Chapter 126

Resilient cities and natural disasters: Analysis of UNDRR parameters for a medium-sized city

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ABSTRACT
Few municipalities have a structure that makes cities resilient in Brazil, whether in terms of studies, planning, and implementation of solutions that facilitate territory management. Most have organizational deficiencies and even lack knowledge of management and control tools to prevent, mitigate or avoid problems related to irreversible urban damage. Thus, a study of the organizational and urban structure in Três Rios-RJ was carried out to recognize these deficiencies and point out synergies and tools to support the decision of urban management.

Keywords: Urban resilience, Master plan, Risk areas, Urban planning.

1 INTRODUCTION

It is common to observe natural areas being modified for the construction of urban areas, agriculture, and construction of highways, among others, to adapt to meet the demands that arise due to the population increase (MMA, 2007). Related to this, it should be considered that the world population has tripled in recent years, causing local issues to gain strength and end up creating different cycles of environmental degradation, as well as promoting an increasingly complex and unsustainable development (UNFPA, 2011).

According to the Climate Analysis and Catastrophes (AON, 2017), 2017 was the second most expensive year ever recorded concerning the damages caused by natural climatic disasters. From these

events, prevention and resilience mechanisms emerge, such as geospatial platforms for sharing data and information on the risk of natural disasters, which in 2010 reached more than 40 million people in 24 countries (Word Bank, 2014). The goal is to effectively achieve and secure the livelihoods of the largest percentage of the population through planning.

As for risk management in Brazil, few municipalities have the structure to promote studies on land use skills within the urban area, indicating the conditions for the occupation of each site. Most of them have organizational and tooling deficiencies in the management of controls to prevent or mitigate natural disasters, either due to a lack of trained teams in the identification of problems, lack of equipment, and updated and insufficient georeferenced information. Corroborating this thought, Assis (2020), discusses that the hazard and risk assessments to the instability of the strands are of interest to several areas of study, especially for professionals of geosciences, engineering, and public agencies responsible for local management throughout the world.

Thus, the implementation of methodologies that assist municipal managers in the planning of public policies, and strategies for the prevention and control of the negative effects arising from natural phenomena, is necessary and urgent. These measures will contribute to the management of urban space, in the face of contemporary challenges of facing disorderly growth and the emergence of informal settlements, which for all related complexity, can be worked with advanced planning and transformative actions. Such measures have a multidisciplinary character because they involve spatial, technical, environmental, and social issues, and the proposed solution should consider such points from reliable data.

In this process, geotechnologies emerge as a support for planning and decision-making, which help the understanding of the urban environment and its vulnerabilities. Enabling the application in several areas of knowledge, in multidisciplinary character, in the analysis and visualization of data, where it is possible to perform simulations of possible environmental scenarios.

This is the case of the municipality of Três Rios/RJ, which has been undergoing intense development due to its good positioning in the southeast region with access to the main centers facilitated by federal highways (BR-040 and BR-393) and railroads, as well as incentives for the renewal of industrial investments. According to Almeida et al. (2010), this development brought a series of benefits such as job creation, population growth, and urban expansion, which, in turn, generated some negative impacts due to the deficient planning in the occupation of urban spaces. Consequently, the formation of underdeveloped neighborhoods and communities without any urban and social planning was generated, which contribute significantly to urban environmental degradation.

The municipality is located between the geographical coordinates Latitude 22°07'00" S and a Longitude 43°12'33" W, has a population of approximately 85,000 inhabitants (IBGE, 2021) in a territorial area of 326.135 km², with topography marked by rounded hills, with a typical valley relief, the municipality is located between the Paraíba do Sul, Paraibuna and Piabanha rivers. This condition reflects on the growth of areas susceptible to disasters, according to the Integrated Disaster Information System (S2iD, 2017),

some events of floods, floods, landslides, and even the rupture of a small rural dam resulting from the heavy rains that hit the region were recorded in the period between 03/01/2000 and 01/01/2020.

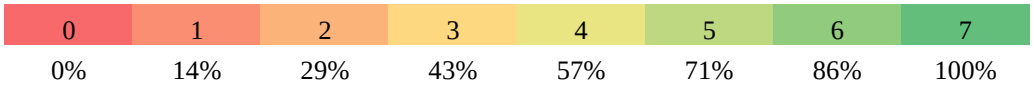
This work is inserted in the context of urban development, aligned with the concept of resilient cities. In this, it is sought to identify the problems and indicate ways to enable the site without significant structural damage in the region. This concept was proposed by UNISDR (2012) – United Nations Office for Disaster Reduction – and establishes ten precepts that cities must comply with to make them ready for natural disasters, such as mass movement and floods.

2 MATERIALS AND METHODS

The work began with the application of questionnaires and interviews in the municipal departments of Education, Health and Social Promotion, Public Service and Transportation, Urban Infrastructure and Projects, Environment and Agriculture, Finance, Works and Housing, in the Mayor's Office and in the Civil defense of the municipal government Três Rios/RJ, where the legal representative of the sector was qualified to answer it. With this, information related to the basic precepts proposed by UNISDR (2012) for a city to be qualified as resilient was collected, which are:

1. Promote organizational and coordination actions to apply risk reduction tools to natural disasters;
2. Allocate a budget to encourage residents of these areas to invest in risk reduction;
3. Maintain up-to-date data on the situation of vulnerability of local homes, through assessments and mappings that will subsidize the review of urban development plans;
4. Expand and maintain urban infrastructure as a way to reduce susceptibility;
5. Evaluate the security condition of the agencies that provide public services;
6. Create and apply specific legislation of land use and occupation, imposing criteria and limitations for the occupation of inappropriate areas;
7. Propose education programs and perception of disaster risks in communities;
8. Protect ecosystems to reduce the impact of flooding and other potential problems;
9. Installation of early warning and alarm systems, in addition to providing the agencies with resources for emergency management;
10. Have an emergency action plan for survivors and post-disaster response for recovery.

The answers to the questionnaires helped in the quantification and evaluation of the degree and capacity of care of these organs, being inquiring about the vision of each one each one and verifying what percentage (%) of alignment they have with the proposed action, being able to then evaluate the degree of urban resilience. The percentage (%) was quantified from the perception of the manager as to the degree of adherence, choosing among the possible options to the one closest to the service capacity of his secretariat, according to the scale below:



It was permissible for the precepts that had shared attributions or for the secretariats that were not fully prepared, to answer both "Yes" and "No" regarding the degree of adherence.

As a cartographic subsidy, we used the Continuous Vector Cartographic Base of the State of Rio de Janeiro, on the scale of 1:25,000 (BC25_RJ, 2018), and the susceptibility data developed by the CPRM (2016) for the municipality.

Subsequently, the cartographic bases were prepared and environmental parameters such as the slope of the terrain were obtained from MD-ALOS orbital images using the ArcGIS ArcMap 10.3.1 software. In addition, field surveys were conducted to identify and spatialize the data obtained, also considering surveys conducted by Ayres (2018). Finally, the interpretation of the data was performed to obtain details and relevant information for the conclusion of the research and generation of the thematic maps.

3 RESULTS AND DISCUSSION

The answers given by the municipal representatives on the precepts of UNISDR (2012) and their applicability in the municipality, which are shown in Tables 2 and 3, were tabulated. These present the percentages of the precepts of the questionnaire evaluated by each entity.

Table 2 – Systematized table with the answers of the secretariats

Municipal Secretariats	Precept 1		Precept 2		Precept 3		Precept 4		Precept 5	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Civil Defense	100%	0%	0%	100%	100%	0%	The	The	The	The
Education	100%	0%	The	The	33%	67%	The	The	67%	0%
Health and Social Promotion	100%	0%	50%	50%	100%	0%	0%	100%	67%	0%
Public Service and Transport	100%	0%	0%	100%	48%	33%	50%	0%	The	The
Mayor's Office	83%	17%	80%	20%	83%	17%	40%	10%	The	The
Urban Infrastructure and Projects	33%	0%	50%	50%	33%	67%	45%	55%	The	The
Environment and Agriculture	100%	0%	100%	0%	67%	0%	50%	0%	The	The
Farm	The	The	0%	50%	The	The	The	The	The	The
Works and Housing	B	B	B	B	B	B	B	B	B	B

Note: A – It is the competence of another instance; B – There was no response

Table 3 – Systematized table with the answers of the secretariats

Municipal Secretariats	Precept 6		Precept 7		Precept 8		Precept 9		Precept 10	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Civil Defense	The	The	0%	100%	The	The	67%	33%	0%	100%
Education	The	The	100%	0%	The	The	0%	100%	The	100%
Health and Social Promotion	The	The	100%	0%	0%	50%	33%	67%	50%	50%
Public Service and Transport	The	The	The	The	The	The	The	The	0%	100%
Mayor's Office	58%	8%	The	The	The	The	87%	13%	80%	20%
Urban Infrastructure and Projects	33%	67%	The	The	The	The	33%	0%	70%	30%
Environment and Agriculture	33%	0%	100%	0%	100%	0%	0%	33%	100%	0%
Farm	The	The	The	The	The	The	The	The	The	The
Works and Housing	B	B	B	B	B	B	B	B	B	B

Note: A – It is the competence of another instance; B – There was no response

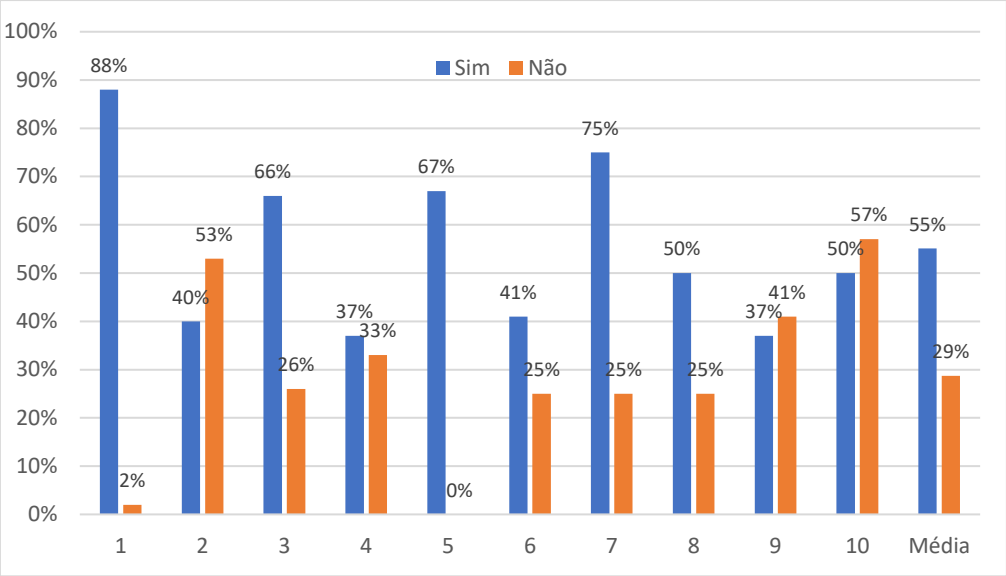
The results indicate how much the public organisms o s are aligned ados with the respective individual precepts, where 100% indicates greater alignment and 0% indicates ignorance, lack of priority, or indifference to the factor. Despite this, it is worth mentioning that some precepts were often not met due to some structural or financial deficiency, alignment of the organ with the required action, and the shared responsibility that each organ has.

In general, the sectors with direct relation to the actions presented good yields, even not having a tool for sharing the information via database or integrated system, generating low synergy, duplication of studies, rework, and even incompatibilities of applications of solutions. This lack of information sharing slows down the decision-making process, which, in turn, can be decisive for the preservation of lives and infrastructure in a calamity situation. In this case, the use of an integrated ERP (*Enterprise Resource Planning*) *system online* can allow the interchangeability between information and database, making the process agile and efficient.

The idea of a "Resilient City" is to think the whole to act on the spot, planning holistically and always acting with a focus on the solution to the problem addressed. For if each secretariat develops individual actions, it may not have a comprehensive and lasting effect, as if they worked together. In this way, if the actions are well planned and based on reliable information, they can impact directly or indirectly on society, the economy, and the environment, with the least effort and operational cost.

Graph 1 shows the average of the answers of the secretariats for each precept obtained from Charts 2 and 3; and, finally, the general average for Yes and No answers considering all the precepts together, in percentage (%).

Graph 1: Average of the 10 precepts about the Secretariats analyzed and final average (%)



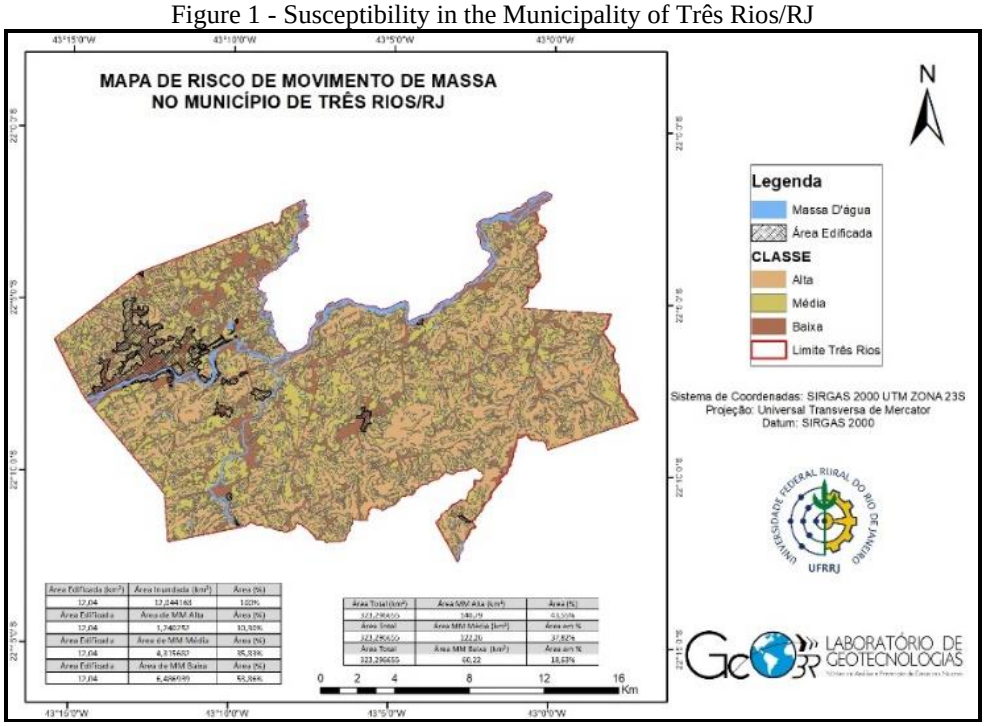
It is observed that the average demonstrates how much the city needs to improve its actions and integrate the different secretariats. In the general average, 55% of the actions have some adherence to the themes related to resilient cities, while 29% of the secretariats do not succeed or have some difficulty in meeting the precepts. This index does not allow the inference of "*non-knowledge*" about the structural and financial deficiencies experienced by the city.

Risk and Natural Disaster Management

Geotechnologies were used to obtain the mapping of areas susceptible to mass movement and flooding in the municipality of Três Rios/RJ, to identify the types of occupation within the municipal territory. Then, the relief was extracted from the MDE (Digital Elevation Model) of the terrain and the slope chart was generated according to the classification of Embrapa (1999). It was considered that the greater the slope, the greater the susceptibility of mass movement due to the gain in rainwater velocity during surface runoff, except in the condition in which the region presents good plant distribution that cushions such movement.

With these data, it was possible to elaborate a map of susceptibilities regarding the mass movement within the municipal territory, identifying the areas conducive to the occurrence of this event. Figure 1 shows the results for the entire municipal territory, but concerning the study of mass movements, the most important areas that need to be verified are urban areas with some degree of occupation. Thus, based on the relief, slope, and type of occupation, it was identified that 10.30% of the urban zone is inserted in a stretch with a high degree, while 35.83% is in a zone with a medium probability of occurrence.

Figure 1 - Susceptibility in the Municipality of Três Rios/RJ

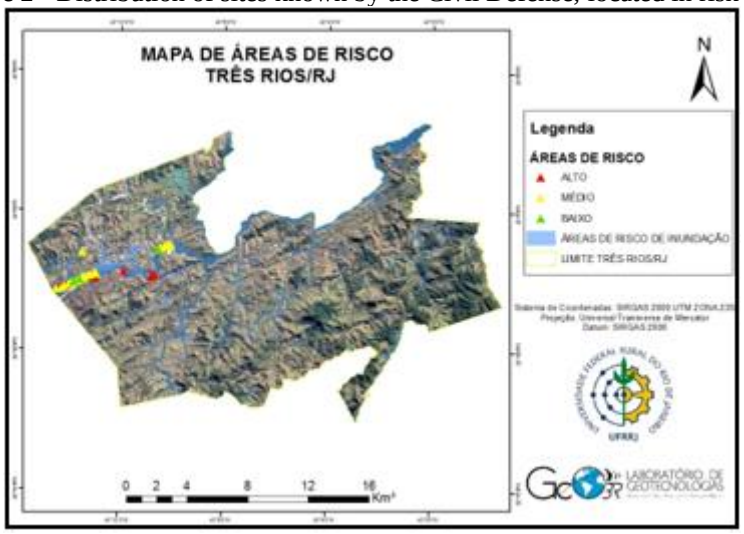


Resilient City: Distribution AND EVALUATION OF VIABILITY

The data obtained were distributed and maps were elaborated, highlighting the precepts 3, 4, 5, 8, and 9 of UNISDR (2012). The reference products used were those obtained by Ayres (2017) for flooding and mass movements.

Precept 3, which requires keeping vulnerability data up to date, was distributed by inference with the help of the Municipal Civil Defense team, given their expertise and knowledge of the areas with the greatest vulnerability. Areas with a history of flooding and flooding were indicated, and that had a large number of families affected. These were systematized in Figure 2 where the areas most susceptible to flooding and whose impacts generate damage above the limits required by UNSDR (2012) are presented, making the area of low resilience.

Figure 2 - Distribution of sites known by the Civil Defense, located in risk areas

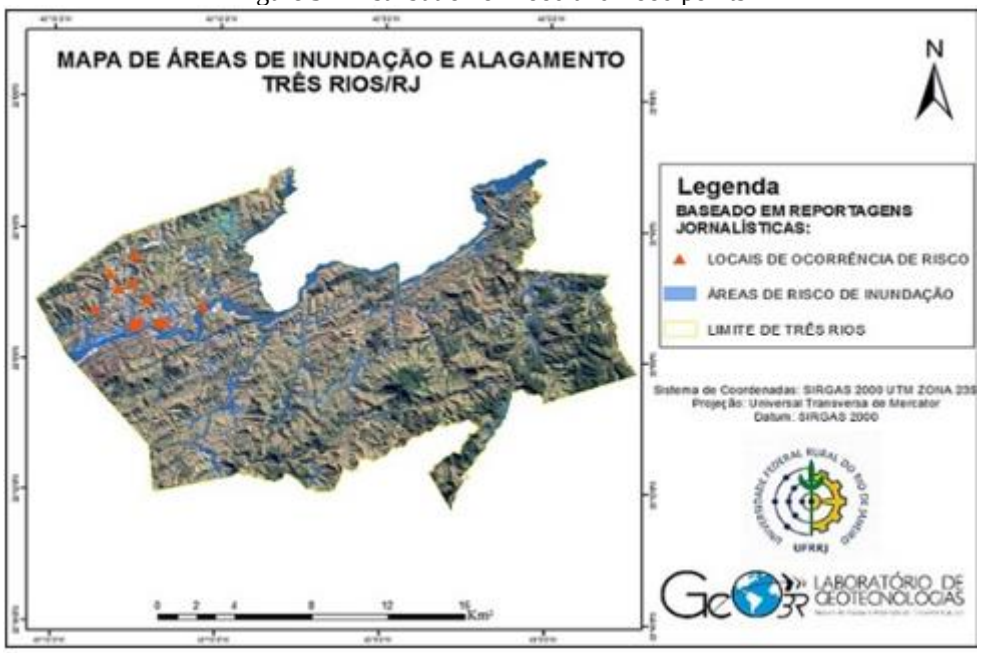


The Municipal Civil Defense carried out a classification of the vulnerability of the areas of the city, being those with a high degree the residences that are below the average quota of the Paraíba do Sul River, those of medium and low vulnerability in the same, and above the average quota of the river, respectively. This classification created empirically by the local agency helps in directing priority efforts since the municipality does not have an early warning system connected to the CEMADEN network.

For precept 4, identification of the infrastructure to reduce susceptibilities, journalistic reports and reports from S2iD (Integrated Disaster Information System) were used between 2000 and 2021. The areas indicated by the G1 (2017) publication were a d d the distributed references on the local map for flooding and flooding (Figure 3).

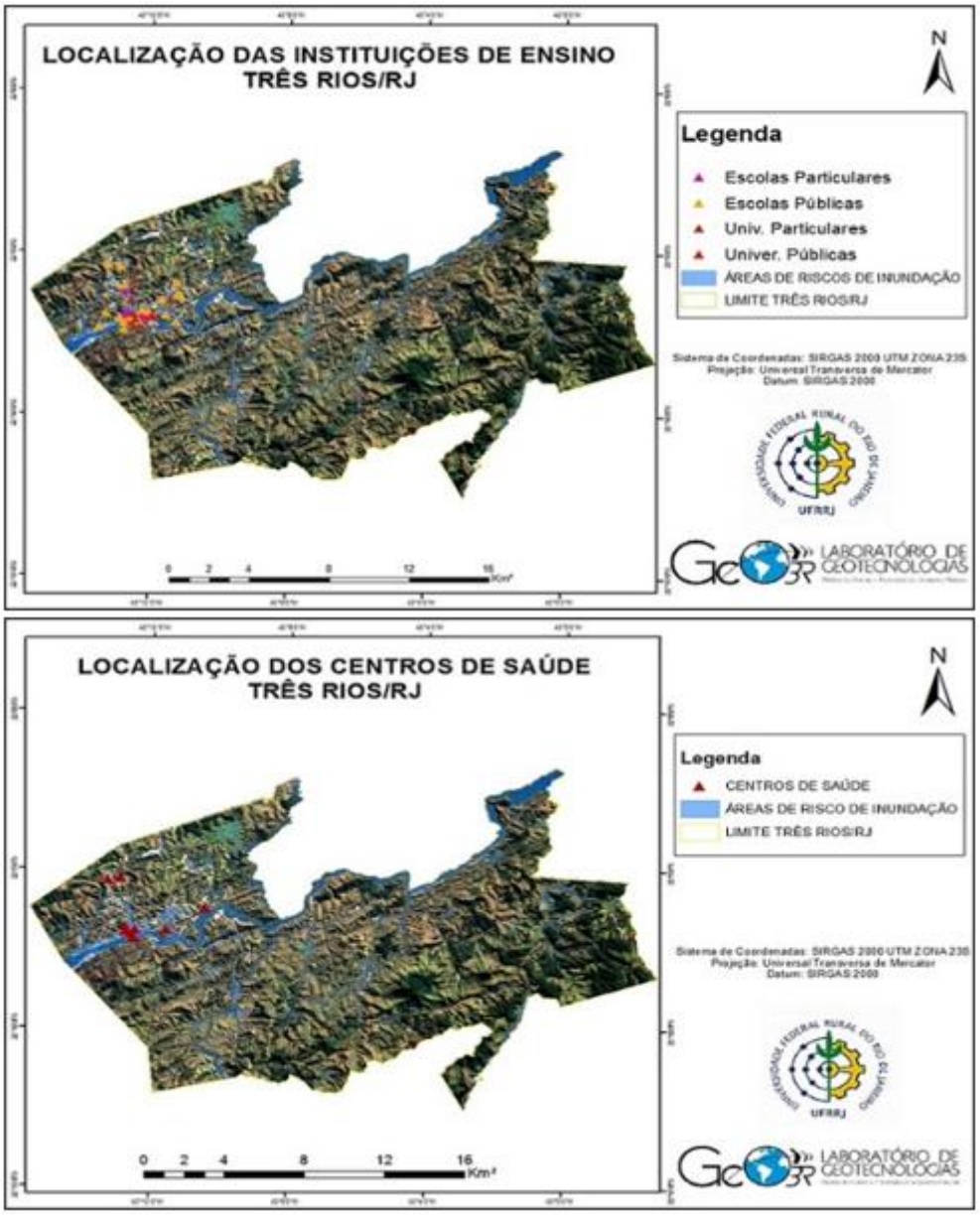
It was verified that the territorial planning linked to the master plan is not obeyed, generating residences and spaces not suitable for human occupation, which, when associated with the lack of urban drainage infrastructure, promotes flooding and flooding of areas. As an example, you can locate on the map the Praça São Sebastião (1), Av. Zoelo Sola (2), Rua Presidente Vargas (3), and entire neighborhoods such as Santa Rosa (4) and Monte Castelo (5), as areas with recurrence of floods and floods.

Figure 3 - Distribution of flood and flood points



In Precept 5, the safety of schools and health centers within the scenarios of exposure to susceptibility was evaluated. Maps were prepared with the location of schools and health centers within the areas identified as vulnerable to flooding, as shown in Figure 4 (A and B).

Figure 4 – (A) Distribution of teaching spaces; (B) and health facilities located in areas susceptible to flooding



These maps elucidated that many public education and health facilities are in areas with the potential for flooding by the waters of the Paraíba do Sul River. Such information is important in a few ways:

i) health facilities in a moment of municipal crisis start to function at their limit, being demanded and not being able to be in sectors or territorial zones with any susceptibility, either to the movement of passes or flooding. During the discussions on the potential for urban resilience, the government must make an effort to identify the appropriate place for the installation of health equipment that is close to the population to be served, but that is in a sector with structural security of the building, access, and heritage.

ii) health facilities in a time of municipal crisis have the flexibility to have their teaching activities suspended during the event. However, these spaces are generally used by the prefectures as points of organization of the actions or reception of the affected population. That is, before installing educational equipment it is necessary to verify a mapping of the best places that guarantee the

permanence of the affected population during the moment of the crisis, in the post-crisis, and in the stabilization phase, when these are redirected to more appropriate places. Therefore, the mapping of susceptibilities ensures more resilience and capillarity of the public power in welcoming the vulnerable population in times of crisis.

iii) Thus, Figures 3 and 4 are relevant in the planning of the support spaces necessary for urban consolidation, both for regular use and mainly for moments of crisis.

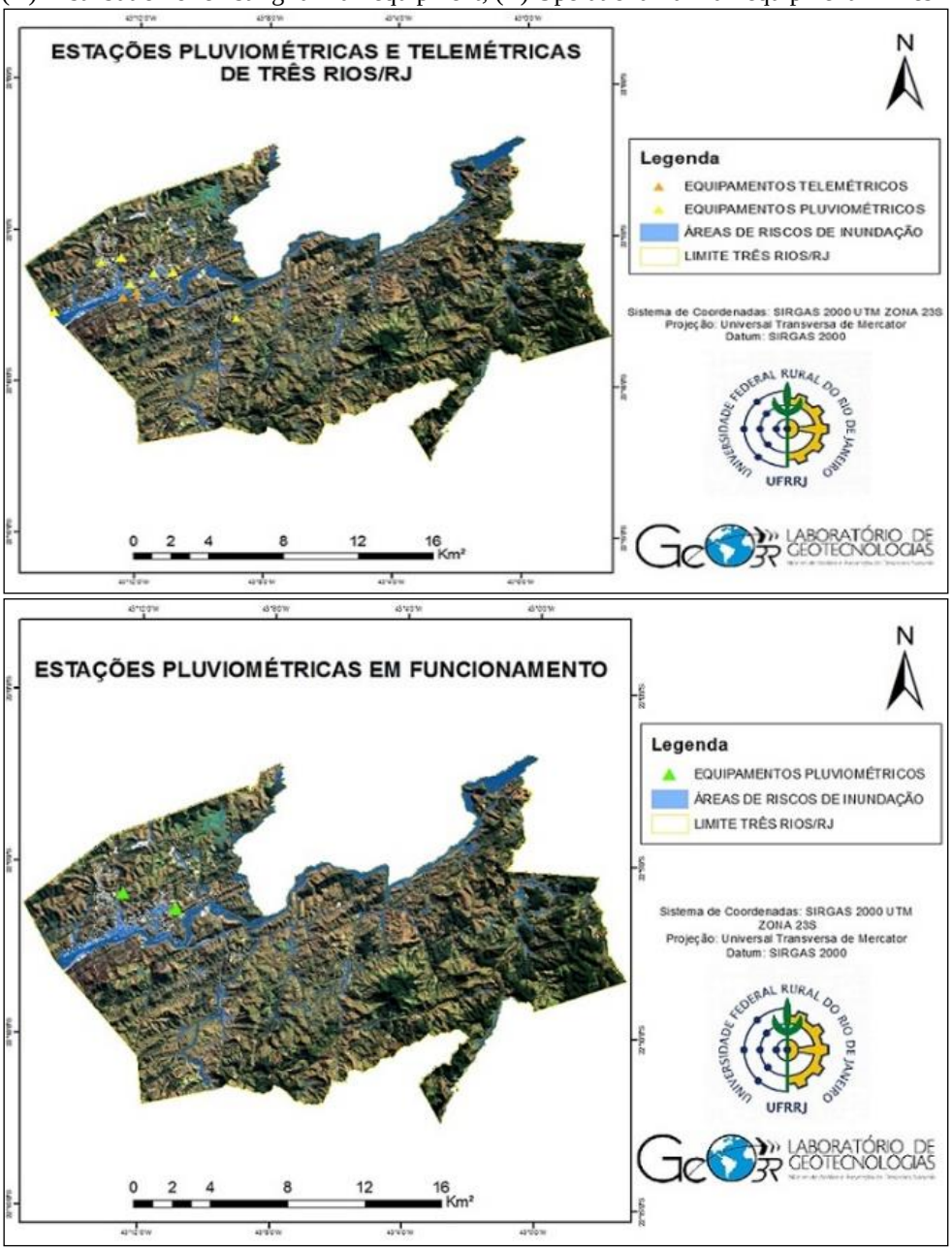
In the discussion of precept 8, protection of ecosystems to reduce the impact of floods and other problems. This precept is aimed at the environmental context and depends on geomorphological information, which indicates the most vulnerable zones to mass movements and flooding. From the analysis of the data obtained for the information model, it was noted that the territory is composed of a large part of the field, having 65.67% of occupation for this feature while the built areas have 22.34% of territorial occupation.

Although we found that the built areas stand out for their low permeability capacity in the soil, it is worth mentioning that the surroundings of this urban area are composed of fields, thus evidencing the need for actions aimed at the preservation and conservation of the natural ecosystems of the municipality, in actions that favor the environmental recovery of regions when necessary or maintenance of the environmental protection areas present in the municipality for environmental and social purposes.

Another issue related to the type concerns the valorization of the flat spaces or the areas of the domain of the river, given its condition of worth bringing a sense of well-being to the consultees. This puts pressure on vulnerable spaces, permanent protection areas (PPAs), and the river's domain strip. In addition, areas whose slope is above that recommended by the land parceling law (>30%) suffer from problems related to irregular self-construction, cuts without adequate technical assistance, and other anthropogenic changes that weaken the urban ecosystem.

In precept 9, the installation of early warning systems, it was verified that there are no monitoring devices installed in the municipality interconnected with the state (Civil Defense) and national (CEMADEN) disaster monitoring agencies, except for the automatic weather station interconnected to the INMET network. As a strategy adopted, the positions in the region of rainfall equipment, linimetric rulers and digital collectors along the Paraíba do Sul River were verified, and distributed on a map (Figure 5). The data obtained from these stations provide important information for the monitoring of the variation of the river level.

Figure 5 – (A) Distribution of existing rainfall equipment; (B) Operational rainfall equipment in Três Rios/RJ.



The data from the listed equipment, distributed on the electronic pages of the organs, subsidize the planning of the action of the municipal Civil Defense. A pre-contingency monitoring measure is the monitoring of the linimetric variation of the ruler in the river, to issue alerts four hours in advance in areas with flood potential. One problem encountered is the non-automation of the alerts, which are manually monitored through the update made available on the websites and field readings by the team itself. That is, there is a need to maintain the installed equipment since only two are operational, with this, there is a discontinuity of the historical series of data harming the anticipated alerts, making the analysis subjective.

Although having advanced information is important, other passive and structuring measures can be taken as a way to mitigate such effects, such as the recovery of floodplain and riparian vegetation, distancing people from the river's domain zone, reducing the rate of urban impermeability and creating recharge zones.

For precept 6, to create specific legislation for planning the use and occupation of land, the municipality of Três Rios has a Municipal Master Plan, which has undergone several updates over time to adjust to the new municipal demands. The current version of 02/10/2013 added the premises of the Statute of Cities, and proposed a modernization of the instruments of management, planning, and territorial control, preserving the continuity of the process of municipal organization, reiterating the principles that aim to ensure the fulfillment of the social function of the city and the full exercise of citizenship. For precepts 1, 2, 7, and 10, it was not possible to analyze and discuss the data, because the necessary information was not provided for the elaboration of the thematic maps.

Resilient City vs. Smart City: DATABASE and Computerization

Among the ten precepts for the construction of a UNDRR Resilient Cities exposed, the municipality meets only one of item 3, which refers to the updating of risk and vulnerability. The municipal Civil Defense raised and prepared a technical report on the susceptibility of landslides, elaborating a general plan with the identification of the areas vulnerable to floods and mass movements. However, the agency has difficulties in keeping the database updated because it is a manual, specialized activity that demands computational resources and instrumentation often unavailable.

This lack of up-to-date information hinders the elaboration of effective public policies in the prevention of disasters or the elaboration of contingency plans in case of high-intensity adverse events. This situation can be identified by the Urban Master Plan itself (DRM, 2012; City Hall, 2013; Nunes, 2013) which does not discuss the theme, which is increasingly worrisome in growing cities due to the occupation of vulnerable spaces.

The departments of Housing, Works, Education, and Environment were consulted to verify the knowledge about this database and the level of interaction with the Civil Defense in projects that foster participatory management and dissemination of information on natural disasters. It was found that there is no knowledge and interaction between these agencies, which makes the implementation of campaigns in the municipality more complex. That is, for the municipality in question to become resilient, there are many aspects to be worked on in line with the guidelines of the "Building Resilient Cities" campaign.

As well as the municipality of Três Rios, according to G.R.R. (2014), several others around the world have problems sharing information, either by the lack of an efficient information system or by the lack of training of personnel and even the lack of standardization of shared data. With the new cloud-based systems, where data can be fed by multiple industries and integrated and analyzed by a data science team, that situation could change. These systems allow a graphical, advanced, and objective analysis of urban problems, enabling managers to make decisions based on priority levels.

With this, it is expected that cities that integrate their information will tend to move closer to the precepts of UNDRR for a resilient city. But for this, they will need to go through a process of computerization of the city, as mentioned by Souza (2017) and Félix Junior et al (2022), since these need

to be technologically equipped to provide sustainable and economic services to their residents, promoting the socioeconomic development of the city.

4 FINAL CONSIDERATIONS

The municipality of Três Rios/RJ has well-structured actions for some precepts, but it shows deficiencies in interrelated actions. The data presented show that several sectors are unaware of their attributions or do not have the resources to carry out actions, and could improve management through the sharing of information and resources.

This situation directly impacts the condition of urban resilience that is desired. Some measures of simplification and optimization of resources can help in the mitigation of problems, in particular, the natural disasters resulting from disorderly expansion. Among the tools, mapping is the efficient way to present susceptibilities and plan solutions for a resilient city, followed by direct interventions.

About the 10 precepts, it was identified feasibility of making thematic maps in 50% (3, 4, 5, 8, and 9) contributing to decision support. For the others, it was not possible to develop the maps due to a lack of information. Such subsidies allow the structuring of public policies aimed at the organization of infrastructure and urban resilience, talking directly with the master plan. Thus, the elaboration of integrated strategies allows for the identification of problems, and synergies and indicate preventive solutions in search of the social, economic, environmental, and physical resilience of the municipality.

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