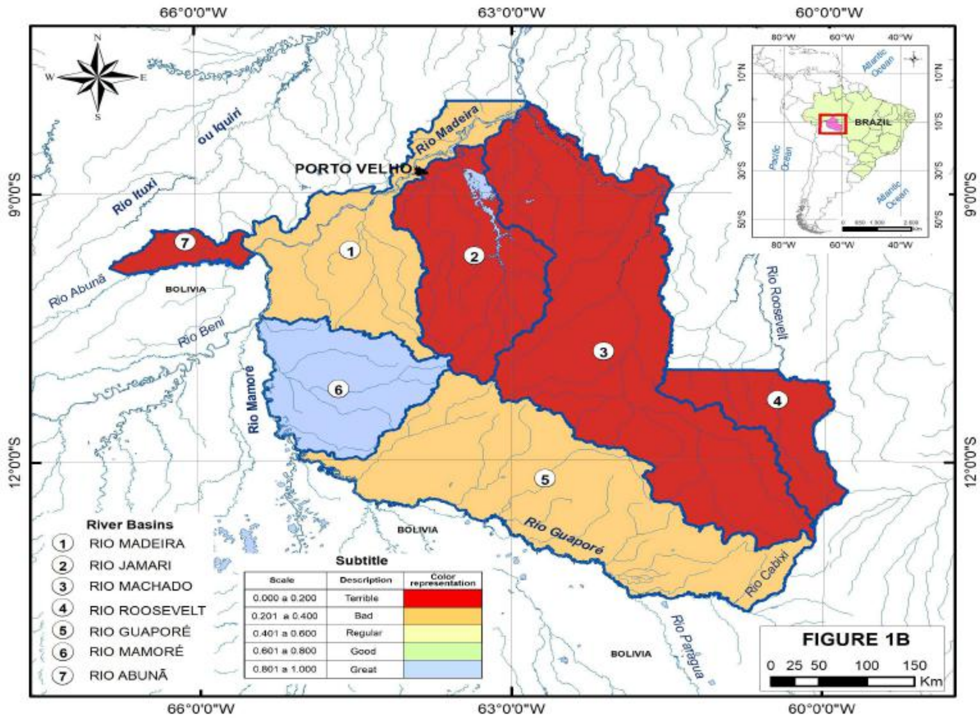

Fig.1B: Environmental management index for the hydrographic basins of rondônia, 10 years later.

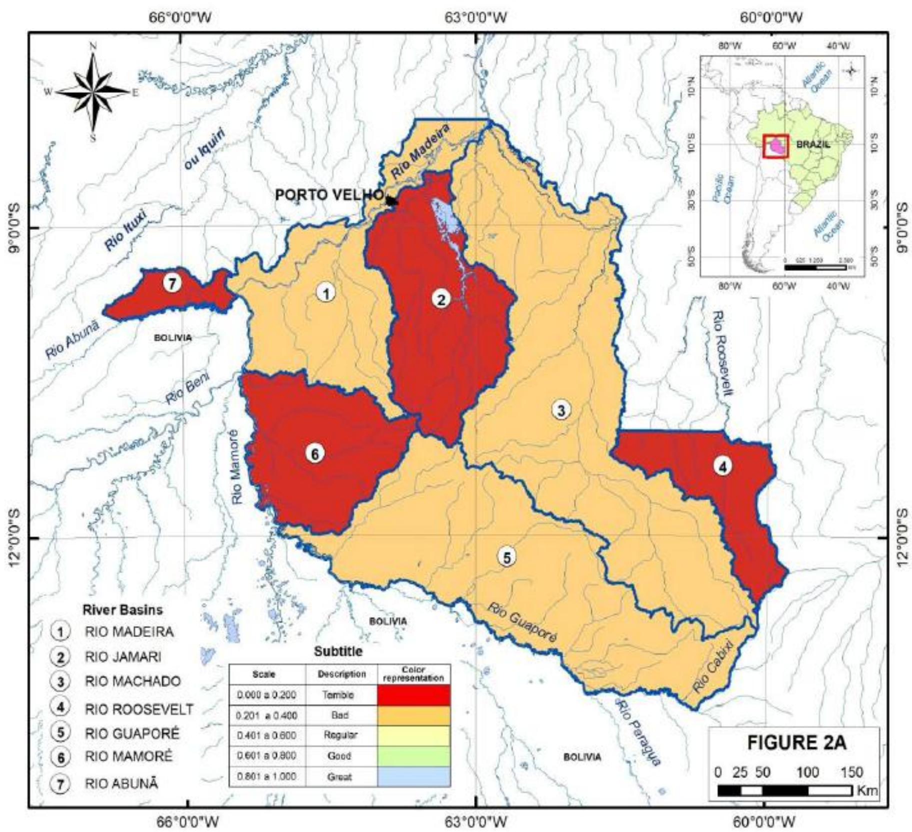

Fig.2A: Economic index of river basins in rondônia, in the reference year.

https://dx.doi.org/10.22161/ijaers.77.26 ISSN: 2349-6495(P) | 2456-1908(O)

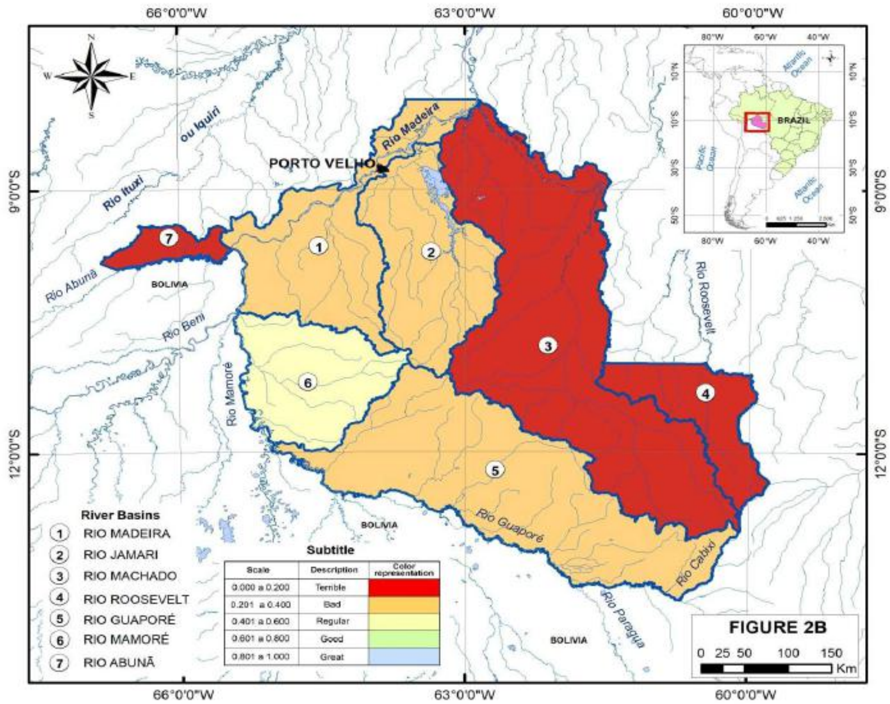

Fig.2A: Economic index by hydrographic basins in rondônia, 10 years later.

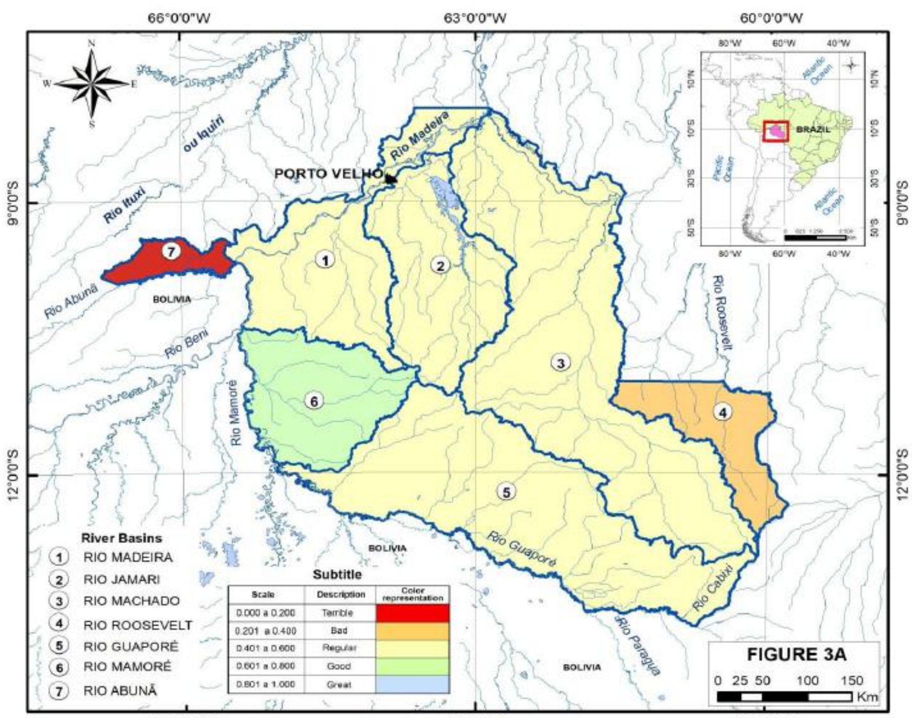

Fig.3A: Social index by hydrographic basins in rondônia, in the reference year.

https://dx.doi.org/10.22161/ijaers.77.26 *ISSN: 2349-6495(P) | 2456-1908(O)*

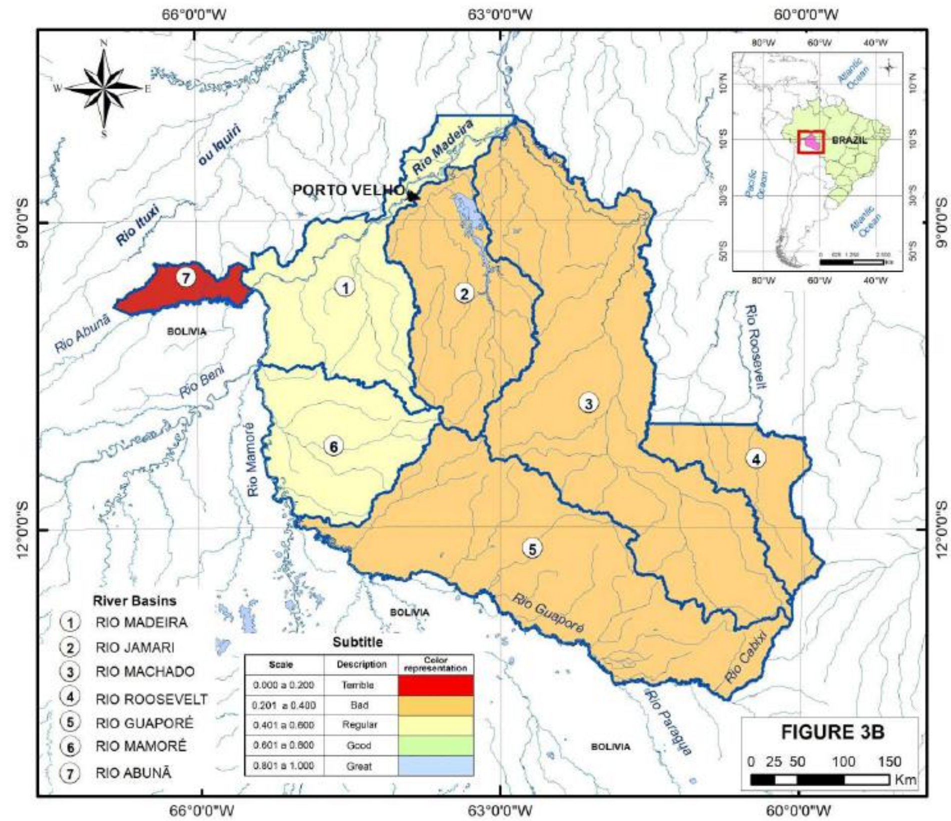

Fig.3B: Social index by hydrographic basins in rondônia, 10 years later.

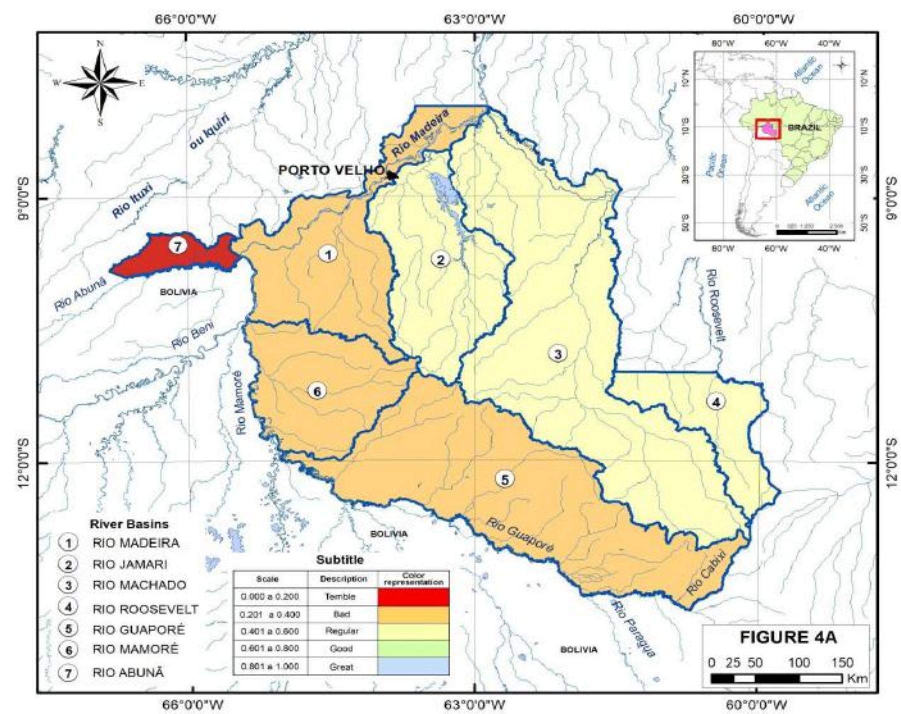

Fig.4A: Political and institutional index by basins in Rondônia, in the reference Year.

https://dx.doi.org/10.22161/ijaers.77.26 *ISSN: 2349-6495(P) | 2456-1908(O)*

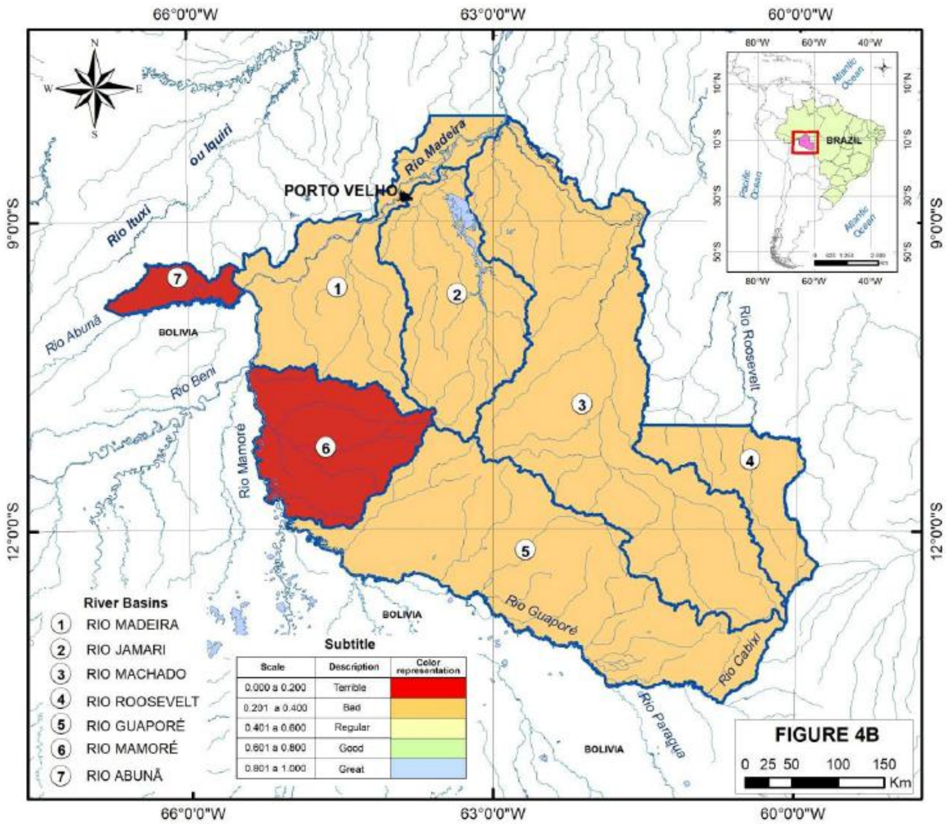

Fig.4B: Political and institutional index by basins in rondônia, 10 years later.

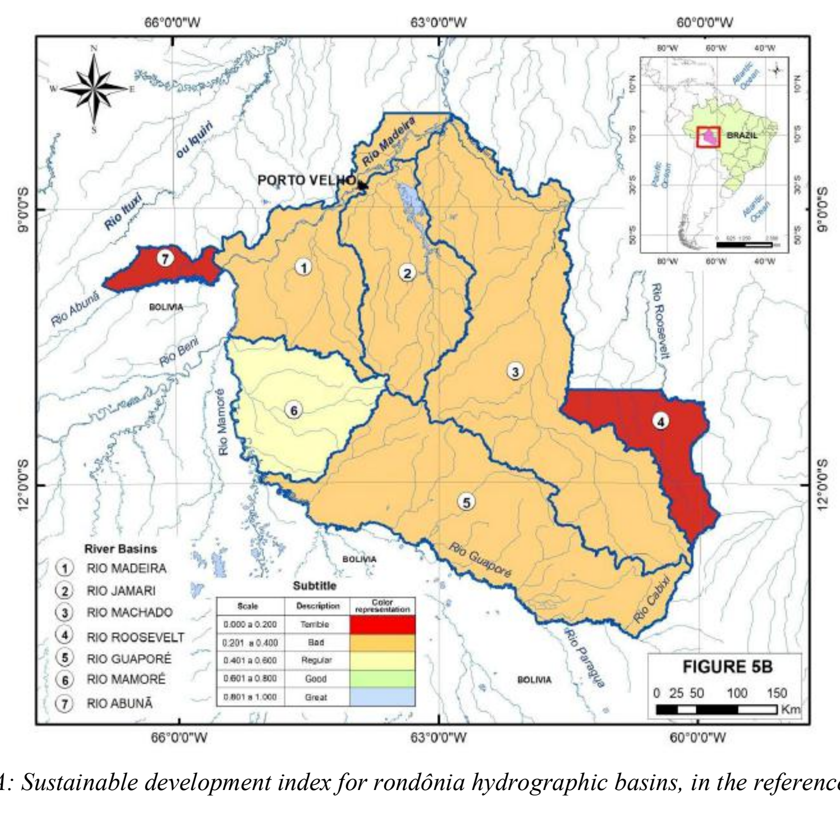

Fig.5A: Sustainable development index for rondônia hydrographic basins, in the reference year.

https://dx.doi.org/10.22161/ijaers.77.26 ISSN: 2349-6495(P) | 2456-1908(O)

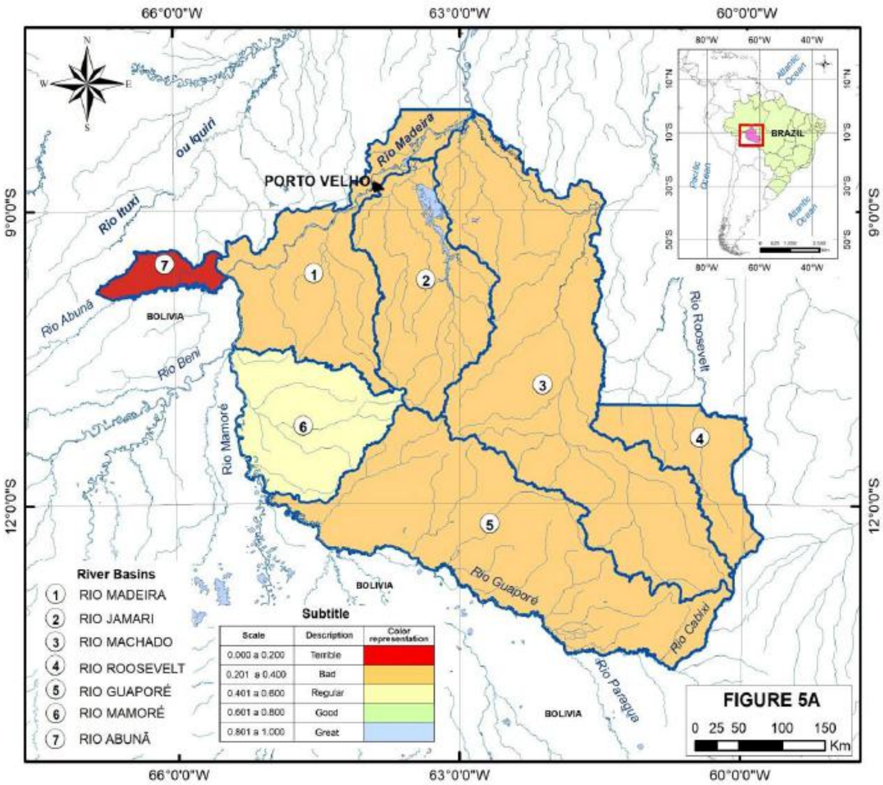

Fig.5B: Sustainable development index for rondônia hydrographic basins, 10 years later.

V. CONCLUSIONS

With the development of this methodology, it was possible to reach the following conclusions: The hydrographic basin of the Mamoré River presented a better index of sustainable development (0.527), however, this index only indicated a "regular" situation, according to the scale adopted, which together with the "poor" performance of the other hydrographic basins, points to a worrying situation in the state of Rondônia.

It was also found that the incipient public policy of strengthening the paradigm of sustainable development at the level of river basins in Rondônia, has contributed to the advance of deforestation in Rondônia.

The generalized decline in social indices, in all studied hydrographic basins, reflects that the current hegemonic model of regional development is not, in fact, bringing an improvement in the quality of life in the respective geographical regions of the hydrographic basins, which, with this, would trigger, among other aspects, the social weakening and the collective effort of local power, thus reducing the criteria for strengthening endogenous social capital.

It is necessary to recognize that the "conservation and development" trade-off is latent in Rondônia and that regional development policies are not being sufficient to solve the problems of regional inequality in the State of Rondônia.It is evident, therefore, with this work that even with the Water Resources Law of the State of Rondônia, approved in the beginning of the 2000s, the results presented demonstrate that the management of hydrographic basins in an effective and full way has not yet been effected.

This is because there are other factors that make it difficult, such as the geopolitical logic established in Rondônia, where a region is practically all preserved to the detriment of economic development even though it is considered a productive region.Thus, it appears that the trade-off "conservation and development" is the biggest challenge to environmental management in Rondônia, as pointed out by Cavalcante [21], Cavalcante; Silva [33], Cavalcante and Góes [30]; [31]; [33], a fact aggravated in the context of river basin areas, where the complexity of interests reaches an even greater dimension.

The factor analysis demonstrated efficiency as a multivariate statistical method in the construction of sustainable development indexes for the river basins of Rondônia.

Finally, it is highly recommended to institutionalize regional public policies in the form of a River Basin Master Plan for Rondônia as a planning and management mechanism for the respective areas, in the perspective of sustainable, integrated and inseparable development of their local communities.

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