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Lessons learned from the 2011 landslide event in Nova Friburgo, Brazil? – A resilience study on the community and municipality levels

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Abstract

The events that happened in the State of Rio de Janeiro on January the 11th and 12th 2011 represent one of the severest disasters in Brazilian history. Neither the State of Rio de Janeiro nor the country were prepared for the disaster that was generated. In the event approximately 300,000 inhabitants were affected and more than 900 died, and there was a total estimated material loss and damage of $4.78 billion *Reais*. The origin of natural hazards such as the landslides, mudslides and flood events in Nova Friburgo has been studied by several researchers, however, as the disasters are not just under a natural category, their study must include social, political, economic, and cultural aspects to understand if the actions taken till 2017 have been improving the resilience in the municipality.

Based on the analysis of secondary and tertiary sources, the present study addressed the theme of resilience under different methodologies such as the Framework for the Promotion of Community Resilience of the International Federation of Red Cross (IFRC), the Baseline Resilience Indicators for Communities (BRIC), and the United Nations University methodology for resilience measuring. In consequence, this project aims to analyze the resilience through six categories, and 31 indicators, comparing each indicator before the disaster, and after the disaster with the purpose of discerning if it is improving or not the resilience process.

Only six years have passed since the disaster affected the municipality, so the government, the community, and the academy, still have plenty of work to do. However, the progresses have been significant in several indicators, and all the stakeholders have been working to improve their capacities, as well as their resilience for similar events.

Key words: Resilience, disaster, social-ecological systems, indicators, measurement.

Resumo

Os eventos no estado do Rio de Janeiro nos dias 11 e 12 de janeiro de 2011 representam um dos maiores desastres da história brasileira. Nem o Estado do Rio de Janeiro nem o país foram preparados para o desastre que foi gerado. No caso, aproximadamente 300.000 habitantes terem sido afetados e mais de 900 morreram, e houve uma perda material estimada de US $ 4,78 bilhões Reais. A origem dos riscos naturais, como os deslizamentos de terra, deslizamentos de lodo e eventos de inundações em Nova Friburgo, foram estudados para vários pesquisadores, no entanto, como os desastres não são apenas uma categoria natural, seu estudo deve incluir aspectos sociais, políticos, econômicos e culturais para entender se as ações realizadas em 2017 melhoraram a resiliência no município.

Com base na análise de fontes secundárias e terciárias, o presente estudo de caso abordou o tema da resiliência sob diferentes metodologias, como o Quadro para a Promoção da Resiliência Comunitária da Federação Internacional da Cruz Vermelha - IFRC, os Indicadores de Resiliência Base para Comunidades - BRIC , e a metodologia da Universidade das Nações Unidas para a medição de resiliência. Em conseqüência, este projeto vai analisar a resiliência através de seis categorias e 31 indicadores, comparando cada indicador antes do desastre e após o desastre com o objetivo de discernir se está melhorando ou não o processo de resiliência.

Apenas seis anos se passaram desde que o desastre afetou o município, de modo que o governo, a comunidade e a academia ainda têm muito trabalho a fazer. Entanto, os progressos têm sido significativos em vários indicadores e todas as partes interessadas têm trabalhado para melhorar suas capacidades e sua resiliência a eventos semelhantes.

Palavras-chave: Resiliência, desastre, sistemas socio ecológicos, indicadores, medições.

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1. Introduction

The events in the State of Rio de Janeiro on January the 11th and 12th, 2011 represent one of the severest disasters in Brazilian history. Torrential rains in seven municipalities of the Serrana region caused death to more than 900 people and affected more than 300.000 inhabitants (Banco Mundial, 2012). On this matter, (2014) mentioned that "*landslides, mudflows, and floods are the most common disasters in Brazil. Most of the events are violent, causing fatalities, economic losses and damage to infrastructure, both in rural and urban areas (INPE, 2007; IFRC, 2012)*", and about 150 Brazilian cities, including Nova Friburgo, were affected by this type of events.

On January 11th and 12th, precipitation levels were above historical records, affecting the municipalities of Nova Friburgo, Petrópolis, Teresópolis, Bom Jardim, São José do Vale do Rio Preto, Sumidouro, and Areal in an estimated area of 2.300 km^2 with more than 713.000 inhabitants (Busch, Amarilis & Amorim Sônia). Neither the State of Rio de Janeiro nor the country was prepared for the disaster that was generated. According to the data by (Banco Mundial, 2012), there was an estimated total material loss and damage of $4.78 billion *Reais*.

The project Eco Technologies and Services for a Sustainable Rural Rio de Janeiro (INTECRAL) is supported by the Federal German Ministry of Education and Research (BMBF) and the Ministry of Agriculture and Livestock of the State of Rio de Janeiro (SEAPEC-PRR) for the funding period 2013 to 2017. It aims at improving the competitiveness of Rural Rio de Janeiro by integrating climate and environmental friendly and measures and technologies into rural development. The INTECRAL project includes five work packages (WPs). In this sense, WP1 includes the administration of the project and building relationships with stakeholders. WP2 is dedicated to good agricultural practices and participatory planning. WP3 focuses on

restoration and conservation of degraded lands, while WP4 is related to water monitoring, modeling, watershed management, and sanitation of hydrographic basins. Finally, WP5 includes the cross-cutting topics of ecosystem services, alternative markets, and governance.

The presented master thesis project was elaborated within the frame of WP5 for different reasons. First, it focuses on the conditions for the implementation of climate protection projects. Also, it emphasizes on the use of international models and other models that can be adapted to other regions like the municipalities in the State of Rio de Janeiro. Then, the already mentioned project will be done to gain an understanding of the activities developed by the community and the government when building resilience after the landslides occurred in Nova Friburgo. This is related directly with the purpose of the WP5, in terms of climate protection and ecosystem services, which also includes governance issues, as it was mentioned before.

2. Theoretical Framework

2.1 Political Ecology

The political ecology was mentioned for the first time by Frank Thone in 1935, then, a lot of authors have used the concept without an exact definition. Bryant and Bailey (Bryant and Bailey, 1997) for example, studied the political ecology as the union between cultural ecology and political economy, combining the society-nature relationship with the unequal wealth distribution. In another line, there are authors who refer to political ecology as the union of ecological economics and politics. This union arises from the valorization of nature, and the creation of movements that sought to recover the non-economic value of natural resources (Alimonda and Escobar, 2011; Martinez-Alier, 1997), rethinking the politics from a relationship among nature, culture, and technology (Alimonda and Escobar, 2011).

In the approach of Boaventura de Sousa Santos (2006), he defines Political Ecology as the possibility that science will be part of an ecology of knowledge, where scientific knowledge can create a dialogue with secular knowledge, with people's knowledge, with indigenous' knowledge, with the marginal urban population's knowledge, and with farmer's knowledge, among other types.

This line of thinking supports the importance of a research project that incorporates the community knowledge about the risk, as well their perceptions about daily situations and how to deal with it.

In addition, it will be necessary to understand the processes, decisions, and actions that involve the community and government, and to analyze if they have had an impact on their environmental management.

Beyond the community knowledge, it is important to highlight that politics cannot be disregarded from the society-nature relationship. Therefore, a

decentralized government, whose activities are not commanded from a central government institution, that even encourages decision-making in a disaggregated way, should be studied in its different instances, namely national, state, municipal, and community to understand and establish the best participation strategy.

2.2 Cultural ecology

Regarding the relationship between nature and culture, many authors have spoken many years ago about this theme. The first approaches were made by Julian Steward (1955). He spoke, among other issues, about the multilinear evolution of a culture in response to the environment in which it is located, in such a way that the environment, technology, and forms of work were the main determinants of cultural evolution (Nanda, 1987).

From Steward, several authors have deepened much on this subject, such as Leslie White (1975), (1996), and (1997), who studied the issues related to the evolution and cultural development on the basis of nature or the environment.

Sahlins & Valdivia (Sahlins and Valdivia, 1997) for example, discussed the cultural meaning of the objects and their influence on the way of life of the people and vice versa in "Culture and reason". Also, explaining how from these meanings are given socio-economic and socio-cultural relations. However, in Durand's words (Durand, 2002) *"the real legitimation of Cultural ecology was given when Julian Steward published the theory of culture change (1955)"* where this line of thinking *"is set, then, as the study of the adaptive process by which human societies conform to a given atmosphere from livelihood strategies"*.

It is not the purpose of this project to analyze in depth the cultural ecology, just to emphasize that the study of disaster risk management makes sense under

this theory, because the analysis of the nature – society relationship — is essential to perform an adequate and effective approach.

In addition, to emphasize that plan and to execute intervention strategies, understanding significance of the environment for a community, will generate a 'two-way' acculturation process, in which the involved parts could regard to improving reciprocally (Gallino, 1995). For this reason, to incorporate the perceptions of the community will be very important for this master thesis project.

2.3 Resilience in Disaster Risk Management

Resilience as a concept could have several meanings depending on the area of study. Therefore, to analyze resilience in the context of Disaster Risk Management (DRM), it is mandatory to understand some other concepts such as risk, disaster risk management, and vulnerability. Thus, for the purpose to become aware of the relationship among disasters and resilience there are some matters to clarify.

According to La Real Academia Espanola (RAE, Spanish for the Royal Spanish Academy), ***risk*** is the possibility of loss, injury, contingency, or proximity of damage. However, the concept of *risk* has been used for different purposes and in different disciplines such as medicine, finance, management, environment, among many others. In this way, this term is usually defined as the probability that an event, which generates negative consequences, occurs (UNISDR, 2009). This definition denotes a clear relationship between the event and the harmful consequences. Fortunately, to make it more specific, each discipline has included adjectives or descriptive forms to frame this construct under their study.

For the United Nations International Strategy for Disaster Reduction (UNISDR), means "*the combination of both an unfortunate event with the negative consequences it generates"* just as life losses, health conditions, livelihoods, goods,

and services and the fact that it could occur in a particular community or society in a specific period of time (UNISDR, 2009, p. 30).

Furthermore, it is important to emphasize that the concept of disaster risk cannot be reduced only to environmental aspects. Currently, there are different aspects of it like prioritizing the analysis of social, economic, political, and community aspects associated with natural issues. Thus, moving away from environmental determinism and it is relevant highlighting the close relationship between the occurrence of natural phenomena and human settlements in terms of economic, social, and/or cultural vulnerability (CAPRADE, 2009; Mansilla, 1993; Maskrey, 1993; UNISDR, 2009).

Hence, for this study, ***disaster risk*** is defined as the probability that an event derived from one or more natural hazard, not anthropic, generates an interruption in the normality of a community, affecting its livelihoods and its economic, social, political, and environmental conditions.

Now, having established the concept of disaster risk, it is necessary to make reference to ***Disaster Risk Management*** (DRM). DRM is commonly understood as "*the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster"* (UNISDR, 2009, p. 19).

However, for the sake of clarity, some constructs will be deeply defined. First of all, DRM, from this project's point of view, it is a process of cultural, environmental, economic, and historical analysis that allows coping with the impact of natural phenomena in a community. Within this context, a ***hazard*** is understood as the natural phenomenon that can cause an interruption in the normal life of a

community, causing material and immaterial losses (Ávila Flores and González Gaudiano, 2015; Calderón Aragón, 2001; *Law 1523 of 2012 - SNGRD.* Colombian Republic, April 24 - 2012; Lavell, 1997; UNISDR, 2009).

Another concept that is necessary to understand is ***vulnerability,*** which is defined as the conditions and characteristics of a community that make it likely to be affected when a risk materializes (UNISDR, 2009, p. 35).

Taking into account the above, both vulnerability and DRM concepts should be analyzed from social contexts as the outcome of anthropogenic proceedings involving cultural, economic, and political aspects. This approach strengthens the argument that disasters are not natural (Audofrey, 2007), in contrast, there is a complex system which needs to be analyzed as a multivariate and multidimensional matter.

As a matter of fact, a disaster is studied considering the risk and the vulnerability of the population, allowing raising actions and activities that can contribute to the identification and implementation of factors that promote ***resilience*** in a community or, in other words, to strengthen capacities to prevent, prepare, respond, and adapt to conditions of risk or disaster. Aguirre (2006) for example, goes beyond the concept of resilience and applies it not only to a community since it is understood as part of a complex system:

> *Resilience is the ability of a system to react appropriately to the moments of crisis, which have not been fully anticipated, and its ability to anticipate such crises and erect, through planning and recovery, changes in the system that allow to mitigating its effects. It is a process that does not end [...] a resilient system is where there is both an awareness of potential threats and its physical, biological, psychological, social and cultural effects,*

and taking action for the anticipation of those demands to minimize them. The development of resilience needs a change in our conceptualizations from discrete strategies to reduce vulnerability and risk, to a more integrated and holistic collective approach to highlight the security (Aguirre cited in(Macías, 2015)

There has been a discussion around the term resilience, originally from ecology, subsequently applied to psychology and used later in social and environmental sciences. There are those who agree with its use and there are others who do not. Some authors like Macías (2015) argue that the term vulnerability allows a more holistic and general analysis about environmental issues. This point of view is based on authors who study disasters with greater emphasis on vulnerability and multi-causal disasters analysis, involving social, political, and economic, aspects beyond mere natural affairs (Blaikie et al., 1996).

In order to understand better *resilience*, the Community and Regional Resilience Institute made a complete analysis of the concept in different disciplines such as ecological systems, or physics; and community or individual levels (White, 2013).

The first author who mentioned the Resilience concept was Holling (1973), who introduced it as the ability of systems to absorb changes and still persist, but the concept has changed over time, becoming complete but complex to understand.

Regarding a physical point of view, (2004) talks about the speed of a system to return to equilibrium, and (2004) defines it as the ability of a system under stress to return to its original state. Both of them made important progresses around the concept, but it was not until the last decade when Adger (2003) included the resilience concept in social systems and thereby added the adaptation to it, which

made the difference for future assumptions. He talks about the ability to persist and the ability to adapt, to change unforeseen circumstances, and risks. Moreover, he goes even deeper into the concept of adaptation of a society, defining it as a dynamic process determined, in part, by the ability to act collectively (Adger, 2003).

The concept of resilience changed in that specific moment. It was not just the ability to persist or to resist; it turned into the ability to change, to adapt, to generate the feedback, and the analysis that obliges the society and the community to improve. It became into a process of improvement permanently with the objective to remain and not to disappear.

After the decade of disaster risk reduction, proposed by the United Nations and this new approach of the concept, the term resilience became very popular in areas related to natural phenomena and disasters (Bruneau et al., 2003; Godschalk, 2003; Resilience Alliance, 2010; Sudmeier-Rieux, 2014; UNISDR, 2004, 2005).

According to Macías (2015), it has been thought that vulnerability only refers to failures in risk management, and resilience to the successes. In that sense, vulnerability would be what is done in a wrong way, and the conditions that make communities susceptible. On the other hand, resilience is what is well done; such as prevention; preparation; adaptation; and effective response. His criticism arises because, even though the concept is used for decades, it became fashionable during the 90s in the United Nations disaster risk reduction decade. In contrast, structural issues, associated with social vulnerability, like society, politics, economics among others were not analyzed through resilience, which was just the strength to recover or anticipate from disasters; the strength to resist impacts or crisis (Macías M., 2015, p. 320).

In addition, Macías expresses that there is an association between both the concept of vulnerability and poverty. It is believed that only the poorest people are vulnerable and, in that sense, the efforts are oriented without recognizing the substance reasons that cause not only poverty but also susceptibility to being affected by a disaster. Then, he explains that under the concept of social vulnerability, all the issues can be analyzed, both positive and negative, without the need to divide them into good or bad, through vague concepts or to be politically appropriate (Macías, 2015).

On the contrary, Ávila Flores and González Gaudiano (Ávila Flores and González Gaudiano, 2015) prefer to differentiate between vulnerability and poverty and treat them as related; but separate topics. They even have the intention of establishing a different mechanism between vulnerability and risk to achieve resilience. Sudmeier-Rieux (Sudmeier-Rieux, 2014) on the other hand, explains that increasing resilience does not necessarily mean reducing vulnerability, poor houses for example, are easier to rebuild because of their materials (more resilient), but are at constant risk (more vulnerable) because of the type of settlement.

This research differs from Macías' concept of separating resilience and social vulnerability. In fact, the study of resilience encompasses social concepts such as poverty and economic capacity, as well as concepts of disaster risk management. Also, this research differs from Sudmeier-Rieux's concept, because resilience could not be understood just as reconstruction. Resilience is a process which involves phases before and after the event.

For that reason, this research is based on the concepts of resilience from the International Federation of Red Cross (IFCR, 2014) and the United Nations International Strategy for Disaster Reduction (UNISDR, 2009). These two institutions conceive resilience not only as a process of strengthening and capacity building

when a disaster occurs, but also as a process that covers phases such as “before” (preparation), “during” (response), and “after” (reconstruction); an event that implies some risks for a community or impacts their livelihoods and normal function. In fact, they also envision resilience as a process with different levels, from the household to the national level or even beyond to global level. In this way, the main objective of this project is to analyze resilience process and to study how it is built.

In the same sense, the IFCR and the UNISDR have also categorized resilience into community resilience and urban resilience. The first concept (categorized resilience) focuses directly on strengthening the community and the families that compose it. The second term (urban resilience) is more explained in a holístic matter. It aims its attention at preparing cities for different hazards, involving as many stakeholders as possible.

As it has been discussed so far, the concept of resilience may be general and complex because it involves many different parties, sub-parts, concepts, decisions to be made, and approaches. Due to that complexity, resilience can be categorized into different types of resilience, such as community resilience, urban resilience, and institutional resilience, among others. Each of these types analyses and studies resilience from its own point of view.

Studying resilience in the field of disaster and social issues is complex. That is why there is the need of involving society and incorporating social, cultural, and environmental aspects to be accurate and opportune in the event of a disaster. For this reason, resilience cannot be isolated from community. It should be a result of a participatory process generating shared knowledge and effective actions to work on different levels (IFCR, 2014). As Allan Lavell (Lavell, 1997) said, it is not simply illustrating the population, it is understanding them while understanding their needs, their lifestyle, and differentiating between community, family, social, and

political aspects at the same time that the community makes those distinctions by itself. This understanding needs to take place with the purpose of generating a real resilience process within people, communities, and even within the system as well.

In Figure 1. Concept sequence, it could be found a summary of the concepts that will be used in the present master project. This figure includes Risk, Disaster Risk, Disaster Risk Management (DRM) and also, concepts directly associated with DRM as vulnerability, hazard, and resilience.

2.4 Resilience and Social-Ecological Systems

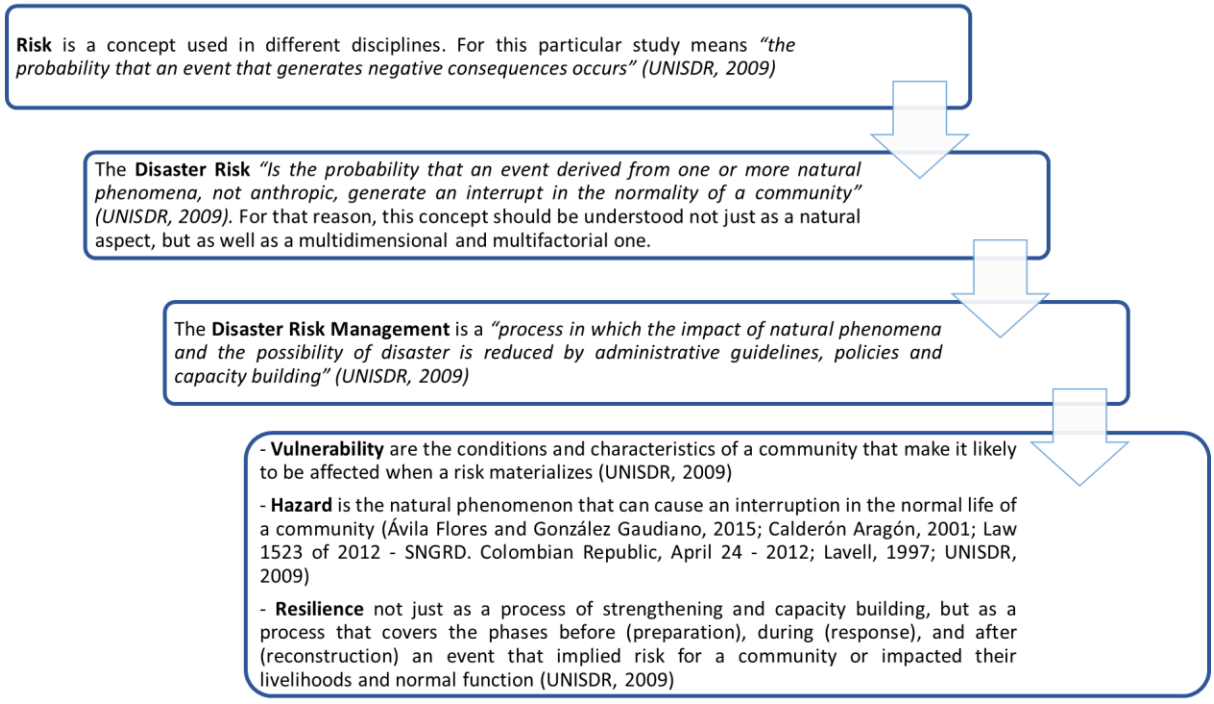


Figure 1. Concept sequence. Own elaboration based on (UNISDR, 2009)

Even when the idea of resilience was introduced in the 70s for ecological systems, it was not until the 90s when the concept was relevant to social systems. And it was in 2000, when the three concepts were working jointly, through the analysis of resilience as a social and ecological concept (Adger, 2003; Bruneau et al., 2003).

The authors who studied this concept usually made reference to cultural, economic, political, and social aspects. Those aspects and their interdependence with nature, make the study of disasters a complex discipline, which involves multiple variables and scenarios.

In words of the Resilience Alliance (Resilience Alliance, 2010), these systems in which cultural, political, social, economic, ecological, technological, and other components interact, are referred to as social-ecological systems. Social-ecological systems (SES) emphasize the "humans-in-nature" perspective in which ecosystems are integrated with human society.

Holling (Holling, 2001) for example, distinguished human systems as part of ecosystem and social system. In these social-ecological systems, they establish foresight, communication, and technology as the three features that made them special and unique systems.

Chapin et al. (Chapin et al., 2010), on the other hand, determined a framework for systems to adapt rapidly to the changing planet. There, they explain that systems are composed by socio-economic, biological, and institutional diversity that provide building blocks for adaptation processes.

In such matter, the situation that was lived in Nova Friburgo is composed of a set of features and particularities that are necessary to analyze, in order to determine if the actions that have been taken, are helping to build resilience in the

community. The work, in this sense, does not only understand them as components of resilience, also empowers the community to provide the tools for understanding their own resilience and act accordingly (Bergamini et al., 2013).

Hence, there is a need to establish whether these activities are generating or not resilience and at the same time, it decreases the vulnerability of the community. For this research, the social-ecological systems encompass and include in a great manner the environmental issues, with some social complexities.

In that context, this case of study is a holistic and complex system, in which the social and ecological characteristics are deeply correlated. For that reason, changes in one aspect may result in changes in other aspects. All the mutual and continuous influence should be examined as strong as possible, in order to understand and explain not just the disaster, but also the reasons, and perhaps, it could be established a way to act and improve the resilience of the community.

Although the resilience approach applied to SES provides a conceptual foundation for sustainable development, one area in which the resilience theory is critically underdeveloped is in metrics, because of its abstract and multi-dimensional nature (Bergamini et al., 2013). In words of Schlüter *et al*. (Schlüter et al., 2014), SES models are also often based on assumptions about human behavior or ecological dynamics with potential effects on model outcomes. Those characteristics made the models extremely uncertain, so, as far as this case is complex, it would not be possible to expose all the elements related, much less, to measure and to explain all of them.

As it was mentioned, there is usually difficulties regarding resilience measurement strategies. Even though, there have been several international organizations developing different types of mechanisms and strategies to measure disaster resilience.

For example, Cutter *et al*. (2008) developed the Disaster Resilience of Place (DROP) model to improve comparative assessments of disaster resilience at a local community level. They provide a conceptual framework including concepts such as hazards, political ecology, global change, and ecosystems in order to create a set of variables for measuring resilience.

> *"Even when it is not obvious what leads to resilience within coupled human-environment systems or what variables should be utilized… As human actions impact the state of the environment and, in turn, a degraded environment provides less protection against hazards (…) for the DROP model the link between community resilience and environmental conditions, as the treatment of its resources is inextricable."* (Cutter et al., 2008, p. 601)

Thus, in the DROP Model, the researchers divide the measurement into six dimensions: namely ecological, social, economic, institutional, infrastructure, and community competence. Each one of these dimensions contains a set of variables, in which the measurement determines the resilience in the community level.

The relevance of this model lies; firstly, on its capacity to work vulnerability and resilience as complementary concepts. Secondly, it is build on its capacity to include antecedent conditions, like inherent vulnerability and inherent resilience, which indeed, are conditions influenced by exogenous factors such as the environment, society, and politics. And thirdly, this model is relevant because it recognizes that models are simplifications of reality, in that sense, several assumptions are implicit.

The use of general dimensions, built on the basis of a set of variables, is a clear way to divide the information and simplify its collection. This model builds a good basis on different concepts, from different sources.

For the reasons mentioned above, the BRIC (Baseline Resilience Indicators for Communities) complemented this model (Cutter, 2010). The BRIC is an empirical methodology, and a set of indicators, for measuring baseline characteristics that foster community resilience. This method allows monitoring resilience changes over the time in the same area, as well as comparing resilience variables in different areas in the same period of time.

According to Cutter (2010, p. 6), "*…there is consensus within the research community that resilience is a multifaceted concept, which includes social, economic, institutional, infrastructural, ecological, and community elements."* In this sense, it is important to analyze different categories and to complement this term.

Other examples of measuring resilience are given by the International Organizations like UNISDR, which works on resilient cities, or IFCR, which works on resilient communities.

IFCR for instance, measures the adaptive capacity to climate change and adverse situations in communities. This institution developed a framework for their national societies to work together with the community in building resilience indicators. This framework measures six categories, the basic unsatisfied needs, social cohesion, economic opportunities, infrastructure and access to public services, natural resources management, and connections between the community and the government.

Although IFCR methodology to measure resilience in communities is inclusive, it is not totally adequate to employ for this project because some of the indicators used by IFRC are not measurable or there are no parameters to compare what is been measured. In addition, the workshops and the indicators measurement of this institution require a lot of specific information, which is not always available.

On one side, UNISDR has been focusing on resilient cities, which eventually have oriented this institution to analyze more deeply urban resilience, better than social resilience. It is important to address how they have been working to encompass all the stakeholders. However, the more general this approach is, the more complicated the social issues get.

On the other side, the United Nations University (UNU), with the Satoyama Initiative, developed a toolkit for the indicators of resilience in socio-ecological landscape productive systems (SELPS). As the name suggests, this methodology is more oriented to natural issues, than to disaster risk management. Besides, this approach is closest to the conservation of biodiversity than to social and political issues; they developed a strong measurable procedure.

Each indicator of the UNU methodology could have five possible scores (1 the lowest and 5 the highest), depending on previous established characteristics or requirements. This type of measurement allows the researcher to take a parameter and compare the actual status of the variable with the ideal one.

Other researchers have measured similar issues. Coelho-Neto and Freitas (2011Avelar et al.; 2015; 2007; Freitas et al.; Freitas et al.) for example, have worked on several projects with the community of Córrego D'Antas after the landslides in Nova Friburgo. Also, Lange *et al*. (2014) studied resilience on the perception of risk and climate change on the ecosystems of the Mata Atlântica.

Despite the fact that these researches contributed to the construction of this project, it would take a lot of time and resources to perform workshops and to analyze community perception. Nevertheless, it would be ideal to adapt these methodologies in order to fulfill this research, but unfortunately, the lack of resources and time did not allowed to execute these procedures.

In order to measure socio-ecological issues, it is very important to use as much quantitative as qualitative analysis methods. For that reason, assessments like Assessment of Impact and Adaptation to Climate Change (AIACC) performed in Sudan are really important. In this assessment, different investigators, from diverse institutions, developed a method to measure resilience. This method contains a set of qualitative and quantitative indicators that were qualified in five levels through community workshops, resulting in a chart of resilience indicators considering multiple scales for social and for ecological issues (Elasha et al., 2005).

Similarly, other investigators have agreed on the importance of social and ecological analysis to understand community resilience contexts. Even though there is no consensus on how to measure resilience (UNDP, 2014), there has been an advancement in the study of disaster and post-disaster scenarios. Therefore, multiple indicators and variables have been developed to gain understanding in the process of building resilience in Social-Ecological Systems (Community Resilience Building Organization; Cutter et al., 2008; Cutter, 2014; FAO, 2013; IFCR, 2014; UNISDR, 2012).

With the aim to generate specialized strategies in the community resilience process, there are differences between national, federal, and municipal governments, in this matter, it is important to have in consideration the multilevel governance for the analysis (IFCR, 2014). In this respect, Brose (Brose, 2015) referred to the relevance to engage the mentioned levels for a resilience framework in pursuit of disaster risk management improvements. Moreover, it is essential to understand resilience as a process in which various components in different levels, are integrated and supportive, namely environment, infrastructure, social, economic, and institutional (Cutter, 2014).

In consequence, this project will intend to analyze the resilience as a holistic concept, but avoiding generalities as possible, comparing the situation in 2011, before

the disaster, and the situation in 2017, to discern if the resilience process is improving or not

Source: Self-created

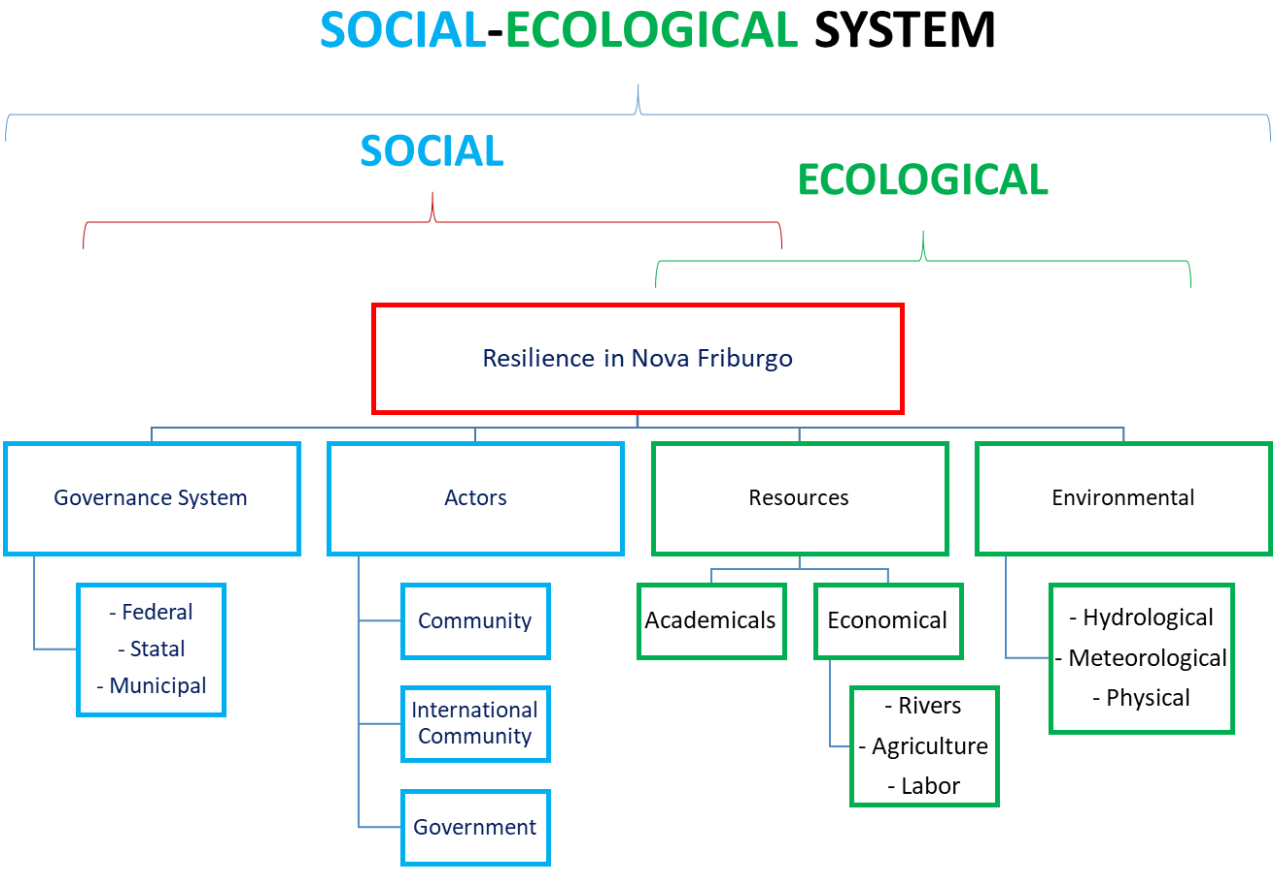


Figure 2. Social-Ecological system model. Source: Own elaborated

3. Justification

When referring to the event of disasters per se, Cavazos (Cavazos, 2015) states that hydrometeorological disasters are the most frequent and significant catastrophes in the world, including the climate related ones. Thus, in the period of 1980-2016, more than 70% of the losses caused by disasters reported worldwide (Munich Re, 2016) were associated with events such as tropical cyclones, torrential rains, floods, landslides, droughts, forest fires, and frosts. As it is shown in Figure 3. Number of Disaster events during 1980 – 2016 and Figure 4. Hydrometeorological and climate events associated with disasters.

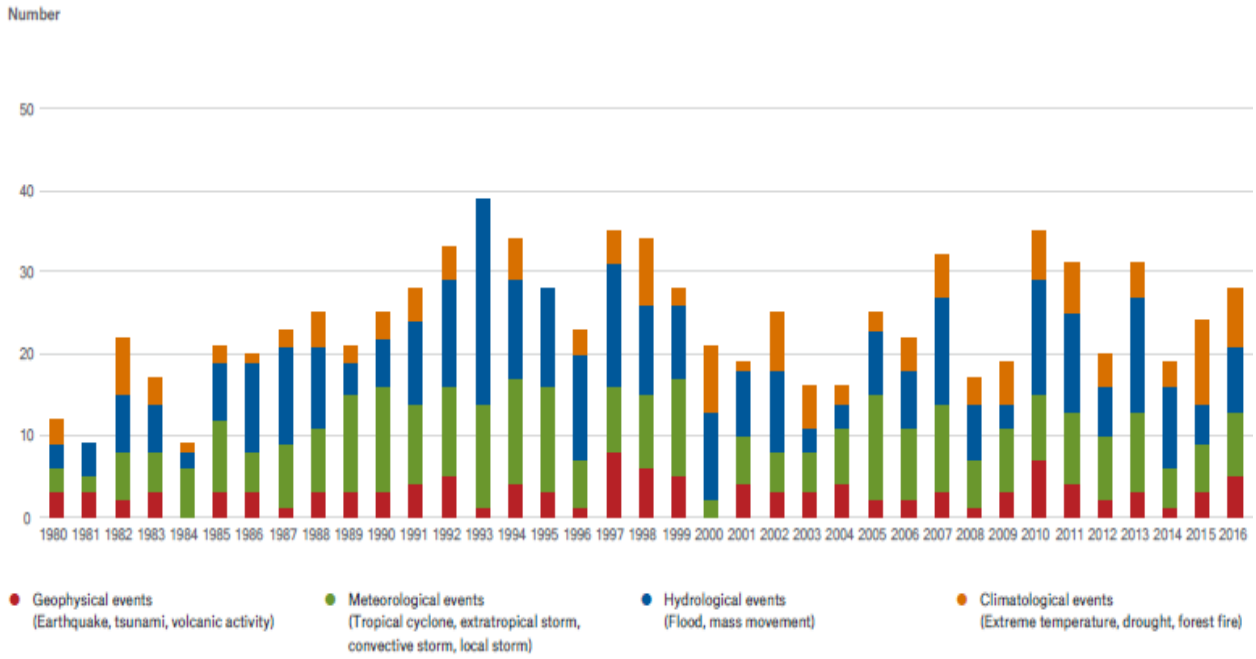


Figure 3. Number of Disaster events during 1980 – 2016. Reprinted from Munich Re (2016)

In addition to the above, Figure 4. Hydrometeorological and climate events associated with disasters shows an annual number of catastrophic events of natural origin on a global scale during 1980-2016 according to data from Munich Re (2016).

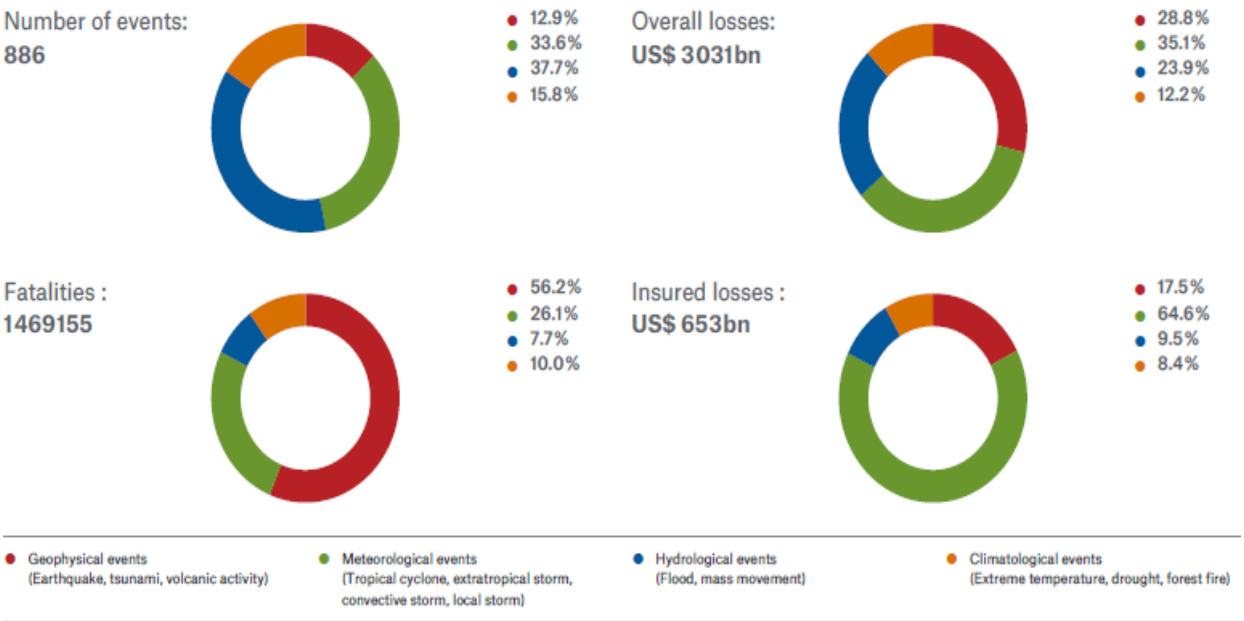


Figure 4. Hydrometeorological and climate events associated with disasters 1980-2016. Reprinted from Munich Re (2016)

As reported above, the study of hydrometeorological and climatic phenomena is important to help to mitigate the impact of this type of event, giving specialists the opportunity to generate prevention mechanisms and tools. Developing those mechanisms and tools may reduce not only the effects but also the hazardous occurrence that affect the normal conditions of communities.

According to Maskrey (1993), those affections of the normal condition are understood as being vulnerable to a natural phenomenon. In this sense, this is

translated into being susceptible to suffer damage and having difficulties to recover from it. Now, not always the human being is vulnerable, but there are situations in which the population is exposed to suffer damage if a dangerous natural event occurs (earthquake, flood, hurricane, electrical storm, etc.). It could be specified that a community could be more or less vulnerable according to different socio-economic, and environmental conditions. One example of this could be if a community is urban or rural, organized or not, formal or informal in terms of the settlement.

In words of the Andean Committee for Care and Disasters Prevention –in Spanish CAPRADE (CAPRADE, 2009) *"**disaster risk** refers to the social conditions in which a society has been affected when being impacted by physical events from different sources such as earthquakes, hurricanes, floods, or explosions"*. Those social conditions refer to the consequences of the impact in terms of disruption of the community's daily life and normal settings.

However, CAPRADE defines two different and divergent lines to the concept of disaster risk. The first one is the probability of a harmful physical event to occur. Whereas, the second one is the probability of economic and social damages and even future losses associated with the event of a harmful physical incident (CAPRADE, 2009). The line of disaster risk that this project is framed with is the second one.

Mansilla (Mansilla, 1993) explains the relationship between disaster and social aspects in the following way: *"Currently it is known exactly how an earthquake originates, a hurricane or a volcanic eruption [...] the disaster that is caused by the occurrence of these natural phenomena, as well as those who are the product of human activity, may not be analyzed from this perspective, which is usually restricted*

to actual natural or technological knowledge, since the concept of disaster, itself, is a purely social category".

Considering what has been mentioned before, if a disaster is a social category and the DRM is a process of cultural, environmental, economic, and historical analysis, then they should reduce the impact, and consider the preventive and corrective phases as just as important as analyzing different levels. Now, the community, the government, and international levels cannot be analyzed in isolation to the previously mentioned aspects, which enforces the idea of risk management as a social process, not just as an ecological one.

Regarding resilience, the UNISDR (2009) states that the resilience of a community is determined by its capacity to generate resources and to be organized before and during the disaster. It is essential to remember that resilience is not preventing a natural phenomenon to occur because it is not possible. However, it is an adaptation of the community to reduce the impact when hazardous events occur (reducing vulnerability). This means to be able to generate a synergy between the community and the environment to be as prepared as possible to face the least possible damages.

This master thesis project intends to study the participation strategies in different levels both for the prevention phase increasing its ability to be prepared, and for the recovery and reconstruction phase, reducing impacts. Also, this study aims at gaining understanding of the adaptation process and the actions that are taken by the government or the community and to analyze if a certain level of resilience is achieved. Ergo, this study will focus on the landslide phenomenon that occurred in Nova Friburgo, Brazil in 2011 and the actions taken before and after this event.

All of this, considering political, social and cultural aspects, framed in an environment that determine them and makes them react in a certain way. On this basis, of wide complexity, these matters will try to be analyzed jointly, not merely under a scheme of environmental determinism.

4. Objective

To analyze if the governmental and community actions taken after the 2011 landslide, mudslide, and flood disaster promoted the construction of resilience in the municipality of Nova Friburgo.

4.1 Specific Objectives

- To identify the factors that generated the disaster that occurred in Nova Friburgo in January 2011.
- To analyze the actions taken by the population, the government and/or the international community to cope with the disaster.
- To analyze the socio-ecological conditions before and after the disaster in 2011, comparing diverse socio-ecological indicators.
- To identify lessons learned from the landslide in Nova Friburgo, both for the government as for the community's resilience building process.

4.2 Research question

Which actions were taken by the community and the government, after the 2011 event to build resilience in the municipality of Nova Friburgo?

5. Study Area

5.1 History

The municipality of Nova Friburgo is composed by the union of different groups of people from diverse nationalities such as Swiss, German, French, Italian, Portuguese, Japanese, Polish, Lebanese, among others. The first ones arrived in 1818, when the King D. João VI adopted by decree the possibility to establish a colony from Swiss families in order to increase the colonization of Brazil's interior. Then, thanks to coffee production, other families, from various countries arrived in Nova Friburgo, making it the only municipality in Brazil colonized by 10 cultures from different countries (Nova Friburgo; Prefeitura Municipal de Nova Friburgo, 2012).

5.2 Climate

The municipality of Nova Friburgo is located in the intertropical zone, the climate type is a Tropical climate of altitude (Dourado et al., 2013) (Durand, 2002). It has a mild temperature in summer and cold in winter, with the four seasons well outlined, it undergoes the action of different masses of air (Prefeitura Municipal de Nova Friburgo, 2012). One example is the Equatorial Continental air masses, which act in the summer, provoking hot and rainy weather. Another example is the Tropical Continental air masses that act in summer, spring, and autumn causing a high daily temperature range and sunny days with low humidity. Also, the Atlantic Polar air mass is most frequent in winter, but also acts in autumn and spring, provoking cold days. And finally, there is Tropical Atlantic air mass which acts at any time of the year and causes slight precipitations (Nova Friburgo, 2015).

In between seasons, there is usually a rainy season with higher temperatures (summer) and a dry period with lower temperatures (winter). The rainy season is from October to April, in which December is the month with the highest rainfall volume in the year. In contrast, July is the month with the lowest rainfall (Nova Friburgo, 2015).

5.3 Geographical relief

A vast chain of mountains surrounds the Municipality of Nova Friburgo. The alignment of the main mountains in the municipality has at its southern limit the scarp of *Serra dos Órgãos* that is part of *Serra do Mar*. This municipality is cut in the middle by a set of mountains that form the watershed of the *Paraíba do Sul* and *Macaé* river basins (Prefeitura Municipal de Nova Friburgo, 2012).

The Serrana Fluminense has a rugged relief, with rocky outcrops with abruptly rounded ridges, usually formed by gneisses (Asevedo et al., 2014). The soil is formed by rocks that have suffered a natural abrasion since its appearance. It is a clay soil that retains tons of water with the rain, for that reason it has increased its volume and is susceptible to landslides (Agenda 21, 2011).

5.4 Hydrography

All the rivers of Nova Friburgo have their sources in the municipal territory. The conservation of these springs is of great importance for all the municipalities that are downstream (Agenda 21, 2011). This situation locates the municipality in a strategic position, considering that all the water bodies of the municipality have their springs in its own territory (Nova Friburgo, 2015).

The main river is the *Rio Grande*, which is born in the *Serra do Morro Queimado*, in the district of *Campo do Coelho*. It crosses the districts *Centro and Riograndina* and receives many rivers including the *Bengalas*. The union of the *Rio Grande*, with the *Rio Negro*, formed the *Rio Dois Rios*. One of the main tributaries of the *Rio Paraíba do Sul* (Agenda 21, 2011; Nova Friburgo, 2015).

Sadly, the *Bengalas* River, which is the most important for the Urban zone, is now in a state of pitiful pollution. Also, the *Rio Grande* and the streams *São José, Capão* and *São Domingos* are polluted by pesticides used in floriculture and

horticulture, which affect not only rivers but also the soil and the health of the population (Nova Friburgo, 2015).

6. State of art

Through the analysis of secondary information, it can be determined that there is a great variety of data related to geomorphological and topographic aspects, especially in the south and southeast of Brazil, where most events related to floods and landslides tend to occur (Lorentz et al., 2016; Oliveira et al., 2016; Seluchi and Chou, 2009).

Furthermore, a gap of information was clearly observed as the projects have a high propensity to research about natural rather than social and political issues. In most of the documents analyzed, social and policy issues were scarcely mentioned and most references were made to factors such as precipitation, soil types, or natural and environmental matters in areas affected by landslides.

In those articles, which vaguely mentioned social and political issues (Coelho-Netto et al., 2007; da Silva, 2014; Guerra et al., 2007; Machado et al., 2014), it was possible to identify a marked tendency of the different researchers to question the reactive and non-preventive actions taken. Usually, in those articles, both the government and the entities in charge of dealing with emergency situations are criticized. In addition, it was possible to observe an evident lack of community participation in the actions taken. It could be said that the government is the only one responsible for preventing and avoiding hazardous situations.

For a society, it is of great importance to be aware of the capacities of the Government, especially in Latin America, where the State, as is well known, cannot respond or cover all the needs of the population. In this sense, the processes should be oriented towards community strengthening to prevent and respond effectively

to similar phenomena such as the event occurred in 2011 in the Serrana Region. Also, those activities must be considered to avoid dependence on government agencies and international organizations, recognizing them as sources to boost the results in a vulnerable community, but not depending on them.

For this reason, the investigations must be more inclusive, more related to the community itself, as Valério *et al.* (2012) said in the VI National Congress of the National Association of Postgraduates and Research in Environment and Society – (in Portuguese ANPPAS) *"It is necessary to understand the lives of these people, their rituals better, and their daily lives, to remake the worn link with neglect and abandon, and to gain the confidence of these communities to have the convincing power necessary to take these"*.

Having in mind the above, in first instance, it is intended to make a brief summary of the disasters in Brazil and the natural reasons for this type of phenomena. And then, it is intended to make a short analysis of the social and political implications in the event occurred in 2011.

6.1 Events in Brazil

"Floods, landslides, and mudflows are the most common disasters in Brazil. Most of the events are violent, causing fatalities, economic losses and damage to infrastructure, both in rural and urban areas (INPE, 2007; IFRC, 2012)" cited in (Nehren, 2014, p. 11). In Brazil only in 2011, there were officially reported 795 natural disasters, which caused the death of 1,094 and affected 12,535,401 people. As for the municipalities, 2,370 were affected, and 65.44% of them were caused by hydrological events (Brasil et al., 2012).

Table 1 Affected municipalities by Macroregions

REGION	AFFECTED MUNICIPALITIES
Centre-West	122
Northeast	355
North	77
Southeast	569
South	1,247
TOTAL	2,370

Source: Anuario de desastres naturais (2011).

In accordance with Carmo and Anazawa (Carmo and Anazawa, 2014), who analyzed and extracted information from the Mortality Information System (In Portuguese SIM), in the period from 1996 to 2011, there was a totality of 2,202 victims caused by avalanche, landslide, and other movements of the terrestrial surface and cataclysmic storms. In total, 1,468 people were from Rio de Janeiro, and 1,153 people were victims in 2010 in the metropolitan area of Rio and in 2011 in the Serrana Region disasters.

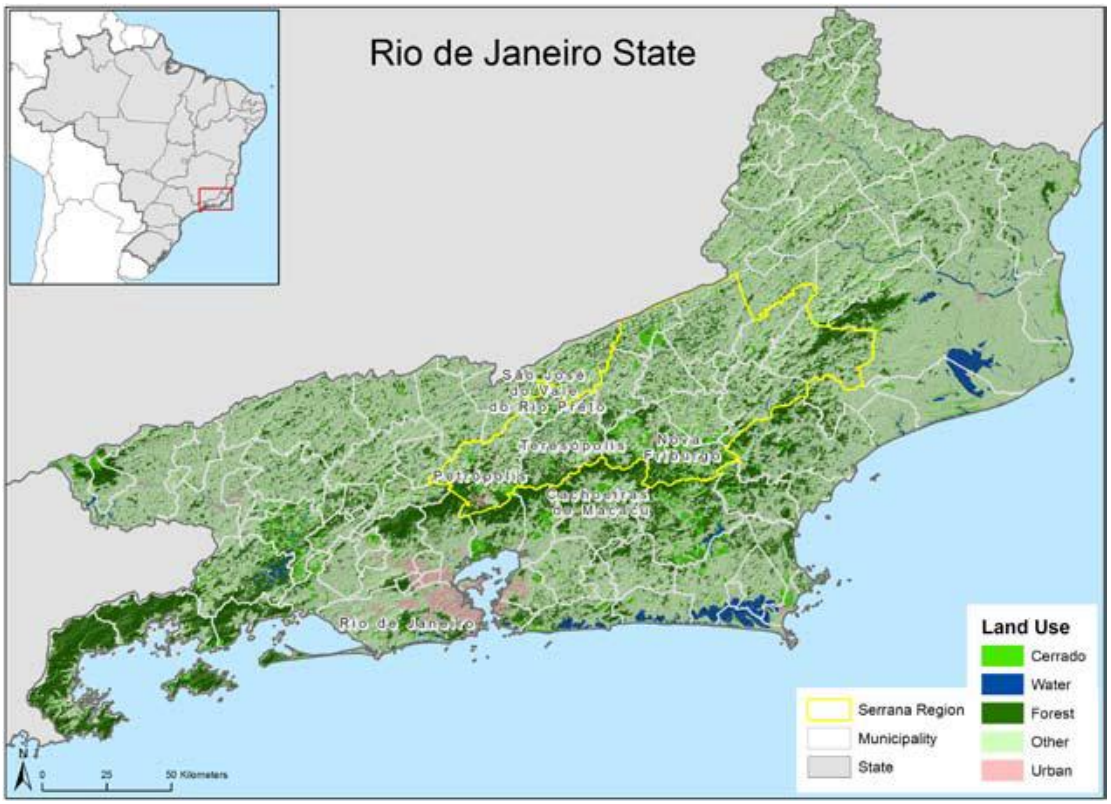
The previous data confirms the claims of Dourado *et al*. (Dourado et al., 2013), in which they explain that every year, in Rio de Janeiro State hundreds of people die and thousands are affected by disasters related to extreme climatological events, especially to floods and mass movements as the event previously mentioned.

With only a year apart between the events in the Rio metropolitan area and the mountainous region, the number of dead, material losses, and costs for the government were alarming.

Although, it is necessary to understand, as the previous data can support, that the southeastern and southern regions of Brazil have been continuously hit by similar events. The states of Rio de Janeiro and São Paulo are permanently facing situations of danger and emergency.

6.2 The Region Serrana and the 2011 disaster

Maps 1 Rio de Janeiro State



Source: Cartography by Wolfram Lange, data by INEA 2011 cited in (Nehren, 2014)

The Serrana Fluminense has a rugged relief, with rocky outcrops with abruptly rounded ridges, usually formed by gneisses (Asevedo et al., 2014). This mountainous area receives the constant humidity of the Serra do Mar, a reason to classify the climate of the Serrana Region of Rio de Janeiro as Tropical of Altitude (Dourado et al., 2013). The municipalities bordering the mountain range, such as Petrópolis, Teresópolis and Nova Friburgo, have an average annual precipitation that exceeds 2,500 mm (Dourado et al., 2013). In this sense, the high vulnerability occurs due to a combination of the soil degradation and the indiscriminate land occupation, with natural factors such as torrential rains, susceptible soil and geology, rugged topography, among others (Nehren, 2014).

Specifically, it should be noted that it was an extreme event on the mountain region. According to the Statal Institute of Environment (INEA), usually the annual average rainfall in the region is superior to 1,500 mm and the precipitation in the whole month of January is about 227 mm. In 2011, in only 12 days of January, the precipitation was approximately 500 mm. This data shows that due to the heavy rainfall compared to the annual average, there were natural reasons for the phenomena to become a hazard for the population (Dourado et al., 2013).

That phenomenon occurred because in addition to the typical humidity received from marine currents, it coincided with air currents from the Convergence Zone of the South Atlantic causing vigorous and continuous rains. This, associated with the use and occupation of the soil in an uncontrolled way, would be causative agents of the landslides of the Serrana Region (Banco Mundial, 2012; Presidéncia da República do Brasil, 2011; Valério et al., 2012).

In total, this event caused the death of more than 900 people in seven different cities and affected more than 300,000 people; this is about 42% of the population of the affected municipalities (Banco Mundial, 2012).

6.3 Geophysical and climatic data

To understand the natural aspects of the event in Brazil, there exist multiple sources. For example, there is an analysis of the precipitation trends from 1978 to 2014 in Southern Brazil to understand spatial and temporal changes in the precipitation patterns (Ávila et al., 2016).

Also, there are studies which include multi-criteria evaluations, counting the technical and environmental issues and the relation between rainfall and landslides. An example of that are the researches from (Lorentz et al., 2016; Oliveira et al., 2016; Seluchi and Chou, 2009). Also the research of Gomes *et al*., (Gomes et al., 2010) who analyzed different types of landslides in a specific area of the National Park in the Serrana Region.

In addition, (Coelho-Netto et al., 2007; da Silva, 2014; Guerra et al., 2007; Machado et al., 2014) try to establish a deeper analysis of the geomorphological reasons of the event in the region. They developed historical and ecological analysis of the soil type and tectonic plates in the region. Those studies generated enough information to understand the magnitude of the issue from the natural and ecological points of view, the causes of the natural event, and the reasons to be considered as a hazard for the population.

At this point, and discussing specifically the Serrana Region, it is important to understand the difference between types of landslides, their characteristics and which of them are most common in the Serrana Region. In Table 2 Type of landslides in Brazil, there are shown the different type of landslides occurred in the disaster of 2011 according to Dourado *et al*. (Dourado et al., 2013).

Table 2 Type of landslides in Brazil

TYPE	CHARACTERISTIC
Mass, debris, earth or mud races	Characterized by movements along the drainages.
"Parroca" type gliding	It begins at the ground/rock contact at the top of the rocky cliffs.
Creep-type landslides	Caused by river erosion of the base of slopes, which cause upstream destabilization.
"Suspended Valley" type glides	They are underground, planar, circular movements that occur in tributaries with a pronounced slope to the main valley and involve the formation of cracks as the drainage carving occurs following evolution Relief.
Catarina type slips	In reference to the main type of movement that reached the state of Santa Catarina in summer of 2008, it is a high-speed movement, where the mobilized material undergoes a rupture in the young soil / mature soil transition.

Source: Own elaboration based on (Dourado et al., 2013) information.

On the same subject, it is worth noting the work done by (Silva et al., 2014), who studied the Bengalas River Basin in Nova Friburgo. They used indicators that allow them to describe the morphology, pedology, lithology, among other characteristics of the soil type. Then, they made an index of susceptibility and vulnerability that can be applied in different zones. The most relevant information of this study is the possibility to establish early warnings by entities or institutions dedicated to prevent, mitigate and to monitor landslides.

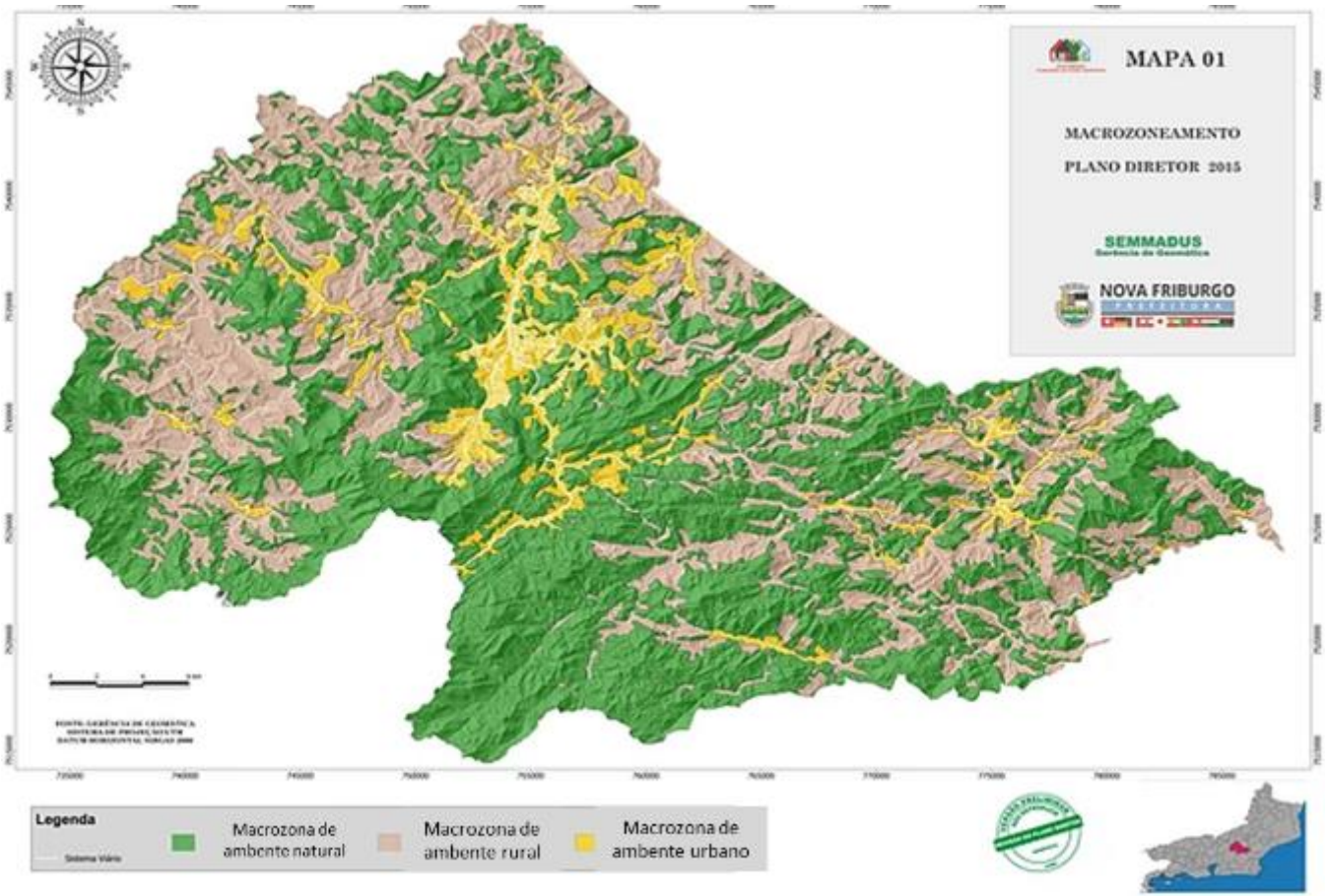
Three maps of Nova Friburgo are shown below. Maps 2 Macro-zones in Nova Friburgo corresponds to the zones established in the municipality depending on the

land use. It is noteworthy from this image that the yellow zone is equivalent to urban areas.

Maps 3 corresponds to the landslides of 2011 in the so-called ***"Mega-disaster of the Mountain Region"***. This map was elaborated by the Secretary of Environment and Sustainable Development, like the previous one. It is important to note that although most of the landslides were in rural areas, as can be seen when comparing both maps, the urban area was also affected.

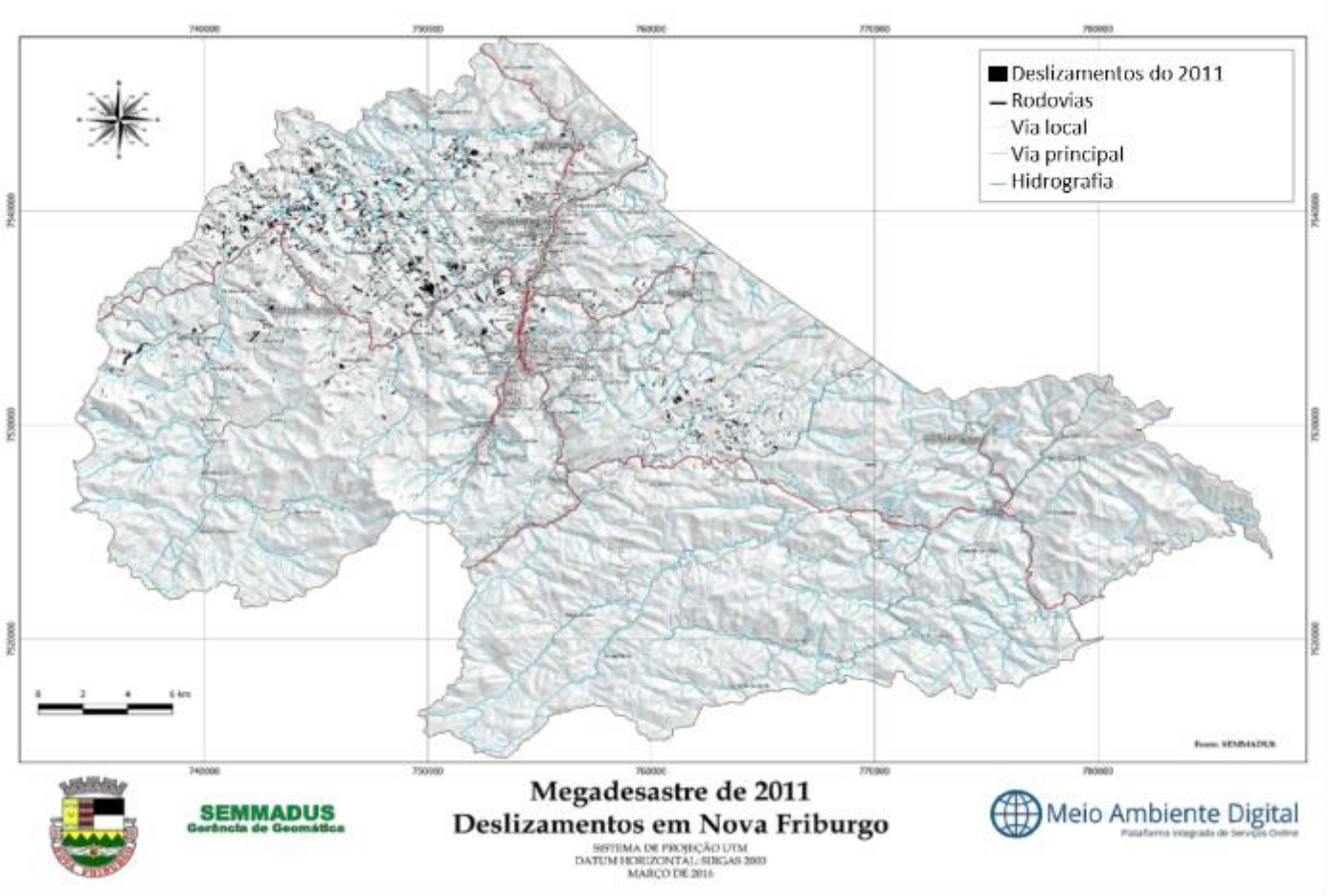
Finally, in Maps 4, the above mentioned Secretary identified the slopes in the municipality, which allowed them to understand the susceptibility of the terrain as well as to identify where there is a high susceptibility and populated areas so they could determine the vulnerability of the area and take actions considering that. These maps were developed together with the Japanese government, with the aim to increase the risk knowledge in the governmental institutions.

Maps 2 Macro-zones in Nova Friburgo



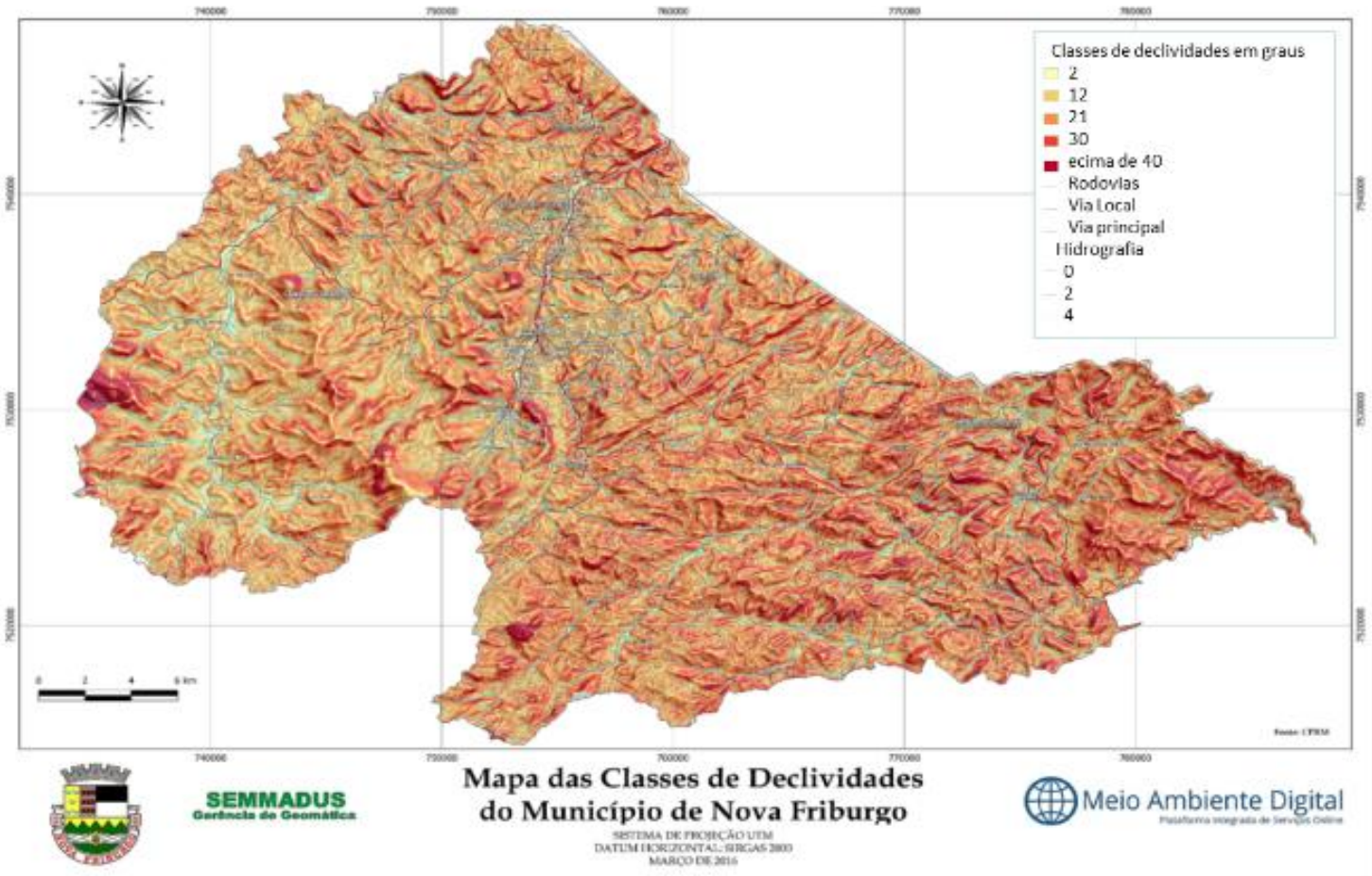
Source: Secretary of Environmental and Sustainable Development of Nova Friburgo

Maps 3 Landslides in 2011 in Nova Friburgo



Source: Secretary of Environmental and Sustainable Development of Nova Friburgo

Maps 4 Slopes in Nova Friburgo



Source: Secretary of Environmental and Sustainable Development of Nova Friburgo

6.4 Social and political causes

As mentioned before, it was possible to observe a gap research because of the lack of studies oriented to social and political issues. Most of the studies in the region were focused on environmental, topographical, and geological issues. The challenge, in social and political studies, is the methodology to construct indicators based on social and political information. Therefore, this could allow an objective and independent analysis of the disaster situations, from qualitative and quantitative data.

For political and social analyses, several human and unexpected elements must be considered. In this sense, understanding the event is as important as understanding when a natural phenomenon becomes a disaster, in which the social issues play an important role. In words of (Mansilla, 1993), we understand the disaster that is caused by the occurrence of different natural phenomena, as well as those who are the product of human activity, but to analyze them only from the natural perspective is not enough because the concept of disaster is a purely social category.

In this respect, the combination of natural, political, and social factors causes a seemingly normal situation to become a disaster. Despite heavy rains, there are other reasons that could make the situation a disaster, such as the lack of investment in prevention and mitigation compared to the high investment in response and reconstruction. For example, in 2010 the amount invested (R$ 80 million) for the reconstruction of sites affected by rainfall was ten times higher than the amount invested (R$ 8 million) for the prevention of catastrophes (Campanato, 2011) cited by (Mello et al., November 7th of 2011).

Besides that, the elimination or degradation of most of the natural ecosystems in the Serrana Region, adding to this the irregular occupation of the territories, lead to increase the risk of disasters. As a consequence, nature cannot

sufficiently fulfill its functions of stabilizing slopes and regulating water bodies (Lange et al., 2014). As an example, it could be mentioned the environmental protected areas occupied by official and public statements (such as schools and health centers, among others), or the zones illegally occupied due to conditions of poverty or absence of governmental presence and control (Freitas et al., 2012; Nehren, 2014).

Just a few studies have been carried out from the social and political point of view. Some researchers have approached to the affected communities, such as (Freitas et al., 2012; Lange et al., 2014; Pereira et al., 2013; Silva et al., 2014) who analyze how the behavior of society and government participation can be key factors in mitigating the impacts of natural events. They studied how from prevention strategies and community knowledge improvements, vulnerability can be reduced and resilience can be strengthened. As a result, and putting aside the vicious circle that affects the region, it has not been possible to reach a level of preparedness enough to avoid the fatal consequences for this type of continuous phenomena.

According to da Costa and Ferreira, these tragedies must be interpreted globally as naturally political catastrophes; and the Brazilian State along with the inert population walk step by step to purgatory, dealing with urban planning and the environmental management of risks in a dissociated manner and with palliative measures (da Costa and Araújo, 2011).

This type of phenomenon, and even more important, this kind of disasters not only occur in Brazil, but in Latin America where the region permeated by the government's inability to serve all its regions. This may be due to different factors, such as the lack of a system capable of doing so, the lack of government foresight, the lack of scientific research, or even a consequence of misuse of funds, since the money to attend emergencies and prevent disasters could be destined for different causes.

As disaster situations are the result of a great variety of factors, there are also many ways to improve the situation. Not only the response of the entities in charged must be strengthened, also the capacity of the community to face and respond to disasters. Hence, the community could try to avoid the dependence on Governmental agencies and International Organizations or doing so to a smaller extent.

Then, as the disasters have multi variable situations, they must be analyzed from different perspective. It requires a multivariate analysis, including the environmental—community relationship, as well the government—community relationship. It must include the natural and ecological issues, as the social and political aspects.

Another issue, which few sources refer to it, is about the legal and technical aspects. To highlight this issues, the research by (Valencio, 2010), who made an interesting comparison between the Civil Defense actions in the international and the Brazilian context, includes social issues as the poverty, which increases the impacts on vulnerable populations.

Another interesting research was developed by (Calvello et al., 2015), who performed an analysis of technical tools. In this case, they studied the Community Based Alert for rainfall-induced landslides in Rio de Janeiro, called the A2C2. This research is important for knowledge improvement. As well, this research is important because of the involved population, and the possibility to adapt that experience to different regions.

In the same sense, it is worth to mention the work of Lange and his colleagues (2014), who understood the importance of resilience studies incorporating the community perception, and getting them involved in the process. These considerations help the community to realize about their vulnerability, and the relevance of the ecosystem function to commit on preserve and recover it.

To summarize, the irregular land occupation, coupled with deforestation and ecosystem degradation, combined with the government's lack of action (Nehren, 2014), and certain natural and ecological conditions, become an ideal mix for a natural phenomenon such as landslides and this could lead to a catastrophe of enormous magnitudes.

7. Methodology

Based on the analysis of secondary and tertiary sources, a process was followed to determine the best adequate way of measuring resilience in the municipality of Nova Friburgo. This process is depicted in Figure 5. Indeed, all the methodology information is complemented on Table 3 and Table 4, which describe the methodologies analyzed, as well as the indicators measurement respectively.

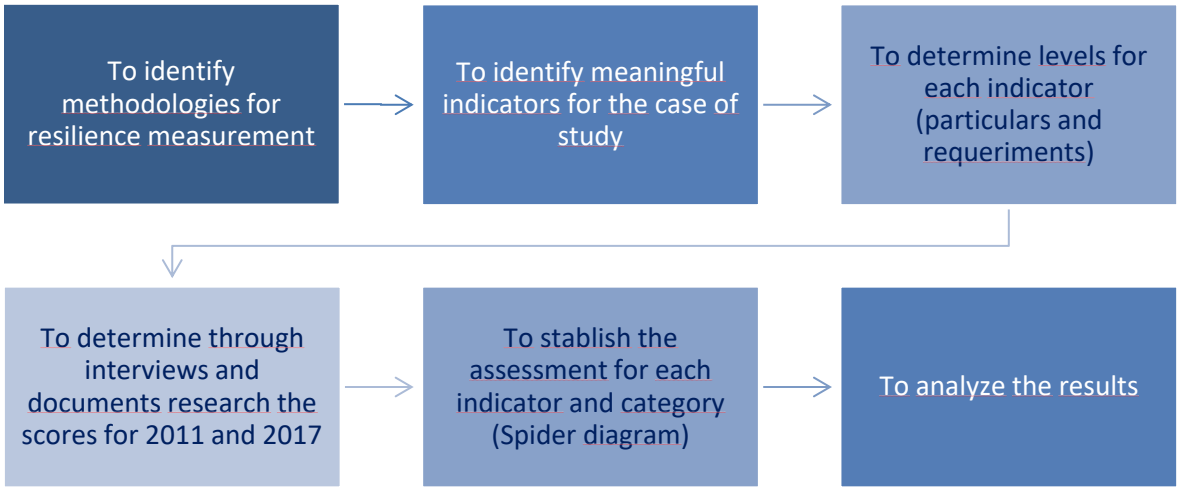


Figure 5. Methodology process. Source: Own elaboration

For the construction of this methodology, different types of resilience measurements from diverse sources were analyzed, as it is shown on Table 3. In this Table It is possible to observe, the international organizations and researchers studied to develop the methodology, in order to measure resilience in the selected municipality.

Table 3 Methodologies analyzed

Title	Author	Selection	Justification
The indicators of resilience in Socio-Ecological Production Landscapes – SEPLS from the UNU	(Bergamini et al., 2013)	PARTIALLY	Indicators measurement relevant for the case of study.
Sustainable livelihoods approach for assessing community resilience to Climate Change	(Elasha et al., 2005)	NO	It requires a large amount of time to perform workshops and community indicators building.
Building disaster resilience: Steps toward sustainability	(Cutter, 2014)	NO	The long-term analysis requires several time and resources.
Framework for community resilience	(IFCR, 2014)	PARTIALLY	Firstly, for its international relevance. There is as well some indicators with great significance for the case of study.
Disaster resilience measurements	(UNDP, 2014)	NO	Theoretical differences regarding resilience and vulnerability concepts and definitions.
Disaster resilience indicators for benchmarking baseline conditions – BRIC	(Cutter et al., 2010)	PARTIALLY	The categorization and some indicators were found relevant for the case of study.
A place-based model for understanding community resilience to natural disasters – DROP	(Cutter et al., 2008)	NO	Not enough information about the measurement process.
Risk and adaptation perception to climate change based on the Mata Atlântica ecosystems	(Lange et al., 2014)	NO	It requires a large amount of time and resources to perform workshops, interviews, and questionnaires to analyze community perception.

To make a deeper analysis of these methodologies, there are several issues to take into consideration. Cutter *et al*. (2008, 2010) for example, mentioned that there is a consensus among researchers regarding the categories to be evaluated. These categories include the ecological, social, economic, institutional, infrastructure, and community competence. Those six categories can also be identified, in some way, in the IFCR methodology. The IFCR framework assesses unmet basic needs, social cohesion, economic opportunities, infrastructure and access to public services, natural resource management, and connections.

Based on the above, and continuing the consensus of the researchers, this project worked on the analysis of six categories, in which the indicators were assigned, depending on their impact. Thus, the categories to assess were community knowledge, social cohesion, infrastructure, environmental management, economics, and governance.

Regarding the indicators, Cutter et al. (Cutter et al., 2008) developed the Disaster Resilience of Place (DROP) as a model to improve comparative assessments of disaster resilience at the local community level. This model was one of the first models to measure community resilience. However, the analysis of the proposed indicators was not entirely clear.

Years later, it was complemented by the Baseline Resilience Indicators for Communities, BRIC (Cutter et al., 2010), which is an empirical methodology with a set of indicators for measuring baseline characteristics that foster community resilience. This model allows monitoring resilience changes over the time and comparing resilience variables in different areas.

In the BRIC, each category is composed of indicators (rated 0 or 1) that have a negative or positive impact on the composite indicator of resilience. This system, although simple, does not allow identifying the resilience as a process of continuous construction. There, the indicators were evaluated by their contribution to the

composite indicator in terms of 1 (contribute) and 0 (do not contribute), so there are no intermediate scores, for example when the variable is in process of construction.

In particular, the IFCR focused on assessing community resilience, for this reason they established a framework to be followed, which includes a set of indicators that feed six categories. Although, the categories and some of the indicators were relevant to measure resilience, but evaluation per se was certainly not the most appropriate approach for this project. There were no adequate parameters of comparison and, in addition, much of the information does not even exist in the community.

In this sense, this project took the six fully identifiable categories and some of the indicators of the mentioned methodologies. And also, this methodology avoided the methodologies chose by them to evaluate their indicators.

To clarify the measuring process, it is worth to mention the methodology from the United Nations University (UNU), with the Satoyama Initiative (Bergamini et al., 2013). They developed a toolkit for the indicators of resilience in socio-ecological landscape productive systems (SELPS). As the name suggests, this methodology is more oriented to natural issues than to disaster risk management in social contexts. Besides, this approach is closer to biodiversity conservation than to social and political issues. The authors developed a measurable procedure more adequate to the objectives of this project. Thus, in this methodology, as in the UNU methodology, could be possible to understand the process of resilience building.

Each indicator of the UNU methodology can have five possible scores (1 the lowest and 5 the highest), depending on previous established characteristics and

requirements. This type of measurement[1] allows the researcher to take a parameter and compare the actual status of the variable with the ideal one, taking also into account intermediate possible scores. Additionally, this measurement supports the decision-making process to improve indicators, or even, understand the resilience building as a process that could be better in diverse phases.

In this sense, a battery of qualitative and quantitative indicators was developed based on the previously mentioned methodologies. Those indicators were divided into six categories, namely ***community knowledge, social cohesion, infrastructure, environmental management, economics, and governance***.

Each category was composed of five indicators approximately, with the task of determining the coping capacities of the municipality or the community. Thus, each indicator was measured in five possible scores, from the lowest (1) to the highest (5), in response to characteristics and requirements previously identified. This characteristics and requirements are shown in Table 4 Indicators measurement.

For the total score, two possible ways were analyzed. In the first one, each indicator had the same weight within the total score. In this case, the value of each category would be the sum of the values of its indicators. The problem with this type of measurement was that categories with fewer indicators were affected because their value was lower. In the second method, each category in the total score had the same weight.

In this sense, to normalize the data of the indicators the average should be obtained in each category. Because the value must be determined by the score of

[1] According to the UNU methodology, indicators should be expressed on Likert (1–5) scales. Those scales provide a simple way of capturing people's impressions and ideas in a quantitative way.

its indicators, not by the quantity[2]. Appart from that, it was possible to maintain five scores with this procedure, both for the indicators and for the categories.

In order to visually show the differences between the years 2011 and 2017, spider diagrams with the indicators of each category were created, for all the indicators as a single set, and an average of each category.

On this basis, the present case study addressed the theme of resilience under different methodologies. One of them was the Framework for the Promotion of Community Resilience of the IFRC for its international recognition and relevance. Also, it is based on the Baseline Resilience Indicators for Communities (BRIC) for its contribution in terms of categorization of the indicators. Finally, this methodology is addressed under the United Nations University methodology for its measurement process.

In consequence, and considering the information already mentioned, this project aims to analyze the resilience as a general concept composed of six categories, as shown in Figure 6, and 31 indicators as shown in Table 4. Also, this project aims to compare the characteristics of each indicator in 2011, before the disaster, and the characteristics in 2017, with the purpose of discerning if it is improving or not the resilience process.

[2] Suppose we have two categories C1 and C2. C1 is composed of two indicators I1 and I2, whose score was 1 for each indicator. C2 is composed of three indicators I3, I4, and I5, each one with a score of 1 as well.

By the first method, the value of C1 would be 2, and the value of C2 would be 3. The importance of C2, in this case, was determined by the number of indicators it had, not by the score.

By the second method, both the values of C1 and C2 would be 1, by the average of their indicators.

Figure 6 Resilience categories. Own elaboration

Community knowledge is when communities strengthen resilience by experimenting, innovating, and learning within and between different knowledge systems, cultures, and age groups, including government and community activities (Bergamini et al., 2013). For this category, is important to take into consideration people's knowledge about the risks and how to face it. Besides that, strategies should be focused on the community information weaknesses, as well on the working knowledge to successfully carry out the procedures. In Table 4 Indicators measurement, more information could be seen.

Figure 7. Community knowledge indicators. Own elaboration

Social Cohesion is the capacity to provide protection and security to all of the members of the community through their official and informal community networks (IFCR, 2014). This would include all the members, and support them in case of necessity. For this reason, measure their networks in the community and municipal levels, and how they try to improve them, is essential to analyze the resilience. The indicator measurements are shown in more detail on Table 4.

Figure 8. Social cohesion indicators Own elaboration

The term **Infrastructure** describes the elements provided by the government to support the population necessities and requirements. The government plays an important role supporting the community with health, transportation, buildings, and supplying all their demands, because it is very complicated that the community provides these services by itself (Community Resilience Building Organization; IFCR, 2014).

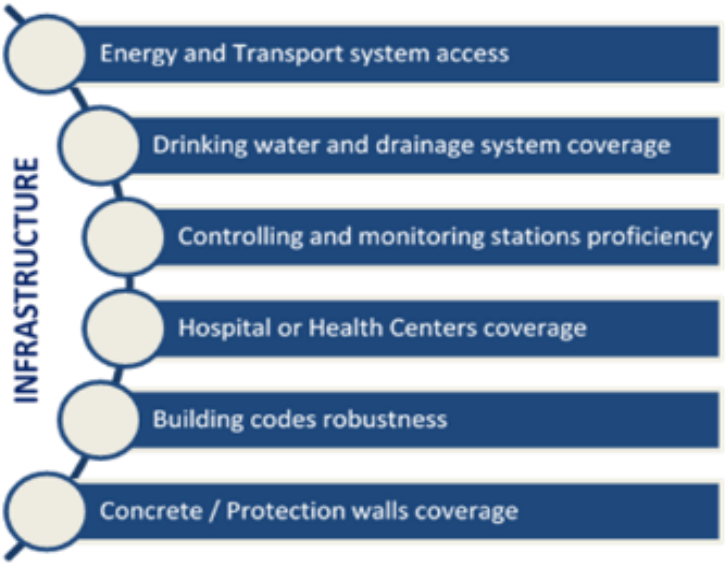


Figure 9. Infrastructure indicators. Own elaboration.

Environmental management includes the laws, programs, plans, policies, and guidelines, in the search of building resilient communities and raising awareness about the environmental issues. For this awareness, it is necessary to take into consideration that humans have influenced most of the Earth's ecosystems throughout activities that have affected biodiversity and ecological processes (Bergamini et al., 2013). Thus, in this process, it is important to combine the social

and ecological systems for a deeper analysis. Studying also, the activities oriented to ecosystem and biodiversity protection.

Figure 10. Environmental management indicators. Own elaboration.

Economics is recognized as one of the most important aspects for various authors and researchers; firstly, because of the importance of having the capacity to face the events with self-resources, and secondly, because it must be an interest of the stakeholders to prevent affectations that could impede the normal life of the population in case of hazardous events occurred.

Figure 11. Economics indicators. Own elaboration

The **Governance** incorporates the relations among different instances such as intergovernmental institutions, and international organizations. Also, the governance is important to understand the community perception about the capacity of the Government to satisfy their demands, and face situations that affect their normal functioning.

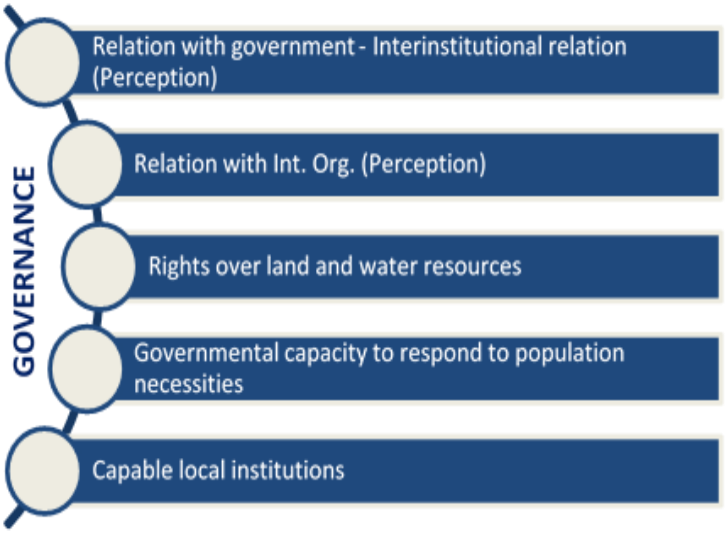


Figure 12. Governance indicators. Own elaboration.

Table 4 Indicators measurement

Category	Nr.	Indicator	MEASUREMENT					TYPE	Source
			5	4	3	2	1		
Community Knowledge	1	Contingency plans existence	Exists and have been proved	Exists	Under construction	In plan	Does not exist	Qualitative	Civil defense & Corrego D'Antas interviews
	2	Early Warning System existence	Exists and have been proved	Exists	Under construction	In plan	Does not exist	Qualitative	Civil defense & Corrego D'Antas interviews
	3	Simulations performed	More than 5, including all the community, and stakeholders	> than 5	from 1 to 5	Planned simulations	0	Quantitative	Civil Defense interviews
	4	Evacuation routes existence	Proved routes and in improvement process	Identified, signed and knew by the community	Identified and signed routes of evacuation	Informally identified routes	No routes identified	Qualitative	Civil Defense & Corrego D'Antas interviews
	5	Education in DRR coverage	The whole community, taking into account different strategies.	The whole community	part of the community	In plan	not performed	Qualitative	Civil Defense information
Social Cohesion	6	Community Organization formality	Formal structure with exclusive dedication for the community	Formal structure with periodic reunions, working for more than 2 years	Formal structure with periodic reunions	Informal structure	Does not exist	Qualitative	Corrego D'Antas and Governmental institutions interviews
	7	Community Network coverage	Communication and participation of the whole community in the decision-making process	Communication and participation of the whole community throw the formal structure	Communication and participation through specific members	Voice to voice communication	Does not exist	Qualitative	Corrego D'Antas and Governmental institutions interviews

	8	Emergency brigades existence and quality	It exists and has specialized equipment and continuous training	It exists and has basic equipment for response	Under construction	In plan	Does not exist	Qualitative	Civil Defense and Corrego D'Antas documents
	9	Integration spaces identified	The community have different spaces for different issues	They recognize the importance of a specific space and a leader	There is a specific space for the community	Randomly defined	There are no spaces of integration	Qualitative	Corrego D'Antas and Governmental institutions interviews
	10	Social inclusion coverage	The whole community include in different activities	Activities planned based on different type of community members	Partial inclusion of the members	Just the leaders of the community	No social cohesion	Qualitative	Corrego D'Antas and Governmental institutions interviews
Infrastructure	11	Energy and Transport system access	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	Quantitative	Secretary of Environment and Sustainable Development Municipal Sanitation Plan - PLAMSAB IGBE Data
	12	Drinking water and drainage system coverage	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	Quantitative	Secretary of Environment and Sustainable Development Municipal Sanitation Plan - PLAMSAB IGBE Data
	13	Controlling and monitoring stations proficiency	Precipitation and discharge stations constantly monitored and under decision-making process from experts	Precipitation and discharge stations under constantly monitoring	Precipitation and discharge stations	Precipitation stations	There are not stations	Qualitative	Basin Agency of Nova Friburgo - AGEVAP information
	14	Hospital or Health Centers coverage	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	Quantitative	Secretary of Environment and Sustainable Development Municipal Sanitation Plan - PLAMSAB IGBE Data

	15	Building codes robustness	Approved by the government and under strict compliance	Approved by the government	In revision with the government collaboration	Just some recommendations	Does not exist	Qualitative	Secretary of Works and Infrastructure information
	16	Concrete / Protection walls coverage	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	Quantitative	Secretary of Works and Infrastructure information
Environmental Management	17	Land use and degradation	<20%	21-50	51-70	71-90	90-100	Qualitative	Secretary of Environment and Sustainable Development Municipal Sanitation Plan - PLAMSAB
	18	Environmental projects existence and quality (Terracing - Reforestation)	Projects developed by the community and stakeholders	Projects developed by the community	Under construction in collaboration with stakeholders	Under construction	Does not exist	Qualitative	Secretary of Environment and Sustainable Development Municipal Sanitation Plan - PLAMSAB
	19	Environmental management plans inclusion	Plan developed by the community and stakeholders	Plan developed by the community	Under construction in collaboration with stakeholders	Under construction	Does not exist	Qualitative	Secretary of Environment and Sustainable Development Municipal Sanitation Plan - PLAMSAB
	20	River basin proficiency	Management performed by the community and stakeholders	Management performed by the community	Under construction in collaboration with stakeholders	Under construction	Does not exist	Qualitative	Basin Agency of Nova Friburgo - AGEVAP information
	21	Territorial and Urban Management Plan existence and formality (considering environmental uses and hazards)	Formal, performed and tested plan for hazard mitigation	There is formal and it is performed	There is formal and it is not performed	Under construction	Does not exist	Qualitative	Municipal Management Plan (Plano Diretor)
Economics	22	Diverse economic activities existence	High diversity and new opportunities for the community	High diversity	Low diversity	Just one activity	There is no diversity	Quantitative	IGBE Data

	23	Members who work percentage	81-100	61-80	41-60	21-40	0% - 20%	Quantitative	IGBE Data
	24	Community resources capacities robustness	Financial protection	Response, recovery and preparedness resources	Response and/or recover resources	Resources for first response	Has not assigned resources	Quantitative	Public Ministry of Rio de Janeiro State
	25	Municipal resources capacity robustness	Financial protection	Response, recovery and preparedness resources	Response and/or recovery resources	Resources for first response	Has not assigned resources	Quantitative	Public Ministry of Rio de Janeiro State
	26	Statal resources capacity robustness	Financial protection	Response, recovery and preparedness resources	Response and/or recovery resources	Resources for first response	Has not assigned resources	Quantitative	Public Ministry of Rio de Janeiro State
Governance	27	Relation with government - Interinstitutional relation (Perception)	Excellent	Good	Regular	Bad	No relation	Qualitative	Corrego D'Antas and Governmental institutions interviews
	28	Relation with Int. Org. (Perception)	Excellent	Good	Regular	Bad	No relation	Qualitative	Corrego D'Antas and Governmental institutions interviews
	29	Rights over land and water resources	Secure tenancy and juridical protection of the patrimony	Secure tenancy of the patrimony	Land possession in process of legal recognition	Land possession with no rights	No land possession	Qualitative	Corrego D'Antas and Governmental institutions interviews
	30	Governmental capacity to respond to population necessities (coverage)	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	Qualitative	Public Ministry of Rio de Janeiro State
	31	Capable local institutions	Excellent	Good	Regular	Bad	No relation	Qualitative	Public Ministry of Rio de Janeiro State

It should be noted that indicators are also part of the risk phases, namely ***governance, knowledge, reduction/prevention,*** and/or ***response/reconstruction***. The UNDP (UNDP, 2014) works resilience as a constructive process, in which is possible to determine not just the resilience capacity of different levels after the measuring process, also to know the weaknesses and strengths in relation to the risk management phase.

The inconvenient regarding this type of measurement is the time it takes. Starting from the analysis before the event to the measured results of the process, it could take a lot of time owing to the necessary baseline that it endures at the beginning. It was not possible for this project to do the research following these steps because of the lack of time, but to analyze in which phase the actions are framed is vital to gain an understanding of resilience.

As measure capacities were evaluated, the risk phases had to be evaluated as well, in order to analyze in which phase the community needs to work more and comprehend the weaknesses and strengths. Cutter *et al.* (Cutter et al., 2008) identified three phases for a community in relation to an event, ***to prepare, to respond, and to recover***. The three of them were very important for this project; therefore, different manners could be analyzed to take some actions on this problem. Despite the assertive method to divide the actions, the resilience is not a process in exclusive relation to disaster risk management. There are a lot of actions related in a deep way with the public administration, such as acts, laws, strategies, policies, or decisions in the government, which are not necessarily oriented to reduce the risk, but they help in a certain way. For example, the health coverage, the energy and transport systems, or the capacity to respond to the population

necessities, which have not been made in order to reduce the vulnerability but indeed they have done it.

Figure 13 Resilience phases. Own elaboration based on (Cutter et al., 2008)

Each of the phases is shown in a different color: grey for the governance, yellow for the knowledge, blue for reduction/prevention, and green for response/reconstruction. In Table 5 the same colors are used in front of each indicator.

It is important to highlight that one indicator could be part of more than one phase. For example, the municipal resources capacity robustness is part of all the phases. This is because the robustness of this indicator is determined for the resources destination to: a) improve the knowledge of the risk, b) to prevent and reduce the impacts of hazards, and c) to respond and reconstruct after a risk is materialized. In this sense, it impacts all the categories.

Then, every phase is composed of a different number of indicators, depending on which of them impacted it. Governance, in this sense, is impacted by 16 of the indicators, the knowledge phase by 8, the reduction and prevention phase by 14, and the response and reconstruction phase by 14.

With this information, the decision makers could identify which phase of the risk is weak, and which is trong. So, they can put their efforts in the phase they consider a priority. In this context, improving the population conditions considering the disaster risk phase would strength the resilience process, because it would be possible to determine if the activities are oriented to prevent or to respond.

Table 5 Indicators in the resilience phases

	RESILIENCE PHASES				
	INDICATOR	GOVERNANCE	KNOWLEDGE	REDUCTION/ PREVENTION	RESPONSE/ RECONSTRUCTION
COMMUNITY KNOWLEDGE	Contingency plans existence				
	Early Warning System existence				
	Simulations performed				
	Evacuation routes existence				
	Education in DRR coverage				
SOCIAL COHESION	Community Organization formality				
	Community Network coverage				
	Emergency brigades existence and quality				

	Integration spaces identified				
	Social inclusion coverage				
INFRASTRUCTURE	Energy and Transport system access				
	Drinking water and drainage system coverage				
	Controlling and monitoring stations proficiency				
	Hospital or Health Centers coverage				
	Building codes robustness				
	Concrete / Protection walls coverage				
ENVIRONMENTAL MANAGEMENT	Land use and degradation				
	Environmental projects existence and inclusion (Terracing - Reforestation)				
	Environmental management plans inclusion				
	River basin proficiency				
	Territorial and Urban Management Plan existence and formality (considering environmental uses and hazards)				
ECONOMICS	Diverse economic activities existence				
	Members who work percentage				
	Community resources capacities robustness				
	Municipal resources capacity robustness				
	Statal resources capacity robustness				
GOVERNANCE	Relation with government - Interinstitutional relation (Perception)				

	Relation with Int. Org. (Perception)				
	Rights over land and water resources				
	Governmental capacity to respond to population necessities (coverage)				
	Capable local institutions				

8. Results and discussion

As mentioned in the methodology, the evaluation would be done through 6 categories and 31 indicators. These results are presented in this chapter, considering that disasters are not a purely natural category, but the combination of many variables involves many other aspects as well.

The opinion, perception, and data of various government entities, as well as representatives of the community and international organizations were considered for such evaluation.

8.1 Community Knowledge

The indicators show the lower score in 2011, mainly, because previous the landslide, there were not contingency plans, simulations performed, neither an Early Warning System (EWS) developed. In 2017, the highest score corresponds to EWS that was greatly developed by the involved institutions (Figure 14 Community knowledge results). Even so, the progress on education in disaster risk reduction (DRR) and evacuation routes are not significant. There are only good ideas for the future, but nothing is concrete. The results of this category are summarized on Table 6 Community knowledge indicators scores.

The results also show an increasing average in 2017 in comparison with 2011 average scores. That means that government and community have been making efforts to improve the community knowledge. But, until there are not inclusive strategies such as for the education in DRR or the evacuation routes identification, this category will hardly be improved.

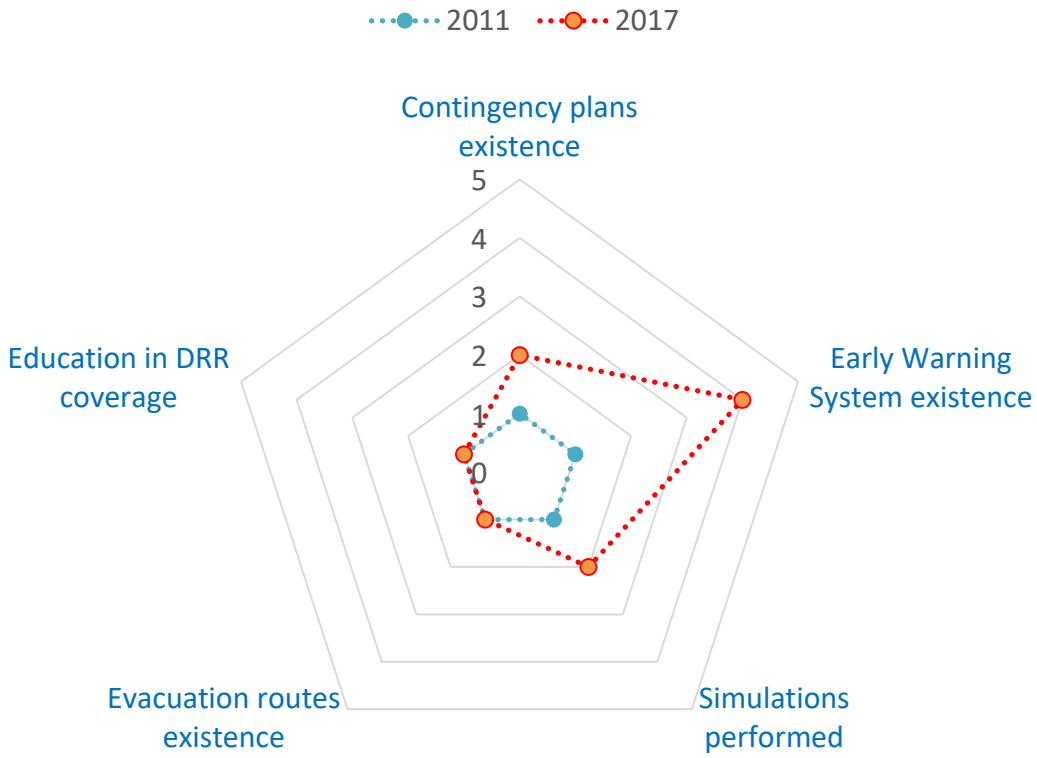


Figure 14 Community knowledge results

Risk knowledge without taking into account the circumstances of the locals, as geography, demography or environment, will limit the effectiveness of the dissemination strategies (UNEP, 2014). In fact, the engagement of at-risk communities at all levels helps ensure the effectiveness of any measure (UNEP, 2014, p. 20). This is specifically the Achilles heel in this category: the lack of community participation at all levels, making the strategy ineffective.

As the law and public policy in Brazil have established, the implementation of risk management models requires joint actions among

diverse stakeholders. Overall, it appears that the coordination between these spheres in Brazil is still in its infancy stage (Leal Filho et al., 2016).

Municipal level: The disaster that occurred in 2011 was evidence of the lack of community knowledge and risk knowledge in general. According to (Teixeira, R., 2017) and (Schottz, S., 2017), the contingency plans for landslides were not even conceived. Neither the government nor the community knew that this phenomenon represented such a terrible hazard. On this matter, actions were not taken to avoid this danger, or to strength the community capabilities.

The situation is different in 2017, at least regarding the Early Warning System (EWS), which is the greatest achievement of the government. They have improved with technical features; for example, they installed alarms along the diverse basins and a system that warns both the population and the involved institutions. Although, they include diverse communities in simulation exercises and EWS training sessions, there is not a clearly multilevel strategy.

Nonetheless, even though the population is aware of the tools used to warn them when a certain level of precipitation is reached, they do not know exactly what to do with this information.

Excluding the improvements of the EWS, the achievements are not so relevant in this category. Both, the civil defence and the community recognize the importance of contingency plans and simulations, but there are little efforts to develop these tools; on the one hand, because of bureaucracy, and on the other because of the lack of human and economic supplies.

In words of UNEP, for the proper functioning of evacuation strategies an immediate and urgent response from communities is required to avoid harmful

paths (UNEP, 2014, p. 26). In this case, the evacuation routes were not well identified and it was not possible to saw signs in the streets of the municipality, because they do not even exist.

According to the Civil Defense Secretary, the contingency plans were elaborated considering the population needs. But, as these contingency plans cannot be implemented if the mayor does not approve them, and they still use the plans from 1999, therefore, this information is completely obsolete.

Despite the information mentioned above, the Civil Defense Secretary has great proposals. One example of that is to include the children and young people in disaster risk management, adding this topic to the education programs in school programs (Teixeira, R., 2017).

It is important for the Government to understand that risk management requires working in networks to connect residents, local institutions, researchers and governments (Leal Filho et al., 2016). In this aspect, it is worth to highlight the work that has been done in risk mapping with the Japanese government, a project that has increased significantly the knowledge about landslides on the governmental institutions.

Community level: For the community knowledge, the education should be a very useful tool. As UNEP explains, the integrated education in disaster risk management could be a tool to promote an effective approach. It could improve protection, also generate risk awareness, and even support the resilience-building process (UNEP, 2014, p. 23).

Sadly, the discrepancy between government and community is evident for the education in DRR. According to Civil Defense (CD), there are continuous efforts, but the community did not recognize them. In fact, they decided to

made alliances with academic sources to improve the education in DRR because of the lack of governmental support.

The researchers have been taking advantage of the rift between government and community. They have strengthened their relationship with the community, developing projects in which the population is really involved. There are great examples such as the ideas proposed by The Fluminense University of Rio de Janeiro (UFRJ) as well the University of Santa Catarina.

According to the evacuation routes, they were identified in documents that the people did not know about, so it could be said that these papers do not exist.

The population is still skeptical on the operation of the Early Warning System, and the information provided by the entities in charge. They do not distrust to be more attentive and to anticipate, they distrust that the alarm system is a voice of alarm and they should take actions to avoid the hazard. Usually, they trust more in their instincts, and in the ability to take action on their own (Schottz, S., 2017).

Table 6 Community knowledge indicators scores

CATEGORY	No.	INDICATOR	MEASUREMENT					SCORES		SCORES AVERAGE	
			5	4	3	2	1	2011	2017	2011 AVG	2017 AVG
COMMUNITY KNOWLEDGE	**1**	Contingency plans existence and quality	Exists and have been proved	Exists	Under construction	In plan	Does not exist	1	2	1	2
	2	Early Warning System existence and quality	Exists and have been proved	Exists	Under construction	In plan	Does not exist	1	4		
	3	Simulations realized	> than 5, including all the community, and stakeholders	> than 5	from 1 to 5	Planed simulations	0	1	2		
	4	Evacuation routes existence and quality	Proved routes and in improvement process	Identified, signed and knew by the community	Identified and signed routes of evacuation	Informally identified routes	No routes identified	1	1		
	5	Education in DRR coverage	The whole community, considering different strategies.	Whole community	part of the community	In plan	not realized	1	1		

8.2 Social Cohesion

The results in this category show that there was an increase in all indicators compared to 2011 (refer to Figure 15 to see more information). Social inclusion coverage, integration spaces, community organization, and community network coverage increase their results in one level considering the previous established characteristics. And, the emergency brigade's existence was the indicator with the most significant increase, going from 1 to 4 because of the efforts, both from the government, and especially in the community brigades (See the Table 7 for more information).

Evidently, as all indicators increased their level, the category average for 2017 is higher than 2011. This shows improvements in the social cohesion of the Community.

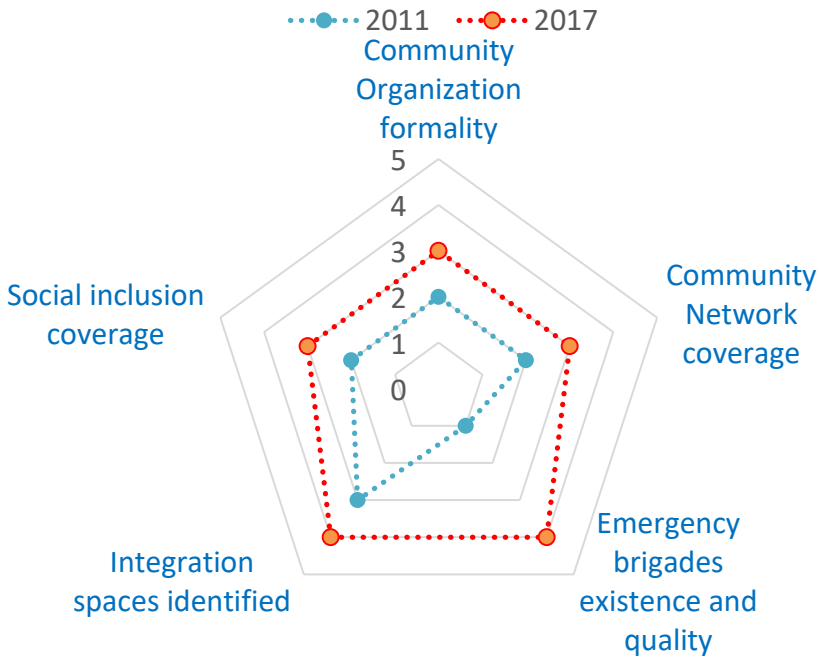


Figure 15 Social cohesion results

The IFCR strategy recognizes social cohesion as one of the most important aspects of resilience. They determined it as having a greater capacity to adapt to and respond to disasters, crises, disturbances and tensions. Also, they ensure that communities should use development achievements to overcome the effects of the underlying vulnerabilities to which they are exposed (IFCR, 2014).

Putnam (1995) defines the concept of social capital, in line with social cohesion, as features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit. This cohesion allows individuals to draw on the social resources in their communities through the benefit of having ties and networks. By Increasing in this manner the likelihood, the communities are able to adequately address their collective concerns (Mayunga)

In the same sense, Beilin recognizes that "*communities can be important sources of information and meaningful arbiters of knowledge, creating social connections and identity, becoming into little institutional memory, further than just short-term and ephemeral supporting links"* (Beilin et al., 2015, p. 1314).

Likewise, it is understandable, that in higher levels involving numerous groups of people, the social labour is extremely difficult. Perhaps, the key is to identify not just the common characteristics, but also those elements whit great significance for the population, and work from this basis.

Hereupon, the integration spaces in which most people are involved, like churches and Schools, seem to be the key for social cohesion. Although, the disaster was a terrible event for the population, the reconstruction process after the event, the presence of the Former President Dilma Rousseff, and the federal

and national institutions, as well as the international organizations had a relevant impact in cohesiveness.

Municipal level: It is very interesting how the neighborhoods get ahead thanks to their neighbors' compromise, even when the social cohesion at the municipal level is usually, very conflictual. An example of that are the communities of Córrego D'Antas, Duas Pedras, and Cónego, which have improved their visibility through the work and labor of their own members (da Silva, P., 2017).

Another example of social cohesion at the municipal level is the *Lupidecs*. The *Lupidecs* are groups of educated people in geology, first aid, and flood or landslide reaction, promoted by the Civil Defense together with the community. In Duas Pedras for example, they have been working very hard to develop this strategy in order to strength the capacities and face the risks in a better way (Teixeira, R., 2017).

During the field research, it was very clear that the politic and economic situation in Brazil, and particularly in Rio de Janeiro State, were not the best in terms of communion with the government. The scandals for misappropriation funds involving the private and public sector, and the bad economic situation of the state have had a direct impact on the city of Nova Friburgo. The inhabitants are in constant solace for what will happen, and to a great extent, express their discontent towards the current government leaders who are under constant scrutiny and criticism by the community.

In the same sense, the community leaders have begun to play a more prominent role. They have become tools of community development, not just as mere links between them and the government. Communities such as *Córrego*

D'Antas, Cónego, Campo do Coelho, among others, have seen a resurgence of their leaders. Then, through community action and social cohesion, have managed to cover the gaps that the government cannot handle for lack of capacity.

Also, it is very common in the urban landscape to see the signs of the diverse type of churches, product of the mixture of different cultures, result of colonization and placement of diverse groups. Anglicans, Catholics, Presbyterians, and Lutherans are part of an endless number of religions in the municipality of Nova Friburgo. Swiss, German, French, Italian, Portuguese, Japanese, Polish, Lebanese among others, have combined not just gastronomic, but also cultural and religion aspects. Thus, this is why the people recognize churches both as a place of reunion with other people, as the place where the words of encouragement and comfort could be found.

Community level: One example of the relevance of religion in Nova Friburgo is found in 2011, when the Community of Córrego D'Antas through the community church collected money for the reconstruction of the neighborhood. Another example was the union of the Catholic priest and the evangelical pastor in the municipality, who raised money for the assistance to the victims.

In a similar way, the Swiss government understood the importance of a place of reunion. In this sense, they contributed with money to build of the Córrego D'Antas Association center, so that the inhabitants could enjoy cultural activities. This is the place where the people of different ages, enjoy physical and entertaining activities, and also assist to health brigades twice per week. This is the place where they found union as a society and as a community.

As Mayunga (Mayunga) recognizes, social capital as a source of community cooperation and efficacy can be measured among others, by the sport and recreational clubs operating in the community.

All this, conjoined with the community rapport after the event, has strengthened the relationship among the neighbor members. Actually, these efforts have taking them to new levels of decision-making process, in which they work on leaving the governmental dependency. For example, a notorious progress can be seen in the community of Córrego D'Antas community throughout the implementation of the emergency community brigades.

Putting aside the reconstruction process, the emergency brigade program has been developed greatly by themselves (Schottz, S., 2017). The institutions and communities living in the Córrego D'Antas basin have created a Disaster Risk Network with the objective to promote the association of knowledge from public, private, and community organizations. This was established in order to reduce geo-hydrological risks, through the elaboration and implementation of public and participative policies (Freitas et al.).

In fact, when the tools and the capabilities are not the best, they have been clever finding assistance from private organizations and researchers. Today, they have maps, procedures, a strong staff, and actually, they were recognized by the community of Nova Friburgo and the researchers as a well community practice (Freitas et al.).

Table 7 Social cohesion indicators scores

CATEGORY	No.	INDICATOR	MEASUREMENT					SCORES		SCORES AVERAGE	
			5	4	3	2	1	2011	2017	2011 AVG	2017 AVG
SOCIAL COHESION	6	Community Organization formality	Formal structure with exclusive dedication for the community	Formal structure with periodic reunions, working for more than 2 years	Formal structure with periodic reunions	Informal structure	Does not exist	2	3	2	3
	7	Community Network coverage	Communication and participation of whole community in the decision making process	Communication and participation of whole community throw the formal structure	Communication and participation throw specific members	Voice to voice communication	Does not exist	2	3		
	8	Emergency brigades existence and quality	It exists and has specialized equipment and continuous training	It exists and has basic equipment for response	Under construction	In plan	Does not exist	1	4		
	9	Integration spaces identified	The community have different spaces for different issues	They recognize the importance of a specific space and a leader in it	There is a specific space for the community	Randomly defined	There are no spaces of integration	3	4		
	10	Social inclusion coverage	Whole community include in different activities	Activities planned based on different type of community members	Partial inclusion of the members	Just the leaders of the community	No social cohesion	2	3		

8.3 Infrastructure

It is shown in the results of this category (Figure 16 Infrastructure results), that is the strongest among the rest of the categories. This is because since 2011, the energy and transport system, and the hospital and health centers coverage are already performing well. Besides that, the efforts from the government in the other indicators, especially in concrete and protection walls, and the stations monitoring have shown positive development. The whole efforts, and the participation of many governmental institutions like the Secretary of Works, the Secretary of Environment for Sustainable Development, the Basin Agency (AGEVAP), and the Health Secretary have promoted this category, going from 2 to 4 in the average of 2011 vs 2017 (see Table 8)

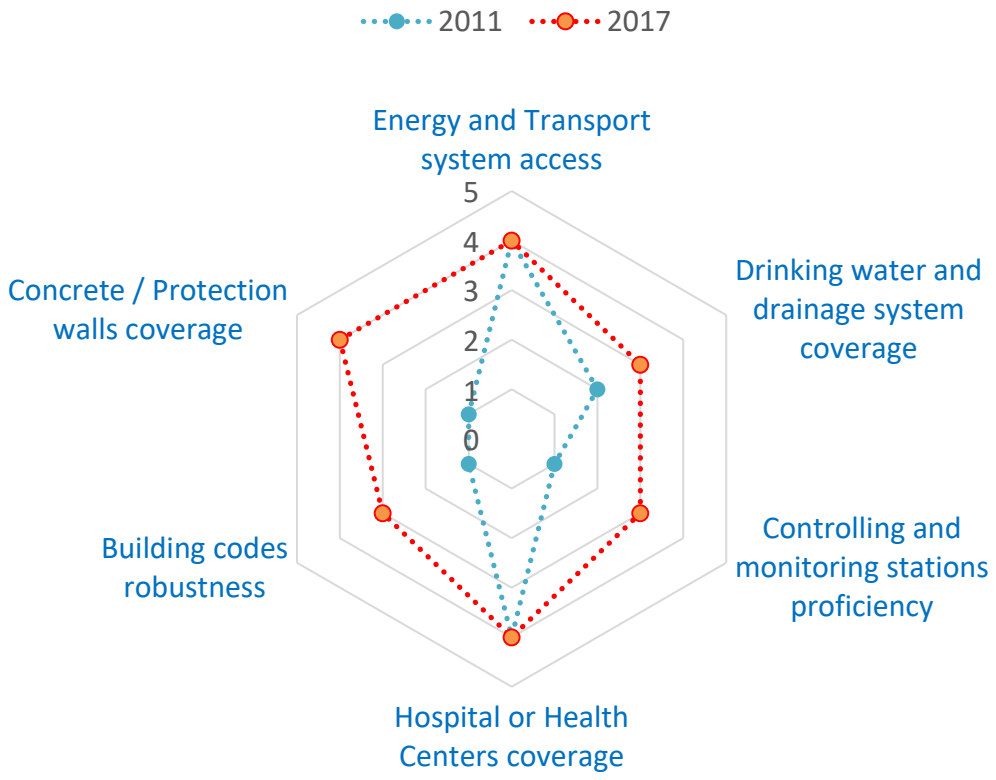


Figure 16 Infrastructure results

As Mayunga (Mayunga) stated, physical infrastructure such as roads, bridges, dams and levees, as well as communication and transportation systems are essential for proper functioning of a community, especially during evacuation time. In this respect, the communities are well intercommunicated with the downtown, which facilitates the municipal response in situations of emergency.

Municipal level: This is the strongest category because of the situation before the disaster and the actions that were taken after the landslide event. The health and transport coverage for the population is still really good, more than 90% of the people have access to health treatment, as well as transportation between downtown and surrounding areas (Melo, V., 2017). Evidently, during the event, the systems were severely affected, but it was possible to restore the situation after a few months.

The government has worked in the *Plano Diretor* official adoption. This document legislates for all the matters related to this category and a lot of others. But, it has not been approved yet, and it was not possible to determine the reason why. It is a “blame game” between the legislative and the executive branches (Bohrer, A., 2017; da Silva, P., 2017; Melo, V., 2017; Schottz, S., 2017).

The Plano Diretor includes several aspects such as the Urban Development Plan for 2050, and the land use and land protection in the municipality. It covers different groups of people from diverse socioeconomic levels, and it is an important tool for community inclusion, but it is still not approved by all the statements, no matter how complete it is.

About other aspects in the same category, the drinking water and the drainage systems are managed by a private sector company. So, to study these

systems was more complex. The drainage system is old and inefficient. It covers only one part of the urban area and a few in rural zones. In addition, there is not a clear difference between pluvial catchment systems, and industrial and household waste systems. In consequence, a lot of residues including solid ones go directly to the Bengalas River, generating high risks for the population due to the clogging.

The last amended for the building codes was written almost 50 years ago (Decreto Lei n° 53, 14/01/1943 – *Código de Obras*), and the current legislation regulates the materials but not the building type (Goncálvez, L. C., 2017). Besides that, the municipal government institutions are trying to normalize the construction through the *Plano Diretor*.

The municipality also has problems due to the irregular occupation of the territory. The situation is very difficult because of the lack of human and economic resources to oversee the norm compliance of the territories occupied by poor families coming from different municipalities.

However, there was a great investment from the *Secretaria de Obras* for the response, recovery and reconstruction actions. There was approximately R$950.000.000 (USD300 million) investment according to data from the Public Ministry of Rio de Janeiro state, in which retaining walls, reforestation, rebuilding, river widening, demolitions, and among others, were included.

Also in this category, it is worth to mention the great work performed by the River Basin Committee. The data reported that it supports the government's short and long-term decisions for adaptive and coping capacities. Even when the work and decision-making are more complex due to the several parts

involved in the Committee, they report permanently to stakeholders and community about the monitoring stations.

Community level: Regarding the hospital system, both private and public organizations are obliged to assist the population in situations of emergency, no matter where they come from (Teixeira, R., 2017). In this sense, the community members have a clear idea about the health attention that the Health center provides, besides there are some difficulties to find proper transportation to get to the Health Center.

Also, it is important to highlight, the relevance of the Association of Córrego D'Antas center for the householders. As it was explained in the last category, it is of great significance for the community members in terms of cultural and social matters.

According to the association representative, the householders have total access to the energy and transportation systems. Even though there are a few problems for some of the owners, because of the timing of the routes.

Besides that, the community recognized the efforts made by the the government on the infrastructure aspects, mitigating and correcting some of the problems of 2011. However, they think there were several issues related to the handling of economic resources in this matter.

Table 8 Infrastructure indictors scores

CATEGORY	No.	INDICATOR	MEASUREMENT					SCORES		SCORES AVERAGE	
			5	4	3	2	1	2011	2017	2011 AVG	2017 AVG
INFRASTRUCTURE	11	Energy and Transport system access	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	4	4	2	4
	12	Drinking water and drainage system coverage	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	2	3		
	13	Controlling and monitoring stations proficiency	Precipitation and discharge stations constantly monitored and under decision-making process from experts	Precipitation and discharge stations under constantly monitoring	Precipitation and discharge stations	Precipitation stations	There are no stations	1	3		
	14	Hospital or Health Centers coverage (beds / inh.)	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	4	4		
	15	Building codes robustness	Approved by the government and under strict compliance	Approved by the government	In revision with the government collaboration	Just some recommendations	Does not exist	1	3		
	16	Concrete / Protection walls coverage	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	1	4		

8.4 Environmental management

This is the weakest category. The scores for these indicators hardly reach level 3, as shown in Figure 17. Even though there were progress in 3 of the 5 indicators. The activities focused on the river basin management, as well as the governmental efforts to improve the land degradation and it was evident that the urbanization process needed to be controled. Sadly, the mechanism to approve them come from *Plano Diretor* project, which is still under review by the government. Therefore, the activities related in this area, still work under obsolete guidelines. Scores are shown in Table 9.

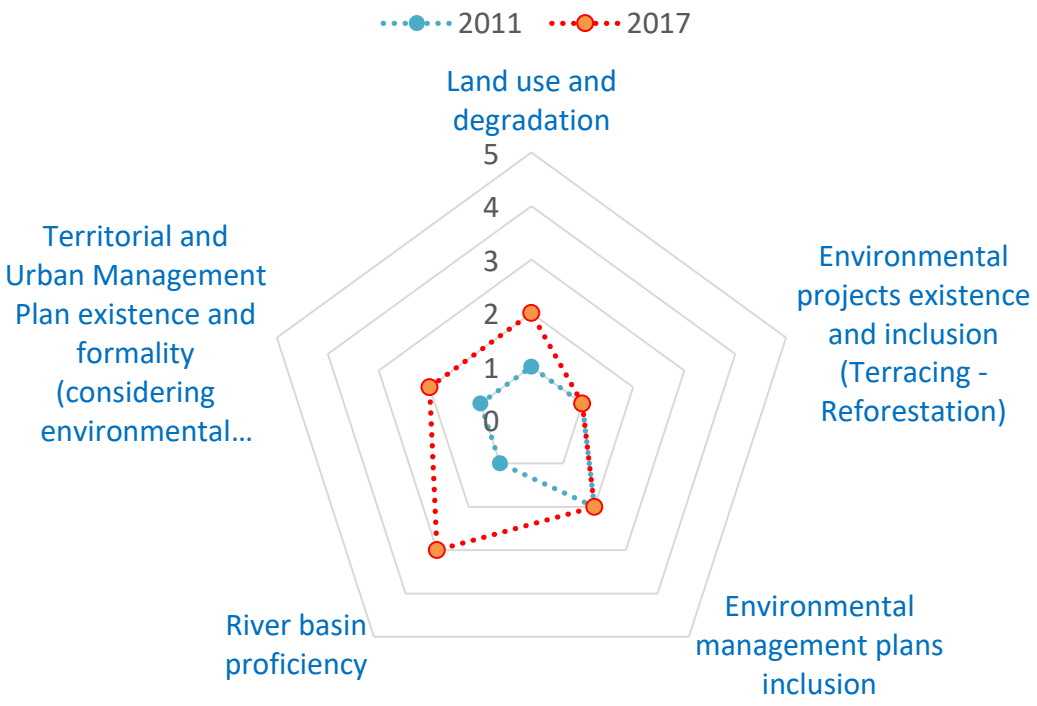


Figure 17 Environmental management results

"The members of a community, often are actively making the landscape through both inherited and co-constructed social-ecological memories" (Beilin

et al., 2015, p. 1315). The environmental management is an essential part of the social construction generation through generation. Even though, sometimes the attention to these matters is not a priority, neither for the population nor for the government.

Municipal level: The regulation of environmental management plans and urban settlement are obsolete. They respond to economic and social conditions that are not the same as 30 years ago. For example, in terms of land use and degradation, the regulation dates from 1988. It responds to unsustainable situations such as the settlement of areas bordering the urban periphery, where there are a lot of mountains and hills with inclinations superior to 30°. According to the Secretary of Environmental and Sustainable Development, these slopes are extremely dangerous for population settlements.

In addition to the previous information, the location of the industrial zones, the solid waste discharge areas, and the waste management infrastructure are not alienated with territorial planning strategies. In fact, they do not consider the hazards in order to regulate the mentioned aspects.

Despite the relevance of environmental regulations to avoid situations as the occurred in 2011, those are the less worked aspects. There are no environmental projects, and the work development in this category is very poor, excluding the river basin proficiency. In addition, the approval of the *Plano Diretor* has taken a very long time, in consequence, the land use, the territorial and urban management, and the environmental management have not been well developed (Melo, V., 2017).

Nevertheless, in the *Plano Diretor*, a lot of efforts were oriented to determine the proper living areas. In the document they have in consideration

the inclination of the slopes, the people living there, the cost of infrastructure projects, among others. Those are important elements, but while the legislation is not approved, nothing can be done it in this sense.

Also, the river basin management is very complex, because of the several stakeholders here involved, causing that repeated negotiations may be necessary to reach consensus (Bohrer, A., 2017). Reducing bureaucracy would be an important change. However, it is important to recognize the progress in making diverse institutions participate in the decision-making process.

Community level: The biggest problem right now, for the community, is the overcrowding, mainly, for inhabitant coming from different municipalities, searching for job opportunities.

In fact, because of the lack of government control, the new households are located in zones where the soil has been degraded because of the solid residues (Schottz, S., 2017). The community does not know the areas that can be occupied; on the one hand, because of the absence of an urban management plan that could orient them; on the other hand, because of the settlements that have been originated by poor population, who does not really care about the location.

Lorenz *et al.* (2016) determined that Nova Friburgo has areas that are highly susceptible to mass movements, due to intrinsic aspects to hillsides like geology, slopes, and shapes. This study assured that only 10 % of the area of the city shows low susceptibility to landslides. However, because these areas may be affected by floods or may be permanent conservation areas, they are not appropriate for urban occupation.

Table 9 Environmental management indicators scores

CATEGORY	No.	INDICATOR	MEASUREMENT					SCORES		SCORES AVERAGE	
			5	4	3	2	1	2011	2017	2011 AVG	2017 AVG
ENVIRONMENTAL MANAGEMENT	17	Land use and degradation	<20%	21-50	51-70	71-90	90-100	1	2	1	2
	18	Environmental projects existence and quality (Terracing - Reforestation)	Projects developed by the community and stakeholders	Projects developed by the community	Under construction in collaboration with stakeholders	Under construction	Does not exist	1	1		
	19	Environmental management plans inclusion	Plan developed by the community and stakeholders	Plan developed by the community	Under construction in collaboration with stakeholders	Under construction	Does not exist	2	2		
	20	River basin proficiency	Management realized by the community and stakeholders	Management realized by the community	Under construction in collaboration with stakeholders	Under construction	Does not exist	1	3		
	21	Territorial and Urban Management Plan existance and formality (considering environmental uses and hazards)	Formal, performed and proved plan for hazard mitigation	There is formal and it is performed	There is formal and it is not performed	Under construction	Does not exist	1	2		

8.5 Economics

The results show that economics is the most uniform category. Almost all of its indicators improve one level. Before the 2011 tragedy the state and also the municipality had enough resources for the needs of the population (see Figure 18). The economics indicators in Nova Friburgo have been improved especially on the assignation of resources for prevention and emergency response, and the member of the population who work. That situation made them stronger in economic issues. More information could be found on the Table 10

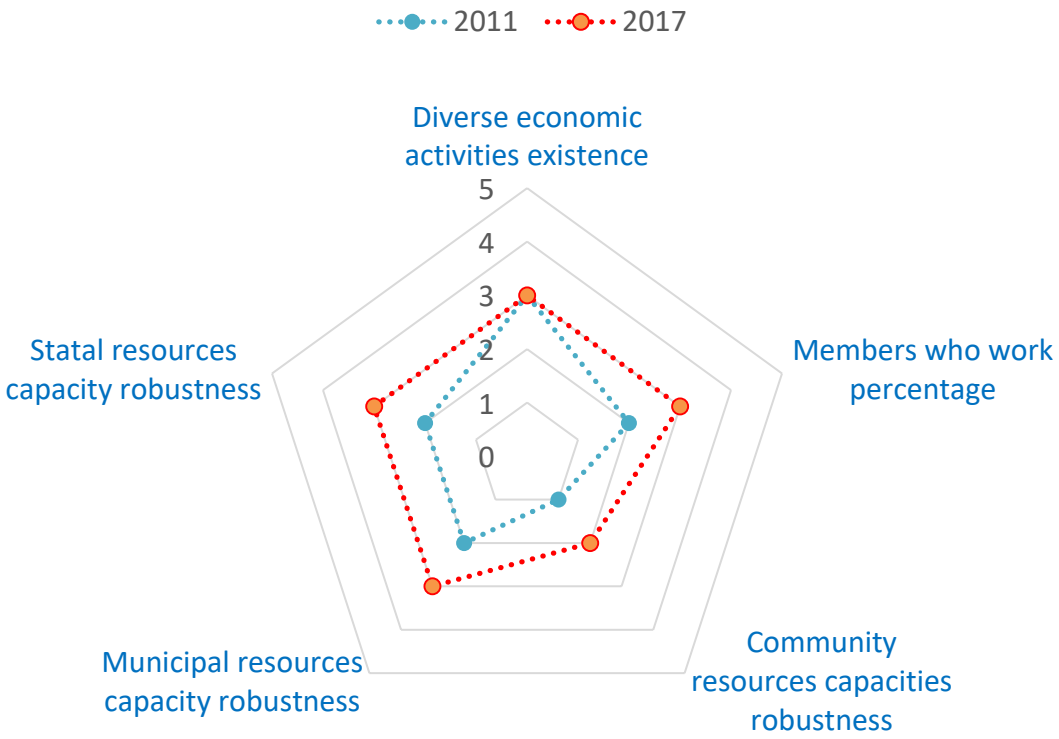


Figure 18 Economics results

Mayunga (Mayunga) recognizes in his methodology that economic capital denotes financial resources that people use to achieve their livelihoods. The methodology includes savings, income, investments, and credits as indicators. The contribution of economic capital to build community resilience is straightforward in the sense that it increases the ability and capacity of individuals, groups, and communities to absorb disaster impacts and speed up the recovery process.

Even when the assumption of Mayunga about economic capital is very interesting, the possibility of study all the elements mentioned above was very improbable; firstly, because of the time it would have taken, and secondly, because it would require a lot of participation from the community, which indeed was not easy to achieve. Furthermore, Cutter and the IFRC measure the economics in a general way, with indicators for all the population (Cutter, 2014; IFCR, 2014), which is better for the objective of this project.

In this sense, the category is strong in comparison with the rest of the other categories; on the one hand, because of the industrial activities developed in the municipality, and on the other hand, because after the event, the municipal institutions became aware of the complications facing natural phenomena as the occurred in 2011.

Municipal level: Agricultural activities, services, and public administration are important sectors of the municipal economy. However, the most important activity is the textile industry, especially the production of women's and to a lesser extent, men's intimate fashion apparel (Prefeitura Municipal de Nova Friburgo, 2012).

According to data from IBGE (2013), the productivity in the municipality is mostly oriented to commercial and industrial services, barely 0.4% of the population is dedicated to agricultural issues, and almost 60% is dedicated to industrial and commercial services. Usually, those activities are related to the production and commercialization of lingerie. In fact, Nova Friburgo produces approximately 30% of total Brazil's lingerie.

For that reason, there is a high range of employment, considering the State of Rio de Janeiro and the situation in Brazil, which is currently going through a difficult period in economic terms.

It is important to point out that the country and the state are facing troubled times, both in the economical as the political aspects. Most of them since the event in 2011, when according to the Public Ministry of Rio de Janeiro, the investment, in order to rectify 247 out of the 431 events in Nova Friburgo was close to 250 million dollars, which magnifies the severity of the event presented in 2011.

Since the disaster, the municipal budget has been hardly affected in the last years because of the lack of resources (da Silva, P., 2017).

Otherwise, since the event in 2011, there were several invests to improve the governmental capacities to cope the hazards. The Civil Defense for example, was converted in a secretary, with its own budget and autonomy.

Also, they assigned resources for projects related to Disaster Risk Reduction. In 2017, there are R$200,000 (USD63,000) for disasters response and R$1,710,000 (USD544,000) for prevention projects; resources that are not usually executed in the absence of projects, because of the bureaucracy obstacles.

During the first two years after the events, there was a wider campaign to combat corruption, which was very common in the subsequent months after the disaster. The legislative branch, commanded by Professor Pierre representative made a deeply investigation, and two Mayors in a row were found guilty of corruption, including federal and national institutions members (da Silva, P., 2017). This bring with it, a careful policy for the monetary resources assignation from the National level and a lot of problems for the municipal one.

Community level: Because of the current situation of the country with corruption scandals, the efforts are oriented to remedy those issues, and, at certain point, the institutions abandon the communities.

For example, the community of Córrego D'Antas have their own resources for different activities, but they are not exclusive to respond to the disaster or to prevent one.

As the community resources are limited, it is important the contributions that come from the Universities, and from the international governments such as the Swiss and Japanese that support the community in diverse aspects and help them to improve their capabilities.

Table 10 Economics indicators scores

CATEGORY	No.	INDICATOR	MEASUREMENT					SCORES		SCORES AVERAGE	
			5	4	3	2	1	2011	2017	2011 AVG	2017 AVG
ECONOMICS	22	Diverse economic activities existence	High diversity and new opportunities for the community	High diversity	Low diversity	Just one activity	There is no diversity	3	3	2	3
	23	Members who work percentage	81-100	61-80	41-60	21-40	0% - 20%	2	3		
	24	Community resources capacities robustness	Financial protection	Response, recover and preparedness resources	Response and/or recover resources	Resources for first respondent	Has not assigned resources	1	2		
	25	Municipal resources capacity robustness	Financial protection	Response, recover and preparedness resources	Response and/or recover resources	Resources for first respondent	Has not assigned resources	2	3		
	26	Statal resources capacity robustness	Financial protection	Response, recover and preparedness resources	Response and/or recover resources	Resources for first respondent	Has not assigned resources	2	3		

8.6 Governance

The results on this category show a great improvement in the relationship with the international community. Both the government and the community, mainly, since the tragedy occurred, have witnessed the increase of international participation. Also, the intergovernmental relations have improved; this is mainly based on the fact that both parties work together and combine both economic and human resources. Even so, there is still a perception in the community, that the government cannot satisfied its needs, as Figure 19 shows, neither the governmental capacities, nor the rights over land have improved since the tragedy. For more information consult Table 11 Governance indicators scores.

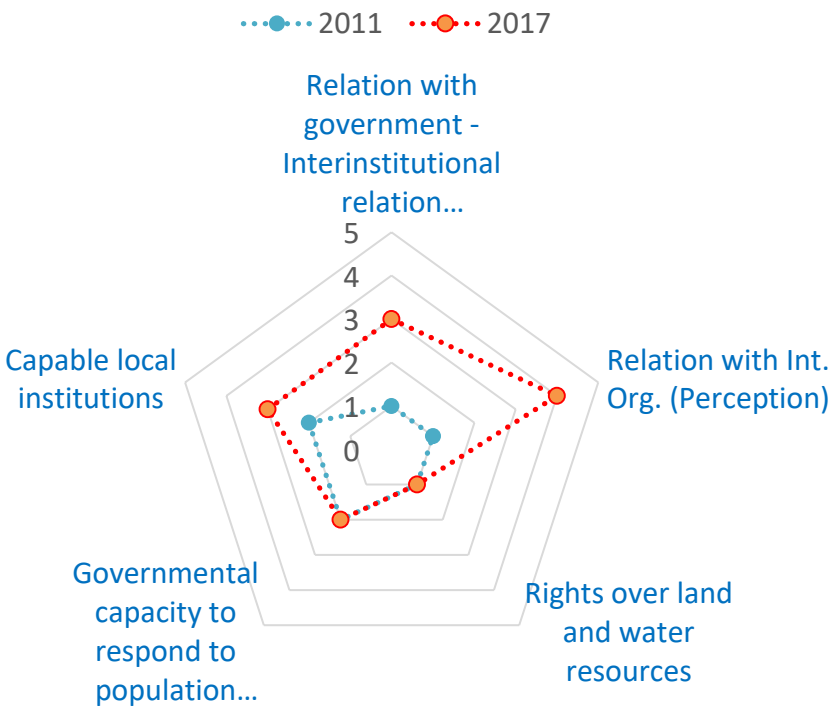


Figure 19 Governance results

The perception among government and community is not so good, usually, the members of the community perceive the political institutions as a group of corrupted people legislating for themselves. So, the trust in them is very low. The last years have been very difficult for Brazil, especially for Rio de Janeiro. Presidents, governors, and mayors have been linked with corruption actions, and a lot of them have been found guilty, which does not help to strengthen this relation (da Silva, P., 2017).

Municipal level: For what was seen in the municipal field research, there is a better inter-institutional relation compared to 2011. The municipal institutions have strong ways of communication between themselves, and the decision-making is a cohesive process involving the right agencies for the right purposes. One example of that is the relationship among the Civil Defense, the Secretary of Environmental and Sustainable Development, and the Secretary of Works, which work together on protection walls, buildings zones, and infrastructure issues (Bohrer, A., 2017; Goncálvez, L. C., 2017; Melo, V., 2017).

Regarding the international organizations relation, the municipality always had well relations in terms of culture improvement. This occurs mainly because of the influence of different cultures since their establishment, almost 200 years ago. Otherwise, in terms of economic and governance, it was not exactly like that, and it is in 2011, when the Japanese and Swiss governments started to support the Nova Friburgo government in that sense.

The Swiss government contributed with economic resources for the community of Córrego D'Antas, and the Japanese government with a project to determine the landslide risks in all the territory including personal capacitation. This project has been essential in order to reduce the risk and to provide up-to-

date scientific information. It improves the decision-making process in relation with DRR and resilience in community and municipal levels (Melo, V., 2017).

Community level: The perception of the community, through its representative, is that there is a lack of attention from the government, and many of their needs have not been answered. In the community it is very common to hear that the government is not capable of satisfying their necessities. In fact, they do not perceive them as capable institutions, as well as the government institutions recognize themselves as agencies with several problems. The lack of economic and human resources have made the government labor very hard, in several cases, the law is good, but the capacity to oversee and to persuade legal, statutory, and technical regulations are so weak (da Silva, P., 2017; Schottz, S., 2017).

Table 11 Governance indicators scores

CATEGORY	No.	INDICATOR	MEASUREMENT					SCORES		SCORES AVERAGE	
			5	4	3	2	1	2011	2017	2011 AVG	2017 AVG
GOVERNANCE	27	Relation with government - Interinstitutional relation (Perception)	Excellent	Good	Regular	Bad	No relation	1	3	1	3
	28	Relation with Int. Org. (Perception)	Excellent	Good	Regular	Bad	No relation	1	4		
	29	Rights over land and water resources	Secure tenancy and juridical protection of the patrimony	Secure tenancy of the patrimony	Land possession in process of legal recognition	Land possession with no rights	No land possession	1	1		
	30	Governmental capacity to respond to population necessities (coverage)	91% - 100% inh.	51% - 90%	21% - 50%	1% - 20%	Does not exist	2	2		
	31	Capable local institutions	Excellent	Good	Regular	Bad	No relation	2	3		

8.7 General results

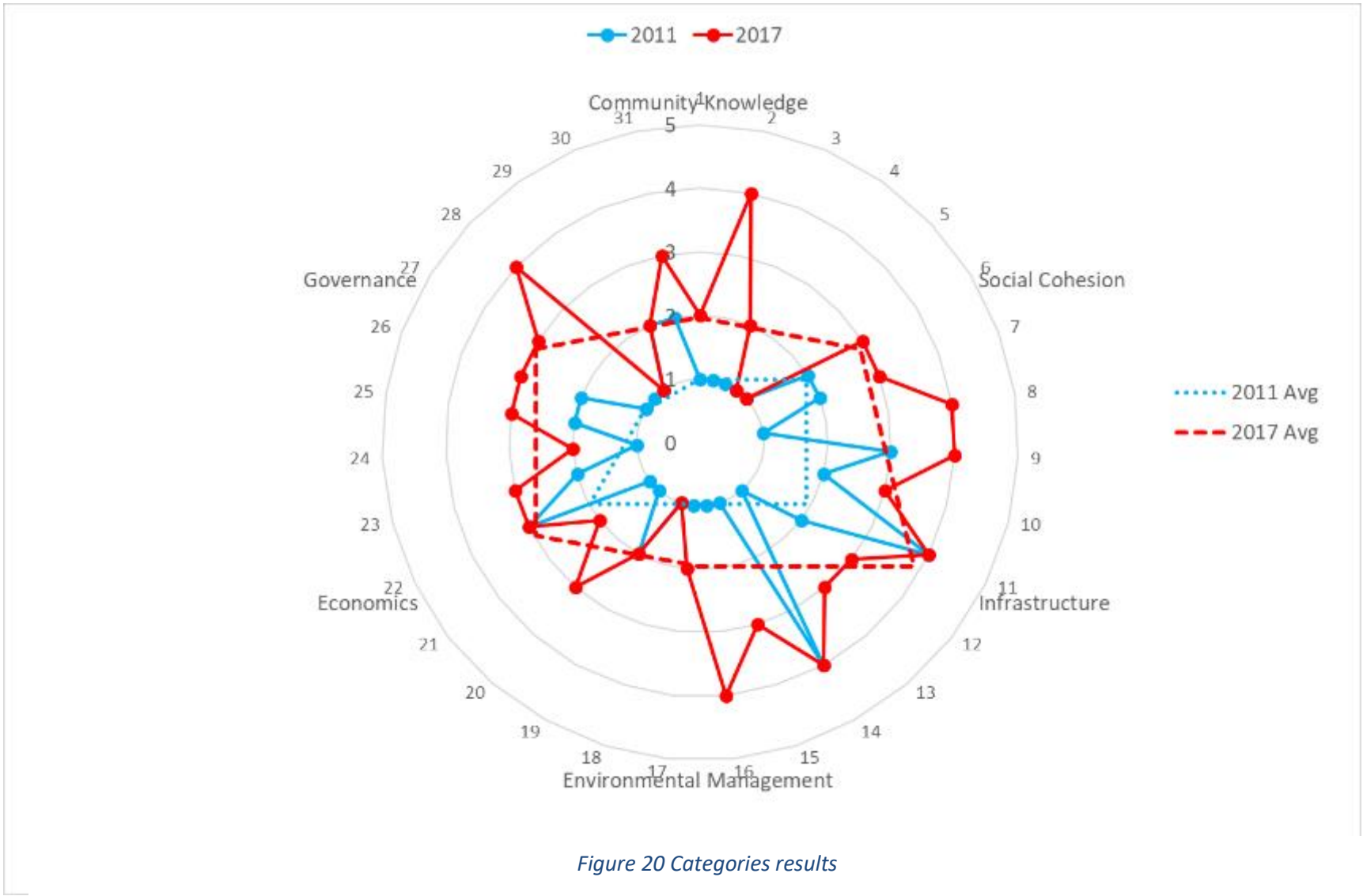


Figure 20 Categories results

In Figure 20 Categories results, it becomes visible that the average in 2017 is greatly superior than average in 2011 in all of the categories. Infrastructure and governance were the categories with better improvements, which reflect the efforts from the government after the disaster. Also, it could be seen in the figure, that community knowledge and environmental management need more attention from both the government and the community. The general results go in line with the phases indicators scores (Figure 21), for example the governance increases one level since the disaster occurred, and the knowledge remains in the same level.

8.8 Phase results

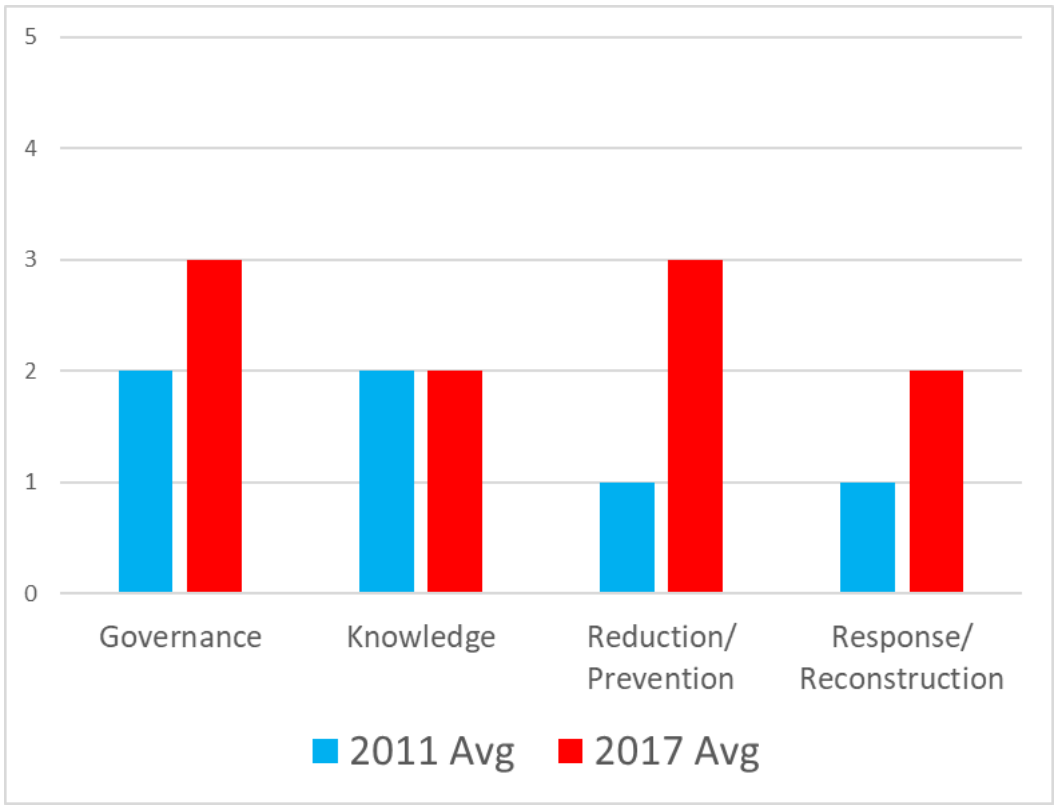


Figure 21 Resilience phases results

In accordance with the measured indicators, and the impacted phase, Figure 21 shows that the government and the community have placed a major emphasis in the reduction/prevention phase. This was promoted mainly by the project with the Japanese government. This project has improved the knowledge of the municipality institutions and preparing them to face similar events in the future through the management plan and the identification of areas prone to landslides. The problem is, as stated before, the lack of resources to oversee the law compliances. In fact, the Secretary of Environmental and Sustainable development has data and

information to strength the laws, normative, and procedures, but acting is very difficult when agreements between legislative and executive branches are not easy and are not possible.

The early warning system and the project with Japan made the reduction/prevention phase the most advanced one comparing 2011 with 2017 but it is not the only one, also the response/reconstruction and governance phases have made progress, especially in the infrastructure sector and the international organizations respectively.

The knowledge is the weak point in the strategy, the community knowledge specifically. The actions taken do not include the whole community, and, with exception of the project with the Japanese government, there are not great efforts in community training to develop their capacities.

9. Conclusions and Recommendations

Resilience is a process that involves social, cultural, political, economic, and environmental aspects. In this process it is important to consider the preventive, response, and reconstruction phases to an event that generates risk for a community. In this sense, to establish specific activities to generate resilience is a complex exercise, which depends on many circumstances. Considering the indicators used in this study to determine resilience, below are certain recommendations to be considered in the process of building resilience:

1. *"This century, more than one million people have lost their lives to disasters related to natural phenomena. Only on 2013 around 20,000 people were killed or went missing in those disasters. The global economic losses due to natural disasters is about to USD 131 billion, which represents almost 2% of Global GDP*" (UNEP, 2014).

Thus, it is essential to strength the Knowledge and Reduction/Prevention phase, because in terms of cost-benefit, it is better to be prepared than to respond to a catastrophe. Thus, the importance of strength the Education strategies for Disaster Risk Reduction.

2. The results showed a lack of attention to environmental issues, on the one hand because of the lack of experts in these matters, on the other hand, due to the delay in approving the *Plano Diretor*. However, the communities and the government should generate better channels of participation with academia, in order to strength the inclusion of environmental issues as cross-cutting aspects in DRM.
3. In 2017, there are R$200,000 (USD63,000) for disasters response and R$1,710,000 (USD544,000) for prevention projects; resources that are not usually executed in the absence of projects. In this sense, the academy and the private sector must also begin to play a most important role in DRM, because the government is not solely responsible for these issues.
4. The municipality must create strategies to improve the communication between the government and the community, especially in reference to the response mechanisms and what to do in the pre-stages of hazard events.
5. To emphasize the importance of community emergency brigades as first responders, with a basic capacity while the relief agencies can reach the affected areas. In this sense, if the municipality grant economic resources to provide to the emergency brigades with training, and at least basic tools would be a breakthrough in emergency care.
6. All stakeholders should create joint projects for the identification, knowledge, education, and improvement of evacuation routes. Communities should know what to do in emergency situations and have in mind the routes and meeting points.

7. Not allowing the population to forget what happened, and the consequences that a similar event can bring to the community. To maintain preparedness strategies and generate inclusive education mechanisms between the Community, the Government, and stakeholders. As Shah and Ranghieri (Shah and Ranghieri, 2012, p. 101) said, talking about the process in Yogyakarta after the devastation caused by 2005 earthquake: *"Once they realized the risks that climate change could bring to them, the community wanted to be prepared"*
8. Disaster Risk Management strategies should be supported by competitive and experienced agencies, such as the GIDES Project with Japan in Nova Friburgo. Through which the Municipal Government has been strengthened in the knowledge of landslides, and the preventive and response capacities were improved.
9. Only six years have passed since one of the severest climate disasters in Brazilian history ocurred. It is understood in this sense, that the government institutions, the community and the academy still have plenty of work to do. However, and even advances have been significant, social inclusion must be the path to adaptation and to make the community more resilient.
10. Give greater importance to the Civil Defense. To stop seeing this agency as a simple office that occupies a space in the *Prefeitura,* and giving them, adequate economic support would help to avoid economic and human losses.
11. Including academia, with its economic and human resources, has provided valuable lessons for the future. This sector could be very supportive, with actions and initiatives that the government does not develop, due to their lack of resources.
12. Tragedies cause material, economic, and human losses, but sometimes they also bring out the best in societies and human groups. Catastrophes help societies to unite in misfortune and find in themselves the strength that governments

sometimes cannot give. The community work, when there is lack of government capacity, is one example of how important is to strengthen communities in DRM.

13. There are essential issues to include in the Municipal sanitation plan (PLAMSAB) and the territorial management plans as well. In this sense, there are issues that need to be properly addressed, both by the industry and the households, such as the drainage system, the collection of rainwater, and the regulation and control of liquid and solid waste, for example.
14. Stopping growth is almost impossible, so it is most important to control the occupation of areas and generate strategies for adequate and orderly settlement, in conjunction with policies to improve institutional capacity.
15. In some cases, laws or regulations are old and obsolete, situations in which the process of drafting and approving new laws should be carried out. But in other cases, the problem lies in compliance with it and the control that the government should perform. Sometimes, this is due to lack of economic capacity, sometimes because of lack of human resources, and others simply because there are no institutions that are willing to do that specific work.

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