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ITZAYANA GONZÁLEZ ÁVILA

SOCIOGEOMORPHOLOGICAL APPROACH FOR DISASTER RISK MANAGEMENT IN RURAL COMMUNITIES

PORTO ALEGRE

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Advisor: Prof. Dr. Masato Kobiyama

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Dedico esta obra a todas as vítimas de desastres provocados por fenômenos naturais, em especial às da recente enchente no Rio Grande do Sul - 2024. Destaco a força que o povo gaúcho e os demais brasileiros demonstraram para superar esse evento climático que entrará para a história, bem como sua coragem. A vocês, políticos e gestores, lembro que quem não gerencia o território sob o conceito de desenvolvimento sustentável está fazendo um pacto com a morte.

I.G.A.

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ABSTRACT

TITLE: SOCIOGEOMORPHOLOGICAL APPROACH FOR DISASTER RISK MANAGEMENT IN RURAL COMMUNITIES

Today's societal planning, infrastructure, and engineering decisions significantly influence the space available for natural processes to adapt to future extreme events. Therefore, the idea is to minimize these decisions' social and economic impacts in nature. This sequence of decisions can be supported by sociogeomorphology applied to different fields of land management. In this doctoral dissertation, the sociogeomorphological approach has been used in natural disaster management. First, through bibliographic consultation, the significant gap in disaster management studies in Brazilian rural areas is identified. Thus, an analysis of land use and land cover in two Brazilian rural communities (Mãe dos Homens and Quilombo São Roque) is carried out to understand the interaction between geomorphological and social aspects. GIS data (territorial delimitation of the community, location of houses or infrastructures, flood spots, geomorphological units, among others) are used conventionally and sociogeomorphological units are defined. A pattern in land use and land cover associated with conservation activities of a traditional Brazilian group (Quilombolas) and other pattern due to agricultural activities related to a non-traditional rural community is distinguished. Altitude and slope are also essential factors in the landscape co-production relationship between humans and nature. However, some limitations are identified that lead to think that the analysis of social interactions needs to be approached in a more "human" way. Brazilian communities are in floodplains and hillslopes, representing a condition of potential disaster. Participatory management in disaster contexts emphasizes that populations face the consequences of planning decisions and practices, making their participation a priority. In this sense, a interview was designed and applied to reveal gaps in risk management, identifying social (place identity, structural measures, lack of education on disasters) and natural characteristics of the studied area that condition risk and its perception. Since these first results are limited to the context of the initial case study, the interview are applied in another area with a different level of development. The interview was applied in Spain, and it is confirmed that the sociogeomorphological approach and the interview are valid for identifying gaps in disaster risk management, making some adjustments such as the definition of sociogeomorphological units. Three rural communities' results were compared to enrich the findings. Relevant attributes are identified to focus efforts on disaster risk management, such as the role of social leaders, disaster education, communication, physical access and access to information, and the paradox of safe development.

Key-words: Interview; risk perception; participative management; rural communities.

RESUMO

TÍTULO: ABORDAGEM SOCIOGEOMORFOLÓGICA PARA A GESTÃO DE RISCOS DE DESASTRES EM COMUNIDADES RURAIS

As decisões atuais de planejamento, infraestrutura e engenharia influenciam significativamente o espaço disponível para que os processos naturais se adaptem a futuros eventos extremos. Portanto, a ideia é minimizar os impactos sociais e econômicos dessas decisões no entorno natural. Essa sequência de decisões pode ser apoiada pela sociogeomorfologia aplicada a diferentes campos na organização do território. Nesta tese de doutorado, a abordagem sociogeomorfológica foi usada no gerenciamento de desastres naturais. Primeiramente, por meio de consulta bibliográfica, foi identificada a lacuna significativa nos estudos de gestão de desastres em áreas rurais no Brasil. Assim, é realizada uma análise do uso e ocupação do solo em duas comunidades rurais brasileiras (Mãe dos Homens e Quilombo São Roque) para entender a interação entre os aspectos geomorfológicos e sociais. Os dados georreferenciados (delimitação de comunidades, localização de casas ou infraestruturas, manchas de inundação, unidades geomorfológicas, entre outros) são usados convencionalmente e as unidades sociogeomorfológicas são definidas. Distingue-se um padrão de uso e cobertura da terra associado a atividades de conservação de um grupo tradicional brasileiro (quilombolas) e outro padrão devido a atividades agrícolas relacionadas a uma comunidade rural não tradicional. A altitude e a inclinação também são fatores essenciais na relação de coprodução da paisagem entre os seres humanos e a natureza. Entretanto, foram identificadas algumas limitações que levam a pensar que a análise das interações sociais precisa ser abordada de uma forma mais "humana". As comunidades rurais brasileiras aqui estudadas estão localizadas em planícies de inundação e encostas, o que representa uma condição favorável ao desastre. A gestão participativa em contextos de desastres enfatiza que as populações enfrentam as consequências das decisões e práticas de planejamento, tornando sua participação uma prioridade. Nesse sentido, uma entrevista foi elaborada e aplicada às duas comunidades brasileiras de interesse para revelar lacunas no gerenciamento de riscos, identificando características sociais (sentimento de arraigo, medidas estruturais, falta de educação sobre desastres) e naturais da área estudada que condicionam o risco e sua percepção. Como esses primeiros resultados são limitados ao contexto do estudo de caso inicial, a entrevista é aplicada em outra comunidade com um nível diferente de desenvolvimento. A entrevista foi aplicada na Espanha, e confirmou-se que a abordagem sociogeomorfológica e as perguntas formuladas são válidas para identificar lacunas na gestão de risco de desastres, fazendo alguns ajustes, como a definição de unidades sociogeomorfológicas. Os resultados das três comunidades rurais são comparados para enriquecer as descobertas. São identificados atributos relevantes para concentrar esforços no gerenciamento de risco de desastres, como a função dos líderes sociais, a educação sobre desastres, a comunicação, o acesso físico e o acesso à informação e o paradoxo do desenvolvimento seguro.

Palavras-chave: Entrevista; percepção do risco; gestão participativa; comunidades rurais.

RESUMEN

TÍTULO: ENFOQUE SOCIOGEOMORFOLÓGICO PARA LA GESTIÓN DEL RIESGO DE DESASTRES EN COMUNIDADES RURALES

Las decisiones actuales en materia de planificación, infraestructuras e ingeniería influyen significativamente en el espacio disponible para que los procesos naturales se adapten a futuros fenómenos extremos. Por lo tanto, estas decisiones sobre el entorno natural tratan de minimizar los impactos sociales y económicos. Estas decisiones pueden apoyarse en la sociogeomorfología aplicada a distintos ámbitos de la ordenación del territorio. En esta tesis doctoral se ha utilizado el enfoque sociogeomorfológico en la gestión de desastres naturales. En primer lugar, a través de una búsqueda bibliográfica, se identificó el importante vacío existente en los estudios de gestión de desastres en zonas rurales de Brasil. Así, se llevó a cabo un análisis del uso y la ocupación del suelo en dos comunidades rurales brasileñas (Mãe dos Homens y Quilombo São Roque) con el fin de comprender la interacción entre los aspectos geomorfológicos y sociales. Se utilizan datos georreferenciados (delimitación territorial de las comunidades, ubicación de las casas o infraestructuras, área de inundación, unidades geomorfológicas, entre outros)convencionales y se definen unidades sociogeomorfológicas. Se distingue un patrón de uso y cobertura del suelo asociado a las actividades de conservación de un grupo tradicional brasileño (quilombolas) y otro patrón debido a las actividades agrícolas relacionadas con una comunidad rural. La altitud y la pendiente también son factores esenciales en la relación entre el ser humano y la naturaleza en la coproducción del paisaje. Sin embargo, se identificaron algunas limitaciones que nos llevan a pensar que el análisis de las interacciones sociales debe abordarse de forma diferente, más humana. Las comunidades rurales brasileñas aquí estudiadas están situadas en llanuras aluviales y laderas, lo que representa una condición favorable para los desastres. La gestión participativa en contextos de desastre destaca que las poblaciones hagan frente a las consecuencias de las decisiones y prácticas de planificación, por lo que su participación es prioritaria. En este sentido, se diseñó y aplicó una entrevista para revelar lagunas en la gestión del riesgo, identificando características sociales (sentimiento de pertenencia, medidas estructurales, falta de educación sobre desastres) y naturales de la zona estudiada que condicionan el riesgo y su percepción. Dado que estos primeros resultados se limitan al contexto del estudio de caso inicial, la entrevista se aplica en otra zona con un nivel de desarrollo diferente. La entrevista se aplica en España, y se confirma que el enfoque sociogeomorfológico y la entrevista son válidos para identificar lagunas en la gestión del riesgo de catástrofes, realizando algunos ajustes, como la definición de unidades sociogeomorfológicas. Los resultados de las tres comunidades rurales se comparan para enriquecer las conclusiones. Se identifican atributos relevantes para centrar los esfuerzos en la gestión del riesgo de desastres, como el papel de los líderes sociales, la educación sobre desastres, la comunicación, el acceso físico y el acceso a la información, y la paradoja del desarrollo seguro.

Palabras clave: Entrevista, percepción del riesgo, gestión participativa, comunidades rurales.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

ALOS	Advanced Land Observing Satellite
CIDH	Inter-American Commission on Human Rights
COMDEC	Municipal Coordination of Civil Defense
CRED	Centre for Research on the Epidemiology of Disasters
DRM	Disaster risk management
DRR	Disaster Risk Reduction
DTM	Digital Terrain Model
EM-DAT	International Disaster Database
F	Floodplain
GEE	Google Earth Engine
GPDEN	Natural Disaster Research Group
Gu	Geomorphological Units
H	Hillslope
IBAMA	*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis*
IBGE	*Instituto Brasileiro de Geografia e Estatística*
IHP	Intergovenmental Hydrological Programme
ILO	International Labor Organization
LK	Local knowledge
LSK	Local Spatial Knowledge
LULC	Land Use and Land Cover
LULCC	land use and land cover changes
MAP	Mosaic of Agriculture and Pasture
MH	Mãe dos Homens community
MH-F	Floodplain in Mãe dos Homens community
MH-H	Hillslope in Mãe dos Homens community
MOVE	Methods of Assessment Vulnerability in Europe
NP	National Parks
NP-F	Floodplain in National Park area
NP-H	Hillslope in National Park area
NP-MH	Intersection of the national parks and the Mãe dos Homens community
NP-MH-F	Intersection of the national parks and the Mãe dos Homens community in Floodplain region
NP-MH-H	Intersection of the national parks and the Mãe dos Homens community in Hillslope region
NP-MH-P	Intersection of the national parks and the Mãe dos Homens community in Plateu region
NP-P	Plateu in National Park area
NP-QSR	Intersection of the national parks and the Quilombola São Roque community
NP-QSR-F	Intersection of the national parks and the Quilombola São Roque community in Floodplain region
NP-QSR-H	Intersection of the national parks and the Quilombola São Roque community in Hillslope region

	intersection of the national parks and the Quilombola community of São
NP-QSR-P	Roque in Plateu region
NUPDEC	Civil Protection and Defense Community Nucleus
OECD	Organization for Economic Co-operation and Development
OTC	Other temporary crops
P	Plateu
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PNAS	Aparados da Serra National Park
PNPCT	*Política Nacional de Desenvolvimento Sustantável dos Povos e Comunidades Tradicionais*
QSR	Quilombola São Roque Community
QSR-F	Floodplain in Quilombola São Roque Community
QSR-H	Hillslope in Quilombola São Roque Community
QSR-P	Plateu in Quilombola São Roque Community
RS	*Rio Grande do Sul*
SC	*Santa Catarina*
SDG	Sustainable Development Goals
SEMA	*Secretaria do Meio Ambiente e Infraestrutura do Estado do Rio Grande do Sul*
SGU	Sociogeomorphological Units
SU	Social Units
TK	Traditional Knowledge
UFGRS	*Universidade Federal do Rio Grande do Sul*
UN	United Nations
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture

LIST OF SYMBOLS

Symbol	Unit	Description
A	km^2	Area
D_d	km/km^2	Density drainage
e	--	Error acceptance value.
L_i	km	Length of the river channels
n	--	*S*ample size
N	--	*T*otal number of households
S	degree	Slope
X_i	--	Precedent time step.
X_{i+1}	--	Subsequent time step
Y_i	--	LULC area for class *i* in the precedent time step
Y_{i+1}	--	LULC area for class *i* in the subsequent time step
Z	m	Altitude

SUMMARY

1 Introduction

1.1 General Aspects

Population growth is associated with increasing records of natural disasters, as human settlements are often established in areas at risk, such as floodplains and hillsides. Disaster risk management (DRM) is essential for reducing the impacts of these events. It involves actions that decision-makers, diverse population groups, and politicians can take before, during, and after a disaster. It is, therefore, necessary to work together with communities to overcome the challenges of territorial management and, consequently, natural disaster management.

Participatory management, in the context of disasters, recognizes that the population faces the consequences of adopting decisions and practices and, therefore, must be involved in the processes. In order to overturn ineffective management practices, it is essential to implement methodologies that promote participatory management (UNESCO, 2022). Thus, vulnerable communities should be the first to be consulted, as they face great difficulties in returning to normal activities. Face-to-face data collection is an alternative in terms of representativeness. In addition, personal interaction with the community during the research creates expectations and increases the community's interest in the research product, facilitating acceptance of the resulting disaster management strategies.

Accelerated urbanization and drastic modification of the landscape alter natural processes that maintain the balance of the system and increase the occurrence of natural disasters. The interfaces between urban and rural areas represent a territorial management and governance challenge (ROS-TONEN *et al.*, 2015) but also offer an opportunity to align development patterns with the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda (ONU, 2015). Given this, alternatives for development in harmony with and based on nature should be even more highly valued. For example, (KOBIYAMA *et al.*, 2021) presented the concept of ruralization of urban areas, highlighting the benefits of maintaining or simulating natural environmental mainstream. In this context, it is essential to study natural environments and work together with the existing rural communities. Thus, DRM strategies formulated based on one-way technical knowledge (from scientists to the community) must be reformulated, as they disregard the knowledge generated by local communities (non-technical knowledge).

The strategic plan (2022 - 2029) "Science for a water-secure world in a changing environment - IHP-IX" of the Intergovernmental Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organization - UNESCO (UNESCO, 2022) is a collaborative effort that highlights five priority areas for action. This plan underscores the importance of hydrology in conjunction with citizen science, with a particular focus on rural and traditional communities, through 5 pillars:

i) Scientific research and innovation;

ii) Education on water in the fourth industrial revolution, including sustainability;

iii) Filling the data-knowledge gap;

iv) Inclusive water management under conditions of global change;

v) Science-based water governance for mitigation, adaptation and resilience.

In IHP-IX, scientific research is an indispensable tool for water governance (first priority area: Scientific Research and Innovation), promoting research methods and tools that include knowledge generated by citizen science and participatory processes. Similarly, the fourth priority area (Inclusive Water Management in Conditions of Global Change) encourages the development of research that guarantees the involvement of vulnerable and minority social groups (women, young people, indigenous people, and national minorities), ensuring that all of society with an interest in water management is included in the process (UNESCO, 2022).

In this dissertation, the collection and analysis of qualitative and unstructured data is of great importance, as it has been identified that research in the area of natural disasters should broaden the sources of data (systematic and non-systematic) and the methods of analysis, focusing on the integration of social and natural sciences (VANELLI *et al.,* 2022). This type of approach is valued in composite sciences, such as sociogeomorphology and socio-hydrology, where society and its elements are integrated into the analysis for a better understanding of the relationship between human beings and nature (GONZÁLEZ-ÁVILA *et al.,* 2021). In this sense, it is necessary to integrate the knowledge that rural communities, such as traditional quilombola communities in Brazil (BRASIL, 2003), have acquired over time and their social processes. The dissertation makes it possible to compare the perception of three rural communities in different countries, two in Brazil and one in Spain, with different development characteristics, identifying opportunities for improving and strengthening disaster risk management. Then, the dissertation considers the region of the traditional Quilombola community of São Roque, the non-traditional community of Mãe dos Homens and Ampuero, a rural community in northern Spain.

1.2 Theorical background

1.2.1 Communities

TAYLOR (2007) defines urban areas as regions where dense human settlements and related activities significantly alter the ecosystem. The author sets urban areas apart from agricultural regions, which, while influenced by human activities, do not typically involve dense settlements, such as buildings, roads, and infrastructure. Consequently, urban areas are marked by extensive modifications of the physical, chemical, and biological environment due to large-scale

construction. Then, population and territory outside of urban areas could be defined as rural areas (USDA, 2024). Historically, agricultural output was linked to rural areas; however, in the present, rural areas are utilizing other services to support their resources, such as tourism, recreation, and residential care, so agricultural services are only one of the available choices. According to IBGE (2023), rural and urban have no unique definitions. This topic has limitations since the dichotomic classification is not enough because it is hard to organize the geographic space. For instance, demographic density has a limitation to be an adequate criterion to define rural areas since there is a limitation to verify exactly the boundaries of communities in developing countries as Brazil (GOMES *et al.,* 2015). Thus, the criteria for classifications depend on each country. The description of geographic space is essential as it subsidizes government politics and specific societal actions.

In Brazil, rural population started to decline in 1940, and by 1960, urban population had surpassed it. The country's urbanization process occurred later than in many other places, primarily due to its robust agricultural activity during that period (IBGE, 2023). In Brazil, there are seven classifications used to describe urban and rural settings. The classifications are: i) urban area with high building density; ii) urban area with low building density; iii) urban center; iv) village; v) rural center; vi) "lugarejo," (small village); and vii) non-conglomerate rural area. It is already different in Spain, a country of Organization for Economic Co-operation and Development (OECD), a distinction is made between five classes to define territories, considering population density and the access time of communities to urban centers. Thus, the following classes are established: i) predominantly rural and remote areas (more than 45 minutes driving time to the closest city); ii) predominantly rural areas but close to a city (less than 45 minutes); iii) intermediate and remote areas (more than 45 minutes); iv) intermediate areas close to a city (less than 45 minutes); and v) predominantly urban areas. In these categories, only 5% of the population of European OECD countries live in predominantly rural and remote regions (MARTÍNEZ *et al.,* 2016).

1.2.2 Quilombola Community: A Brazilian Traditional Community

The world recognizes slavery as a period of extreme human suffering, which left a profound legacy for African and Latin American populations (DIALLO, 2017). The development of the Americas in the 16th century was closely linked to European colonization, a time when the capitalist system began to establish in Western Europe, reaching its peak in the 18th and 19th centuries (DIALLO, 2017). Brazil became a strategic point for the entry of enslaved Africans, who were used as cheap labor, reflecting the capitalistic logic of the time. In the Brazilian territory, an

important economic center was established, and the Americas became a place for the importation of African slaves and the subordination of indigenous peoples. It is estimated that 40% of enslaved Africans were brought to Brazil (GÁLVEZ, 2020). As a result of this history, currently 56.10% of the Brazilian population descend from Africa, as reported by the IBGE Continuous National Household Sample Survey (2020). This percentage is significantly higher than in other countries, such as Colombia (10.62%) (CIDH, 2011).

Given the inhumane conditions of the slavery period, resistance groups were formed that brought together escaped enslaved people, some indigenous people, mixed-race whites, and deserters. These groups were widely established in Latin America and received different names, such as Cimarrones and Garifunas in Central America, Cumbes in Venezuela, and Palenques in Colombia and Cuba (GÁLVEZ, 2020). In common, these groups sought fertile and isolated lands to guarantee their survival, and some still exist today. The term Quilombo was initially used to define communities formed by descendants of African slaves who resisted the slave regime, maintained in Brazil for more than 300 years until its abolition in 1888. Furthermore, a Quilombo is characterized by the sharing of cultural, religious, and socioeconomic status, as well as a common geographic location.

In Brazil, on November 20, 2003, the decree-law (488-7/2003, art. 2, § 1) reformulated the definition of Quilombo, eliminating the criterion of "origin of fugitive slaves" and emphasizing self-identification, as described in the Convention 169 of the International Labor Organization (ILO) on Indigenous and Tribal Rights (O'DWYER, 2002). Currently, Quilombo is understood as a self-identified ethnic-racial community with a history of slavery, oppression, and inequality, regardless of how the community was formed, including quilombos in urban areas (KENNY, 2011). The change in the Brazilian definition encouraged the formation of mobilized political groups, characterized by marginalized minorities throughout Brazil, who fight for federal recognition granted by the *Fundação Cultural Palmares*.

The struggle for recognition of the rights of Quilombolas (people who belong to Quilombo) has been driven by legal and social processes that also affect indigenous communities (ILO, 1957). Although it is common to associate traditional communities with indigenous people, Brazil is home to several non-indigenous traditional communities, such as *Azoreans*, *babaçueiros*, *caboclos*/Amazonian riverside dwellers, *caiçaras*, *caipiras*/*sitiantes*, *campeiros* (pastoralists), *jangadeiros*, *pantaneiros*, artisanal fishermen, *praieiros*, *quilombolas*, *sertanejos*/*vaqueiros* and *varjeiros* (non-Amazonian riverside dwellers) (DIEGUES, 2000).

Traditional communities are defined as "culturally differentiated groups that recognize themselves as such, have their own forms of social organization and occupy or use territories and

natural resources as a condition for their cultural, social, religious, ancestral and economic reproduction, using knowledge, innovations and practices generated and transmitted by tradition" (BRASIL, 2007). These communities have the right to exercise self-identification or self-recognition, autonomously attributing their cultural identity. In this way, Quilombola Communities are part of the broad group of Traditional Communities.

1.2.3 Traditional and Local Knowledge

The word "traditional" can be used as a descriptor of a particular kind of communities in modernity. Thus, "traditional communities" refers to native people and locals who uphold time-honored beliefs and customs as seen in Brazil in the National Policy for the Sustainable Development of Traditional Peoples and Communities – PNPCT (BRASIL, 2007). Traditional communities are recognized for their traditional knowledge based on personal and collective experiences developed over time and passed through generations. Traditional knowledge is closely linked to the features of the surrounding environment and is derived from long-held religious, folkloric, and legendary beliefs.

Local knowledge is a collection of opinions, sentiments, stories, and insights regarding a particular social group's surroundings. It covers information about society, the economy, and the environment. Local information is typically passed down from generation to generation orally and can be improved at any time under the group´s approbation.

Traditional and local knowledge are collectively referred to as Local Spatial Knowledge (LSK). Facts and Values are the two primary frames for LSK, says MCCALL & ALVAREZ LARRAIN (2022). The Facts are the local people's technical understanding of things like soils, flora, and natural resources. Additionally, LSK is fully understood by locals, but only somewhat by externs. The Values represent the many interests and points of view in the community that may conflict with the "official position". The Values also depict how locals and the environment interact (social, physical, spiritual, folklore, and environmental aspects).

Nowadays, scientific knowledge is firmly established because the methods are shared among the scientific community and applied all over the world. In opposition, traditional and local knowledge are linked to ethnic group identity, making it challenging to authenticate and spread methodologies. Furthermore, unlike the unsystematic data that local or traditional groups are used to dealing with, the systematic data connected with the scientific community are produced from rigid techniques and generally recognized explanations. To fill the gap between scientific, local, and traditional knowledge transdisciplinary sciences must be used. Then, integrated approaches could be used as VANELLI *et al.* (2022) describes in the natural disaster context. One

error that frequently occurs in this process is the imposition of knowledge from scientific knowledge on traditional or local knowledge. This circumstance must be avoided. Traditional knowledge belongs to community identity and is linked to the territory so it cannot be overlooked. For instance, VANELLI *et al.* (2022) describe that the absence of engagement from all stakeholders in the formulation of risk reduction strategies, ignores local knowledge and prevents understanding of the community's history of risks, vulnerabilities, and hazards. Additionally, failing to use this local expertise could result in outcomes that fall short of what the community requires and would agree to adopt.

1.2.4 Spatial distribution of manuscripts related to quilombola communities in Brazil

Brazil has a significant amount of information regarding quilombola communities. In the development of this doctoral dissertation the simple search was carried out on April 5th and 6th, 2022.to review some publications that include the participation of Quilombola communities in Brazil are to be found. Thus, a methodology for searching, filtering, and analyzing information was established and executed in order to delimit the existing data for the present study. The database of periodicals of the Coordination for the Improvement of Higher Education Personnel - CAPES (https://www-periodicos-capes-gov-br.ezl.periodicos.capes.gov.br/index.php/buscador-primo.html) was consulted. As search criteria, the words "Quilombola Community" were defined in the main field and supplemented in a secondary field with the word "Brazil". The Boolean operator "AND" was established for the search to find works that considered the words "quilombola community" and "Brazil" in the same document and in any field. The research was limited to the period between 2002 and 2022 since this time window is associated with the publication of the regulation of the processes of recognition, demarcation, and titling of quilombos since the promulgation of decree-law 4887/2003 (BRAZIL, 2003). The filter of articles available with "Open Access" and that had been peer-reviewed was also applied.

Given the quantity of works that were expected to be found, the quantity that was going to be sampled was established. This quantity was established with the aid of an online sample size calculator (https://pt.surveymonkey.com/mp/sample-size-calculator/) in which a confidence level of 95% and a margin of error of 10% were established. The first articles were selected, which were organized by relevance according to the CAPES Portal criterion. The CAPES criterion is based on weights distributed according to the existence of the term in different places of the publications, the number of times the term appears in the text, and the use of the text in citations and publication dates (CAPES, 2019). If any article appeared more than once, it was considered

only once, and in compensation, the same quantity of repeated articles that appeared was added. No filter was considered for the language, accepting articles in languages other than Portuguese. To extract the information from the articles, spreadsheets and tables were created with the Microsoft Excel program for the collection and organization of the data provided by the CAPES Portal, as well as the link of each article. Data such as year of publication, article title, location/state of the study, quilombola community studied, and abstract of each article were identified. According to the abstract, the theme of the article was established. In the case of works that presented multiple themes, the predominance of the theme was used as a classification criterion. In this way, the works will not be classified and counted more than twice. The results of the spatial distribution are shown in the figure below.

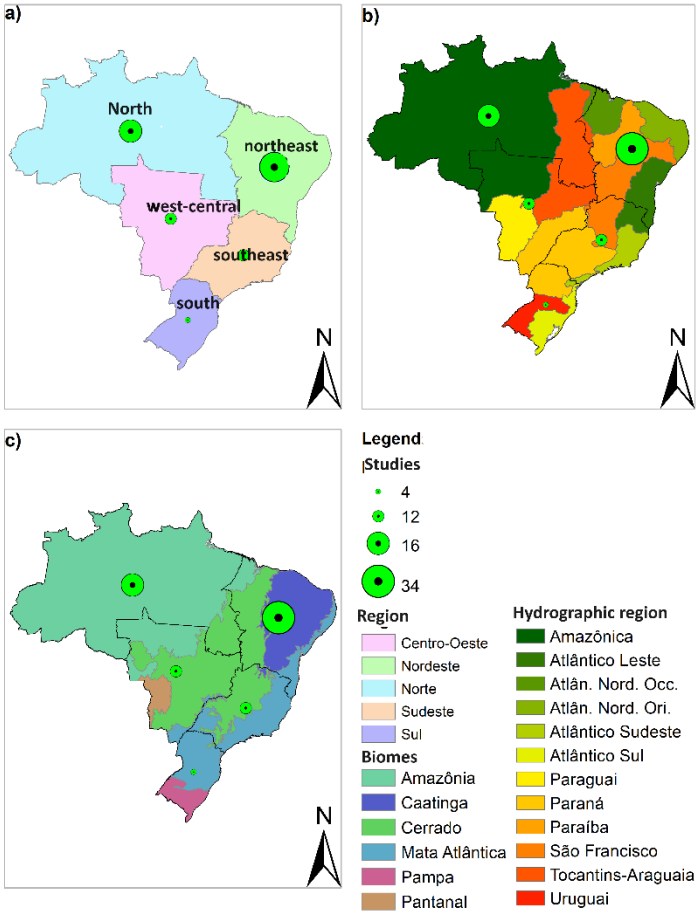

Figure 1-1. Spatial distribution of studies on Quilombola communities in Brazil. a) Major Brazilian regions; b) hydrographic regions and c) Brazilian biomes.

Analysis of the geographical distribution of studies on quilombola communities reveals a significant concentration in the Northeast region of Brazil, especially in areas of Caatinga, Atlantic Forest, and Cerrado. This concentration is directly related to the higher number of quilombola

communities registered in this region, according to IBGE data. Although the Northeast region was the focus of most studies (34), followed by the North (16), Southeast (12), Midwest (12), and South (4), there are still gaps in the precise identification of the specific area (8 studies) and the name of the quilombola community (44 studies) in some of the research. The distribution of studies reflects the distribution of biomes and hydrographic regions, with a higher concentration in areas more vulnerable to extreme climate events. The research highlights the importance of the traditional knowledge of quilombola communities for risk management and sustainable development, especially in regions with high environmental vulnerability, such as the Caatinga.

1.2.5 Risk, Vulnerability and hazard in a Disaster Context

There are five phases of DRM: prevention, mitigation, preparation, response, and recovery/rehabilitation (BRASIL, 2012; UNDRR, 2015). All stages of DRM involve several key terms that need to be clearly understood to address any potential disaster effectively. The following section is based on the work of MONTE (2021), who reviewed various terms related to disasters triggered by natural phenomena. Such disasters occur due to the direct impact of natural phenomena on social structures. Disasters can be exacerbated by poor planning or other human interventions that intensify their effects. A natural disaster results from the interaction between natural phenomena and individuals, communities, or systems in a specific area and time, disrupting social well-being and necessitating external assistance. The duration of a disaster can range from seconds to hours, enough to cause an organized society to halt its operations abruptly. Risk can be defined as a function of hazard and vulnerability, providing insights into the preparedness (or lack thereof) of an individual, community, or system. Risk must be quantified as an index to be practical and applicable, although this is challenging due to the difficulty in quantifying human factors. Temporally, risk precedes a disaster (ALMEIDA *et al.*, 2016). The occurrence of a disaster does not eliminate the risk; instead, past events contribute to predicting future disasters (BECK, 1992). Risk is influenced by an ongoing social process that considers changes and social development (LAVELL, 1999).

The definition of a hazard, a complex and multifaceted concept, is related to phenomena that may cause potential harm to the well-being of communities, and has a given probability, for example floods, landslides, droughts, etc. These hazards could be characterized according to their source, magnitude, intensity, frequency, duration, rise time, the area affected, and spatial dispersion. Then, a hazard can be defined as the possible action of an event with the potential to cause undesirable consequences to an individual, community, or system in each time and area.

To conduct a risk analysis, it is essential to consider the axis of vulnerability, as disasters reveal the weaknesses and strengths of a society. Vulnerability is defined as the state of fragility within a community and the systems it depends on, encompassing physical, social, cultural, economic, technological, and political aspects, thereby reducing overall capacities. This definition of vulnerability to disasters triggered by natural hazards applies to any system interacting with society. Quantifying vulnerability is complex due to the influence of multiple factors, their nonlinear interactions, and the lack of knowledge about their relative weights (SAM *et al.*, 2017). By including vulnerability, applied science focuses on exposure (GABOR; GRIFFITH, 1980) and susceptibility to damage (CARDONA, 2004), often overlooking resilience and coping capacity.

Vulnerability varies among individuals facing the same hazard. Thus, questions like "Who is vulnerable?" and "Vulnerable to what?" are crucial. The inventory of elements at risk from a given hazard is typically extensive, placing certain groups at higher risk based on their socioeconomic variables. Vulnerability can be reduced in two ways: a) if assets are less susceptible to damage, and b) if people are more aware of disaster risks (i.e., prepared and perceiving the risk), including understanding what to do during an emergency and having access to emergency services and post-event support. Addressing vulnerability offers significant opportunities to mitigate risks and disasters, especially when reducing the hazard itself is impossible (CARDONA, 2004). Within the understanding of vulnerability, it is necessary to define other terms that are shown in Table 1-1.

Table 1-1. Key terms for DRM.

Term	Definition
Susceptibility/ Sensitivity	The degree of damage that an individual, community, or system may suffer due to a hazard.
Exposure	The condition in which the hazard may be experienced is perhaps the most perceptible variable.
Resilience	The ability of an individual, community, or system to develop and engage in coping mechanisms, recover from disturbances, and return to social well-being and functionality without external assistance.
Coping capacity	Encompasses society's ability to react to and absorb the impacts of hazards, making it more extensive than mere resistance but less comprehensive than resilience. It represents the potential of an individual, community, or system to respond to, resist, and absorb disturbances to mitigate the severity of an event.
Recovery capacity	Potential to achieve a new level of social well-being following an event.
Adaptive capacity	The potential of an individual, community, or system to adjust its structure and behavior to reduce the risk posed by new hazards.
Adaptation	The extent of autonomous or planned interventions (such as creation, improvement, and implementation) that leverage opportunities or lessons learned, either reactively or proactively, to decrease

Term	Definition
	vulnerability. Maladaptation, on the other hand, refers to interventions that inadvertently increase vulnerability and ultimately harm communities.

Adapted from (MONTE et al., 2021)

Due to the complexity of vulnerability, several approaches allow for the assessment and quantification of different vulnerability factors (CIUREAN *et al.*, 2013; TURNER *et al.*, 2003). These approaches reflect various models and concepts that guide the development of indicators. For example, the Methods of Assessment Vulnerability in Europe (MOVE) (BIRKMANN *et al.*, 2013) is based on practical experience and knowledge to evaluate vulnerability.

One of the main objectives in developing the MOVE framework was to better conceptualize the multifaceted nature of vulnerability. This includes considering key causal factors such as exposure, susceptibility, and lack of resilience (lack of societal response capacity). The framework incorporates the concept of adaptation to DRM, thereby explicitly distinguishing between coping and adaptation. The different thematic dimensions of vulnerability are:

- Social Dimension: Propensity for human well-being to be harmed by the disruption of individual social systems (mental and physical health) and collective systems (healthcare, education, etc.) and their characteristics (e.g., gender, marginalization of social groups).
- Economic Dimension: Propensity for economic value loss due to damage to physical assets and/or disruption of productive capacity.
- Physical Dimension: Likelihood of damage to physical assets, including built-up areas, infrastructure, and open spaces.
- Cultural Dimension: Potential for harm to intangible values, including the meanings attributed to artifacts, customs, habitual practices, and natural or urban landscapes.
- Environmental Dimension: Potential for harm to all ecological and biophysical systems and their various functions. This includes specific ecosystem functions and environmental services but excludes cultural values that may be attributed to them.
- Institutional Vulnerability: Likelihood of damage to governance systems, the form and function of organizations, and the formal/legal and informal/customary norms that govern them, any of which may need to change in response to deficiencies revealed by the disaster and the response.

1.2.6 Perception of risk disaster

Risk perception in risk management represents a challenge. Being a cultural and subjective construct, risk perception affects risk exposure, risk communication, and, consequently, risk reduction management. In this way, risk perception influences both individual and collective

behavior and impacts preparedness and response actions (BRADFORD *et al.*, 2012) as well as an individual's acceptance of and commitment to specific technologies, policies, and standards associated with a hazard as described by SIEGRIST & ÁRVAI (2020).

According to SIEGRIST & ÁRVAI (2020), there is a distinction between the risk perception of people considered experts and that of lay people facing a threat. The knowledge of experts is characterized as quantitative, while that of laypersons is qualitative and difficult to measure. As a result, knowledge from specialists is seen as more trustworthy than that from citizens. Risk perception analyses have focused on studying the characteristics of hazards and how they leads to different responses of individuals (SIEGRIST; ÁRVAI, 2020). However, few studies explain the differences between individuals and how this can lead to varying risk perceptions in the face of similar hazards. For example, when studying the reasons behind variations in risk perception in the face of climate change in an international context, knowledge gaps remain, as noted by LEE *et al.* (2015). SIEGRIST & ÁRVAI (2020) suggest that cross-cultural research should be conducted in developed and developing countries, specifically in Asia and Africa. For these reasons, this dissertation considers it essential to measure the differences in risk perception between a Latin American country and a European one. This will enable a global understanding of risk perception beyond what was suggested by SIEGRIST & ÁRVAI (2020). Additionally, as seen in GONZÁLEZ-ÁVILA *et al.* (2023) and CARVALHO *et al.* (2023), risk perception varies within the same community. This reveals development issues that influence DRM.

The study of risk perception has been approached from two paradigms: constructivist and rational. The constructivist paradigm considers the context of the individual and explains the perception of risk through political, historical, cultural, and religious influences. On the other hand, the rational paradigm is based on quantifiable elements closer to the threat, such as the proximity of the individual to the hazard, age, and educational level.

LECHOWSKA (2022) reveals a vital study reviewing research on risk perception conducted between 1998 and 2018. This study identifies that between 2008 and 2009, there was a great deal of interest in understanding risk perception, specifically about flooding in Europe. As a result, the interest in this type of study has diminished since efforts have generally focused on the rationalist paradigm, while the constructivist paradigm has been less studied. The researcher highlights the moderating role of context in studies on flood risk perception. Constructivist factors may weaken or reinforce the impact of rationalist factors on the level of risk perception. According to the author, more studies are needed with a constructivist approach as the primary objective, so that the rationalist approach is used as a complement. This course of action is the opposite to the one commonly found in previous literature.

1.2.7 Sociogeomorphology for risk disaster management

There is a growing global concern about making landscapes more natural due to the diminishing natural features caused by human activities over time. Various natural sciences, including hydrology, geology, geography, geomorphology, and ecology, support understanding landscape processes and the best approaches to "landscape renaturalization" (FRASCAROLI *et al.,* 2021). Simultaneously, human sciences aim to address current social issues and enhance natural systems, acknowledging the constant interaction between natural systems and society (WAINWRIGHT; MILLINGTON, 2010). Thus, in this section of the present PhD dissertation, we stress the terms society, social activities, geomorphology, and sociogeomorphology to better understand the context of DRM.

Society could be defined as the group of people interacting and having their functions and structure. This group develops events or activities that, individually or jointly, have an objective, called social activities (GONZÁLEZ-ÁVILA et al., 2021). Certain social activities are addressed to DRM. Some examples of social activities to manage disaster risk may include: i) mapping areas of disaster risk; ii) creating policies and mechanisms for mitigating or reducing disasters; iii) environmental and disaster risk education; and iv) implementing sustainable infrastructures.

Geomorphology is a multidisciplinary and empirical science focused on studying, assessing, understanding, and classifying landforms and landscapes. It seeks to comprehend the processes and dynamics that characterize the genesis and evolution of landscapes and their relationships with other structures and processes, including hydrological, climatic, biotic, tectonic, and anthropogenic factors (CHRISTOFOLETTI, 1980; GOERL *et al.,* 2012). In geomorphology, the issues related to social impacts use the term "Anthropogeomorphology" (JEFFERSON *et al.,* 2013). This indicates a growing integration of geomorphology with social sciences. Anthropogeomorphology is widely used in applied geomorphology to study society's direct impact on geomorphic processes and landforms, typically from a unidirectional perspective (JEFFERSON *et al.,* 2013). It is important to note that many studies in anthropogeomorphology do not study the bidirectional interactions between humans and landscape dynamics in specific for DRM.

The term "sociogeomorphology" was first introduced by ASHMORE (2015). Ashmore proposed a holistic approach to highlight the complexity of geomorphology in urban rivers and the need for interdisciplinary study, describing these rivers as hybrid and socio-natural. Sociogeomorphology has also been utilized in other studies of fluvial geomorphology (MOULD *et al.*, 2018a, 2018b), reinforcing this science's focus and importance in river management. MOULD *et al.* (2018a) emphasized the importance of dialogue among stakeholders in river

management and demonstrated how incorporating non-technical knowledge can improve landscape research and management. NAYLOR *et al.* (2020) emphasize the importance of proactive decision-making for resilience and adaptation to climate change by incorporating geomorphological studies. By allowing geomorphic systems to respond more naturally and dynamically to extreme disasters, both present and future (within the next 100 years), these disasters' social and economic impacts can be minimized. Therefore, it is crucial to create interfaces between the science of geomorphology and social sciences in the context of natural disasters. Thus, in this PhD dissertation sociogeomorphology is defined as the study of the bidirectional interactions between geomorphological systems (the physical characteristics of landforms and geomorphic processes) and the development of social activities. As a co-producer in this system, society and its elements are integrated into geomorphological analysis to better understand the relationship between humans and nature.

1.3 Objectives

The present dissertation aims to analyze disaster risk perception in rural communities from a sociogeomorphological perspective and discuss the potential of this approach to develop strategies for improving DRM

The dissertation presents the following specific objectives to achieve this general goal:

- Demonstrate the value and advantageous of using a sociogeomorphological approach for DRM.
- Identify interactions between natural processes and anthropogenic activities that generate changes in the landscape and, thus are relevant for disaster risk management.
- Establish the foundation for developing more effective management plans for Brazilian rural communities with diverse social makeup.
- Understand the risk disaster perception from traditional and local knowledge of rural communities in an international context as a base for suggesting mitigation measures for water-related disasters.
- Demonstrate the circumstances in which a higher level of knowledge or significant cultural differences in rural communities result in disparate responses based on the perceptions so that influence flood risk management.

1.4 Document Organization

This document is divided into 5 chapters. Figure 1-2 shows the workflow of the PhD. Dissertation. The first Chapter corresponds to introductory matters. To achieve the objective of this dissertation, three manuscripts were developed and presented in Chapters 2 to 4, which correspond to publications or manuscript submissions to scientific journals. Figure 1-2 shows the aim of each study in the lower part of the manuscript's title in. The blue boxes marked as findings highlight the main findings or outputs found in each paper. These relevant results were numbered from 1 to 9. At the beginning of the boxes of Chapters 3 and 4, the numbers are shown as inputs for the respective manuscripts. Finally, the last Chapter (Ch-5) corresponds to practical application (Practical Application – Appendix), conclusions, and recommendations. Since the dissertation is based on articles published and submitted to scientific journals, it was necessary to readapt the presentation of tables and figures in each chapter.

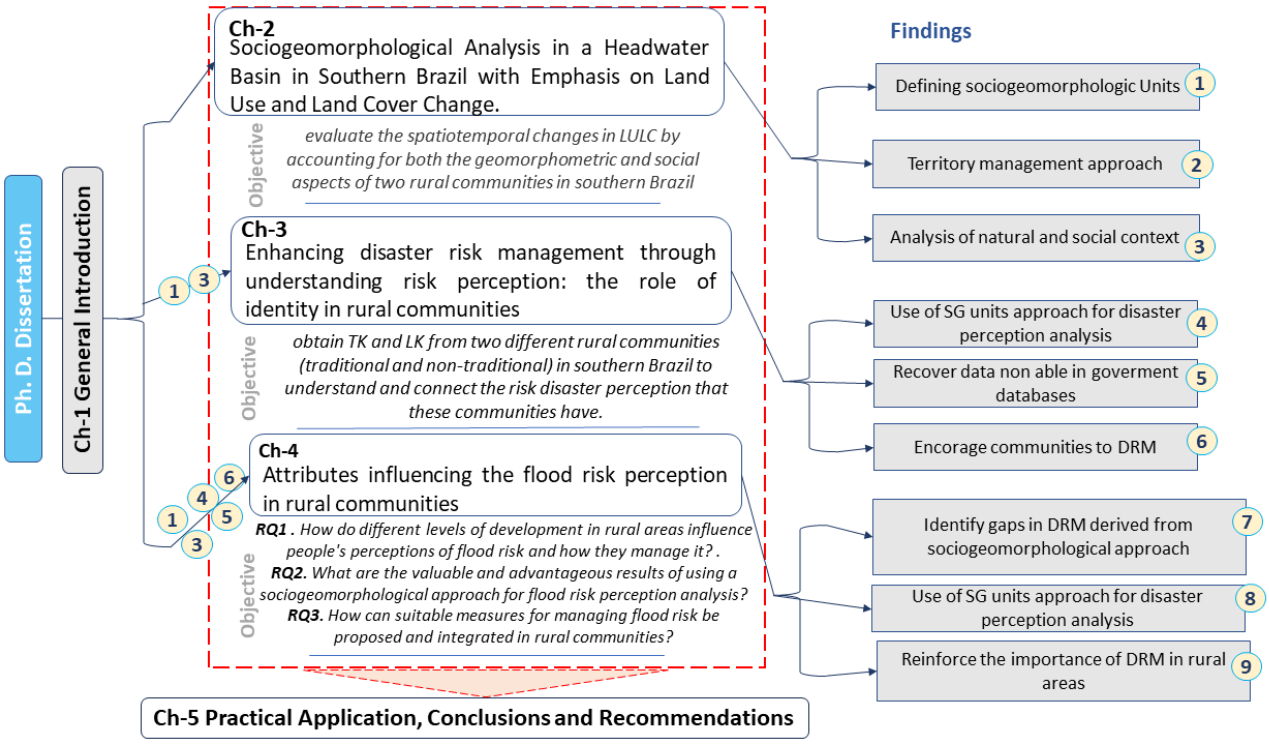

Figure 1-2. Workflow organization

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2 Sociogeomorphological Analysis in a Headwater Basin in Southern Brazil with Emphasis on Land Use and Land

This chapter is based on the following manuscript published in Land.

Resources:

GONZÁLEZ-ÁVILA, I. et al. Sociogeomorphological Analysis in a Headwater Basin in Southern Brazil with Emphasis on Land Use and Land Cover Change. ***Land****, v. 12, n. 2, p. 306, 2023. Available: https://doi.org/10.3390/land12020306*

Abstract

Effects of natural processes on community building and the modification of nature by man's hands are an intrinsic part of the co-production of the landscape between man and nature. However, the interactions of this co-production have scarcely been analyzed. Based on data from the MapBiomas project, an analysis of the variation in land use and cover over 35 years in the Quilombola São Roque and Mãe dos Homens communities in southern Brazil was carried out. The sociogeomorphological units in the study area were established, and its geomorphological units and social units were analyzed and described. There is a prevalence of more than 50% of forest formation. Cluster analysis classified the analyzed variables into two groups, with the first corresponding to forest and grassland formations associated with more natural landscape features. The second group is formed by anthropogenic activities. Social units including traditional communities seem to be more related to the stimulation of forest formation. The action of conservation units influences the variation in land use and land cover. There is a supplementary material which explains abbreviations concerning the manuscript.

Keywords: sociogeomorphology; national parks conservation; natural resources; Land Use and Land Cover; landform; headwater; Brazil

2.1 Introduction

The term "landscape" seen from an ecological point of view is defined as a land area containing a mosaic of habitat patches (DUNNING *et al.*, 1992). However, according to ANTROP (2005), "landscape" from a cultural perspective denotes those areas in which humans have created visible changes in the environment through land restructuring in order to better adapt its use and spatial structure to the demands of society. Furthermore, Ecosystem services (TALLIS; KAREIVA, 2005) provided by landscapes can be altered . Thus, in the present study, the term "landscape" is defined as the space of interaction between natural and social processes in the environment.

Geomorphological (natural) and social features are elements that belong to landscapes. In this context, sociogeomorphology has emerged as a research area that uses concepts from social sciences and natural sciences to understand the interactions between social activities and geomorphic processes (GONZÁLEZ-ÁVILA *et al.*, 2021). In this sense, thinking about landscape analysis units also refers to a set of geomorphological and social units. Therefore, we can conclude that landscape units are very similar to sociogeomorphological units. Figure 2-1 shows the sociogeomorphological approach to land management.

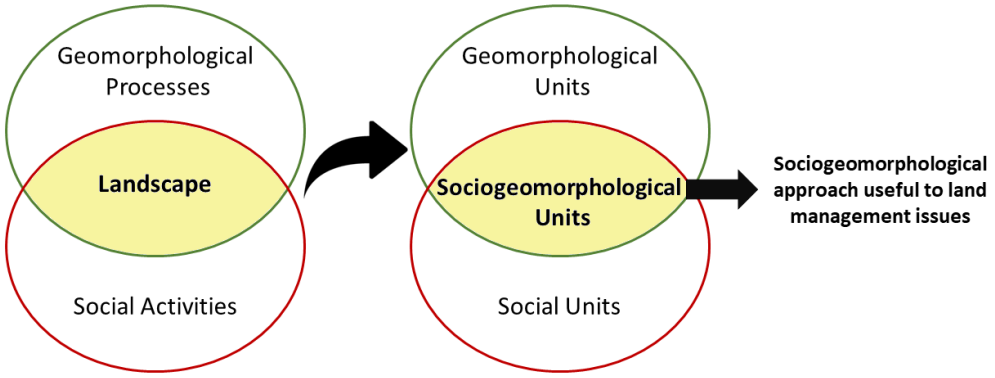

Figure 2-1. Conceptual diagram of the link between sociogeomorphology and land management.

Sociogeomorphological studies suggest that government managers and scientists execute an application of holistic approaches to study the above-mentioned interactions within the co-production of the landscape (ASHMORE, 2015; MOULD *et al.*, 2018a, 2018b). Several studies emphasized river geomorphology (ASHMORE, 2015) and sociogeomorphology applied to river restoration (MOULD *et al.*, 2018a, 2018b). However, concerns with river systems should not be the sole focus of sociogeomorphological studies; there are several challenges with land management that could benefit from sociogeomorphological techniques. It is worth noting that considering historical, political, and environmental conditions within the framework of sociogeomorphology is crucial to make the appropriate landscape changes. However, it is a relatively young field of study and in the process of consolidation (GONZÁLEZ-ÁVILA *et al.*,2021), which offers an opportunity for scientific development in this direction.

A first step towards this path is the definition of the concepts involved in Figure 2-1. Social Units (SU) can be simply defined as activities carried out by individuals or any social organization, such as the demarcation of territories, creation of social groups, and social movements with a specific goal. Here, it should be emphasized that the Land Use and Land Cover (LULC) classification is a relevant part of SU and an attempt by society to organize its territory. There is a lot of terminology related to LULC (NEDD *et al.*, 2021; SREEDHAR *et al.*,2016); however, it usually focuses on man's use of the various physical, chemical, and cultural factors of land in time and space (SREEDHAR

et al., 2016). LULC are relevant to territory management and understanding them is necessary. LULC from agricultural activities and urbanization has intensified over the past few years, while forest and grassland formations have been fragmented (OLIVEIRA, 2020). Several land use and land cover changes (LULCC) have negatively impacted the landscape and ecosystem services, including deforestation (EGUIGUREN *et al.*, 2019) or occupations close to water bodies (KITTIPONGVISES *et al.*, 2020) that normally led to disasters. In response to environmental degradation, society has encouraged the development of nature restoration, preservation, and conservation activities, such as the creation of protected areas like conservation units (DRUMMOND *et al.*, 2010). Other examples are the creation of national parks (FONSECA; CARA, 2021) or river renaturalization (MAZUR, 2021).

Moreover, geomorphological units (GU) are defined as areas with similar geomorphic processes, such as landslides, debris flows, and floods, which influence LULC and modify the landscape. Furthermore, plateaus, hillslopes, and floodplains are also considered kinds of GU. In this sense, sociogeomorphological units (SGU) can be delimited through the combination or union of SU and GU. Table 2-1 illustrates one example of how to establish SGU from several SU and GU. To emphasize social and geomorphological (or environmental) factors, the term SGU is more appropriate than that of landscape unit.

Table 2-1. Delimitation of sociogeomorphological units (SGU) from social units (SU) and geomorphological units (GU).

Social Unit (SU)	**Geomorphological Unit (GU)**	**Sociogeomorphological Unit (SGU)**
SU1	GU1	SGU1
	GU2	SGU2
	GU3	SGU3
SU2	GU2	SGU4
	GU4	SGU5
SU3	GU4	SGU6

Indeed, the interactions between society and nature are complex to understand, because they involve several factors and units of analysis. Although LULCC and some of their impacts have already been addressed (CABALLERO; RUHOFF, 2021; SPOSITO, 2021), there are still few works that have holistically discussed social and environmental factors as a tool in natural resource planning. For this reason, the analysis of SGU is proposed to fill this gap in landscape management issues.

Brazil is a pioneer country, serving as a case study for the evaluation of the principles of sociogeomorphology; however, to the best of our knowledge, there are only two studies that have

addressed this topic. They evaluated water resource systems (COELHO *et al.*, 2018; RAMOS *et al.*, 2017) in non-traditional communities, which are most prevalent in the country. As such, there is still a gap in the application of sociogeomorphology in other areas, such as territorial planning and natural disaster management. Furthermore, Brazilian traditional communities have not been evaluated from a sociogeomorphological point of view.

Therefore, the objective of the present work is to evaluate the spatiotemporal changes in LULC by accounting for both the geomorphometric and social aspects of two rural communities in southern Brazil. Thus, we seek to identify and understand the interactions between natural processes and anthropogenic activities that generate changes in the landscape. The study will describe the concept of sociogeomorphological units (SGU) and their potential uses in land management. The present case study considers the region of the traditional Quilombola community of São Roque and the non-traditional community of Mãe dos Homens. Quilombola communities are defined as "ethno-racial groups, according to criteria of self-ascription, with their historical trajectory, endowed with specific territorial relationships, with the assumption of black ancestry related to the resistance to the historical oppression suffered" (BRASIL, 2003). These rural communities are in the state of Santa Catarina (SC) and partially in the state of Rio Grande do Sul (RS), southern Brazil. It is worth noting that these communities overlap with the conservation units of the Aparados da Serra and Serra Geral Natural Parks, located at the headwater regions of (i.e., the upper) the Mampituba River.

According to UNDRR (2015), Sustainable Development Goal 10 aims to "Reduce inequality within and among countries". More specifically, target 10.2 reads as follows: "By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status". This problem has become increasingly serious in Brazil due to its historical and very complex racial melting pot. Studying the comparison between traditional and non-traditional communities can help improve understanding of this situation.

2.2 Study Area

2.2.1 Physiographic Characteristics

The study area was delimited as a basin with an area of 193.74 km^2 and an outlet at East 595,119.72 m and North 6,765,844.29 m. This basin is in the headwaters of the Mampituba River (Figure 2-2). The study area partially comprises the municipalities of Cambará do Sul (RS), Mampituba (RS), Praia Grande (SC), São Francisco do Paula (RS), and Três Forquilhas (RS).

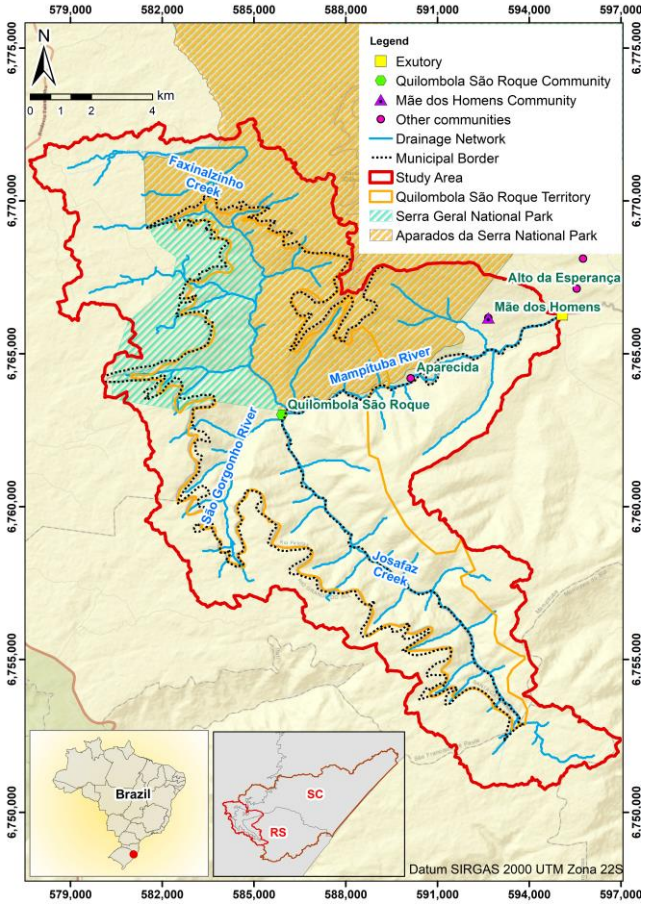

Figure 2-2. Study area location.

The semi-permanent South Atlantic anticyclone and the polar migratory anticyclone influence the study area's climate due to its location in a transition zone of medium and subtropical latitudes. As a result, the region has a mild mesothermal climate of the Cfa type in its lower parts and Cfb in its higher parts, according to the Köppen classification. The region has regularly distributed rainfall that varies between 1450 mm and 1850 mm per year (SEMA, 2020), with municipalities such as Praia Grande (SC) and Mampituba (RS) registering the highest rainfall values. The relative humidity of the air reaches values between 76 and 81%, while the annual evapotranspiration is around 990 mm (BOHN, 2008).

The study area is a transition region in which different types of vegetation, relief, geology, and pedology are found. The soils of the plateau range from shallow to deep, with high fertility and acidity. For example, the soils in Campos de Cima da Serra, which is a kind of biogeographic community located in the plateau, contain a low organic matter content with low base saturation. The hillslopes, on the other hand, are formed from shallow soils of very recent formation, with a high fertility potential. In the part of the floodplains embedded in the rivers, there are shallow to deep soils with a reasonable content of organic matter and high chemical fertility. Rice fields are commonly encountered in this region, where the soils are shallow and poorly drained, with

varying fertility and acidity potential and high organic matter levels (BOHN, 2008; SEMA, 2020; VIERO; SILVA, 2010).

There are three types of primary forest vegetation in the study area. The Atlantic Forest is on the hillslopes and floodplains of the basin. The Submontane Forest is in the drainage headwaters and deep soils. Finally, the Montana Forest is on the plateau escarpments (>400 m.a.s.l.) (BOHN, 2008).

2.2.2 Social Characteristics

There are two rural communities in the study area: (a) the Quilombola community of São Roque (QSR) and (b) the Mãe dos Homens Community (MH). These communities are a typical example of citizenship with a sense of belonging to the landscape (WATERMAN *et al.,* 2021). Downstream of the Mampituba River, next to the QSR, there are some established communities made up of immigrant families of European descent, among them the MH. QSR is a traditional Brazilian community, and many other traditional peoples in Brazil live in or near national parks. This allows the investigation of how nature and traditional people interact today, as well as learning about culture and its interaction with the soil. The MH community is close enough to the QSR community to notice differences and similarities. The MH community also has land in the national park conservation.

The characteristics for both communities described in Table 2-2 correspond to information interpreted from the works of CARMO *et al.,* (2018); LUMMERTZ, (2015) and SPAOLONSE, (2013). It is clearly observed that these communities are very different.

Table 2-2. Social characteristics of communities studied.

Community	**Quilombola São Roque**	**Mãe dos Homens**
Type	Traditional	Non-traditional
Start of Occupation	About 1800 [1]	1840~1900 [2]
Ancestors	Enslaved Africans	European immigrant families
Social Organization	• *Grota* system ("Grota" local name to cave). Organizational system. • Social Association formed in 2003 • Around 30 families	Community
Delimited area	73.28 km²	No
Economy	Agriculture	•Agriculture •Livestock •Logging
Natural Disasters	Floods (1974, 1995, 2006) Storms	Flood (1974) Storms

Community	Quilombola São Roque	Mãe dos Homens
Fluvial network	• Josafaz creek • São Gorgonho creek • Mampituba River	• Mampituba River • Facão River
Geoform and relief	• Pedra Branca mountain • Cliffs • Canyons	• Flood Plain • Wavy Relief

[1] Occupation for more than 180 years, according to personal communication. [2] The first couple arrived in 1840 but it was not until 1940 that there was community infrastructure, i.e., a community saloon.

The most prominent features concern the ancestors: those of QSR were enslaved Africans, while for MH, they were European immigrant families. During the slave regime and after the slave emancipation, the Quilombola communities settled in very remote areas across the national territory. Then, QSR was first founded. Hence, QSR is older and more remote than MH.

Due to suffering over a long period of time, all Quilombola communities have a tradition of uniting residents in terms of legislation and solidarity. Thus, QSR invariably has its own social organization protected by a Brazilian royal decree (BRASIL, 2003), while MH has no official organization. More details about the social characteristics of the study area can be consulted in (CARMO et al., 2018; LUMMERTZ, 2015; SPAOLONSE, 2013).]

2.3 Materials and Methods

2.3.1 Social Units

The study basin was divided into several units of analysis using five different sections called Social Units (SU): (i) the national parks (NP), (ii) the Quilombola community of São Roque (QSR), (iii) the Mãe dos Homens community (MH), (iv) the intersection of the national parks and the Quilombola community of São Roque (NP-QSR), and (v) the intersection of the national parks and the Mãe dos Homens community (NP-MH). The NP, QSR, and MH do not have intersection areas. According to oral communication with the Mayoralty, MH lacks an official delimitation. Thus, the space corresponding to MH was an assumption based on fieldwork.

In the basin, there are unclassified areas that are not included in the aim of the study. These areas belong to other communities or social units that are outside the comparative exercise of interactions between the NP, QSR, and MH. Additionally, the MH and QSR are entirely inside the basin area, whereas the unclassified areas are social units divided by the basin area delimitation.

The division of the territory into units of analysis enables an analysis of the relationship between the SU and GU of the territory, as well as variations in LULC. Figure 2-3 shows the SU used in this study.

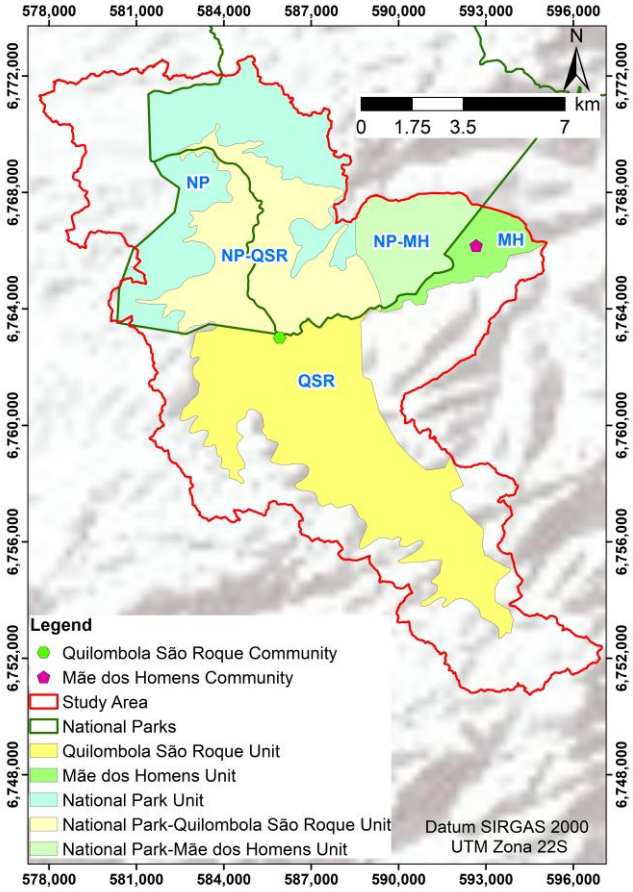

Figure 2-3. Division of the study area into social units (SU).

2.3.2 Geomorphological Characterization

A 12.5 m resolution Digital Terrain Model (DTM) obtained from the Advanced Land Observing Satellite (ALOS) satellite and Phased Array type L-band Synthetic Aperture Radar sensor (PALSAR) ("ASF Data Search", [s.d.]) was used to extract the terrain features. The DTM was geoprocessed using ArcGIS 10.5 tools licensed by the Federal University of Rio Grande do Sul (UFRGS). Previously, the values of altitude of different DTMs were compared (2006, 2007, 2008, 2009, 2010, and 2011), and no evidence of variations with time was identified. This confirmed that there was no remarkable topographic change in the period and scale at which data are available. Therefore, the 2011 DTM was selected for further analysis.

The slope (*S*), altitude (*Z*), and drainage density (*Dd*) in the study area were used for the geomorphometric characterization of the terrain. Both *Z* and *S* are direct outputs from the processing of the DTM. The *Dd* was obtained from the drainage network built with the DTM and rectified with satellite images. In particular, Equation 2-1 was used for its computing.

Equation 2-1

$$D_d = \frac{\sum L_i}{A}$$

where *Li* is the length of the river channels in km, and *A* is the area of the region in km².

The GU were classified according to altitude (BOHN, 2008; ROSS, 1985). However, it is recommended to consider other criteria, such as slopes and field observations (REBELO, 2007; GONZÁLEZ-ÁVILA *et al.,* 2022). According to GONZÁLEZ-ÁVILA *et al.* (2022), the region's territory can be classified as plateau, hillslope, and floodplain. The altitude ranges from these classes were 820–1070 m, 230–820 m, and 86–230 m, respectively. The values of *S* and other characteristics identified in the field helped define altitude ranges for the delimitation of the geomorphological units.

Three slope intervals were established based on landslide susceptibility criteria: 0 to 18º, 18.01 to 25º, and greater than 25º. According to (REBELO, 2007), slopes greater than 18º favor debris flows in prolonged and high rainfall conditions. In addition, faster soil movements occur when slopes are greater than 25º (SIDLE *et al.,* 1985).

2.3.3 Description of LULC

The analysis of LULC used the information provided by the MapBiomas project (MAPBIOMAS, 2020, 2021a). The information was obtained using the Google Earth Engine—GEE (MAPBIOMAS, 2020, 2021a). LULC values were extracted for the years 1985, 1990, 1995, 2000, 2005, 2010, 2015, and 2020. The LULC data for the socio-geomorphological units for the period studied will make it possible to establish the relationships between land use changes and the socio-natural variables that influence them. In addition, the relationship between LULC and the area of the territory analysis units was calculated.

The 6th version of the MapBiomas project provides an LULC classification (MAPBIOMAS, 2021a, 2021b). Therefore, based on a preliminary analysis, six classes of LULC were selected as described in Table 2-3. Due to their low area values, some classes representing soy, rice, flood land, and water were added to the 'Other Temporary Crops' class.

Table 2-3. Description of the LULC classes

Nº	**Class**	**Description**
1	Forest Formation	Woody vegetation with arboreal or arboreal-shrub species, with a predominance of continuous canopy. It includes the following forest typologies: ombrophilous, deciduous, and semideciduous, and part of the pioneer formations.

Nº	Class	Description
2	Silviculture	Tree species planted for commercial purposes (e.g., pines, Eucalyptus)
3	Grassland Formation	Vegetation with a predominance of grassy herbaceous strata, with the presence of herbaceous and subshrubby dicotyledons. In most cases, it corresponds to native vegetation, but patches of invasive exotic vegetation or the use of forage (planted pasture) or livestock may be present. Local name is "*Campos de Altitude*"
4	Pasture	Pasture area, predominantly planted, linked to agricultural activity.
5	Mosaics of Agriculture and Pasture (MAP)	Areas of agricultural use where it was impossible to distinguish between pasture and agriculture. It may include cropland, winter or summer pasture, and horticulture. It includes rest areas between agricultural crops (fallow).
6	Other Temporary Crops (OTC)	Areas occupied with short- or medium-term crops, generally with a vegetative cycle of less than one year, that need to be planted again to produce after harvesting.

Source: Adapted from (MAPBIOMAS, 2021a).

2.3.4 Estimation of LULC Variation

For each units of analysis, the variation in LULC was estimated using five years as a time step, starting in 1985 and ending in 2020. This period, which was set according to the data availability in the MapBiomas project, was split into ranges of five years for analysis purposes. As a result, the trend in *LULCC* was determined using Equation 2-2.

Equation 2-2

$$LULCC = \frac{Y_{i+1} - Y_i}{X_{i+1} - X_i}$$

where *LULCC* is the variation in LULC area during a five-year period; Y_{i+1} is the LULC area for class *i* in the subsequent time step, Y_i is the LULC area for class *i* in the precedent time step, X_{i+1} is the subsequent time step, and X_i is the precedent time step.

2.3.5 Statistical Analysis

2.3.5.1 Statistical Comparisons of LULC

The LULC variation data series for each SU (NP, QSR, MH, NP-QSR, and NP-MH) were first tested to evaluate their distribution and variance homogeneity. Subsequently, comparison tests were carried out. The used test type depended on whether the data was normally distributed and homogeneous (ANOVA and Student's *t* tests) or not (Kruskal–Wallis and Mann–Whitney tests). These tests enabled a determination of whether the variations in LULC classes were statistically significant across the different units of analysis. The same procedure was also conducted for the LULC areas for each unit of analysis. For all statistical analyses, Minitab software was used.

2.3.5.2 Cluster Analysis

Each SU (NP, QSR, MH, NP-QSR, and NP-MH) was defined by its values of area (*A*), length of drainage network channels (*Li*), drainage density (*Dd*), altitude (*Z*), average slope (*S*), and average variation in LULC. Before running a cluster analysis, the data were standardized by subtracting the mean from their values and dividing them by their standard deviation to avoid the scale effect. Then, a hierarchical clustering was carried out using the average method (JARMAN, 2020). The analysis was configured to obtain a dendrogram with clusters with more than 50% similarity in their data. In this context, cluster analysis was performed to identify the similarity between the analyzed variables that represented natural or anthropic characteristics.

To complement the results obtained from clustering, the Pearson's correlation test was applied to the groups obtained to identify the strength and direction of statistically significant correlations among the variables considered.

2.4 Results and Discussion

2.4.1 Sociogemorphological Characterization

The *Z* values varied between 86 and 1070 m above sea level, and the *Z* mean values for PN, QS, MH, PN-QSR, and PN-MH were 959.9 m, 592.63 m, 239.26 m, 570.35 m, and 510.92 m, respectively. In addition, the height of canyon walls was ~700 m, whereas S values of > 45° in the hillslope were observed according to the literature (CAMPAGNOLO *et al.*, 2021; WILDNER *et al.*, 2006). The value of S of the territory and the division into SU and GU are shown in Figure *2-4*. The SGU were shaped from the intersection between SU and GU, so 15 SGU were established, as shown in Table 2-4.

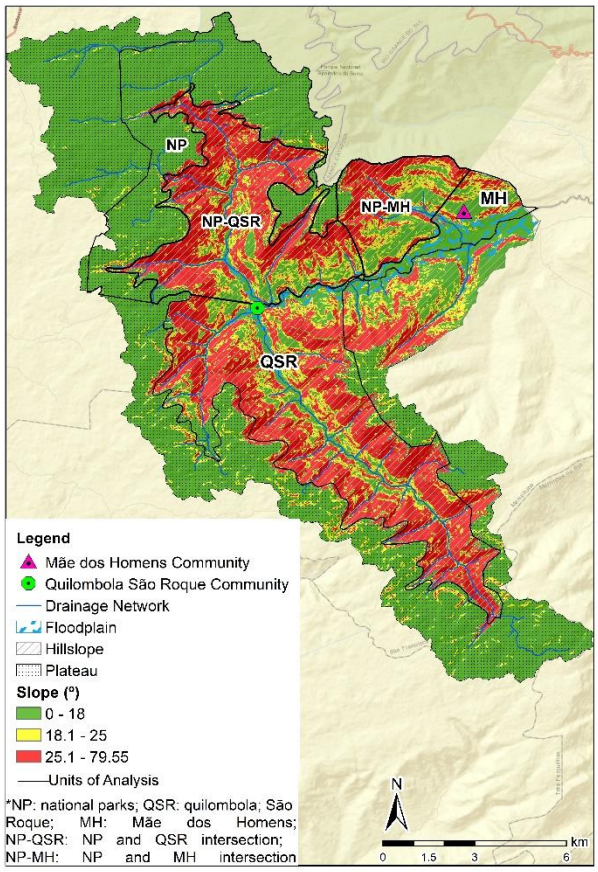

Figure 2-4. Geomorphological units (GU), social units (SU), and slope information.

The S values ranged from 0 to 79.55° over the study area. Its average across the entire basin was 17.95°, a value close to 18°, which is known as a conditioning factor for mass movements due to high slopes (REBELO, 2007). The average S values for both SU and GU are shown in Table 2-4, which also allows us to analyze each Sociogoemorphological Unit (SGU).

Table 2-4. Data for area and slope corresponding to units of analysis.

Units of Analysis	Units of Analysis Type	Area (km²)	Maximum (°)	Average (°)	Average Slope Description	Standard Deviation	Coefficient of Variation (%)
Basin	-	193.4	79.55	17.95	Medium	13.41	74.71
Plateau (P)	GU	91.65	50.7	8.33	Low	5.8	69.63
Hillslope (H)	GU	93.95	79.55	28.26	High	11.56	40.91
Floodplain (F)	GU	7.8	35.84	9.62	Low	6.25	64.97
NP	SU	29.28	76.6	8.57	Low	7.91	92.30
QSR	SU	45.55	76	28.06	High	12.15	43.30
MH	SU	5.85	43.38	14.02	Low	8.42	60.06
NP-QSR	SU	27.7	79.55	28.87	High	12.5	43.30
NP-MH	SU	10.64	77.75	23.36	Medium	10.44	44.69
Unclassified	SU	59.6	-	-	-	-	-
NP-P	SGU	27.29	36.35	7.25	Low	5.16	71.17
NP-H	SGU	1.63	76.6	31.27	High	10.42	33.32
NP-F	SGU	-	-	-	-	-	-
QSR-P	SGU	3.29	39.06	13.64	Low	6.75	49.49

Units of Analysis	Units of Analysis Type	Area (km²)	Maximum (°)	Average (°)	Average Slope Description	Standard Deviation	Coefficient of Variation (%)
QSR-H	SGU	40.71	76	29.79	High	11.27	37.83
QSR-F	SGU	1.55	35.84	10.83	Low	5.92	54.66
MH-P	SGU	-	-	-	-	-	-
MH-H	SGU	3.08	43.38	18.85	Medium	7.23	38.36
MH-F	SGU	2.77	26.88	8.69	Low	6.08	69.97
NP-QSR-P	SGU	1.74	41.61	14.3	Low	6.95	48.60
NP-QSR-H	SGU	25.37	79.55	30.61	High	11.9	38.88
NP-QSR-F	SGU	0.59	26.63	10.45	Low	5.87	56.17
NP-MH-P	SGU	0.39	30.97	9.89	Low	6.41	64.81
NP-MH-H	SGU	9.98	77.75	24.08	Medium	10.15	42.15
NP-MH-F	SGU	0.26	25.17	14.34	Low	5.3	36.96

The GU hillslope presents high *S* values (maximum of 79.55°), which agrees with the findings of the previous literature (WILDNER *et al.,* 2006). This characteristic is also observed in the NP-QSR-H unit. The low average *S* value in the plateau region (8°) may relate to the presence of relief undulations common in *Campos de Altitude* (CAMPAGNOLO *et al.,* 2021; WILDNER *et al.,* 2006). In the floodplain, the mean and maximum S values were 9.6° and 35.8°, respectively. Thus, the plateau and floodplain show low values of mean slope similar to NP-P, MH-F, and NP-MH-P, which coincides with the observed reliefs and characteristics. The maximum slope indicates the transition zone between the floodplain and the hillslope, known as the foothills. A greater variation in slope values was identified for the following units: NP-P and MH-F (SGU), NP (SU), and plateau and floodplain (GU). Apart from the foothills, this can be explained by the transition zone between the plateau and hillslope, which includes the Josafaz and Faxinalzinho canyons (Figure 2-2), areas affected by scarp retreat and rock erosion processes (WILDNER *et al.,* 2006).

The hillslope is the predominant GU present in the SGU, unlike floodplain and plateau. Hillslope predominates in the SGUs associated with overlaps (PN-QSR-P, PN-QSR-H, PN-QSR-F) and QSR/SGU (QSR-P, QSR-H, QSR-F). The MH/SGU (MH-P, MH-H, MH-F) is composed of hillslopes and floodplains in a similar proportion. Furthermore, the plateau unit is predominant in the NP/SGU (NP-P, NP-H, NP-F) and shows some high *S* due to canyon walls in the area. NP-F and MH-P could not be analyzed because there is no overlap between the respective SU and GU.

According to (CABALLERO *et al.,* 2020), a well-drained basin must have a *Dd* index greater than 3.5. Lower drainage density occurs in regions of highly permeable subsoil material, under dense vegetative cover, and where relief is low (SINGH *et al.,* 2019). The Dd values of the SU vary between 0.46 and 1.62 km/km², while SGU show values of *Dd* between 0.33 and 6.24 km/km² (Table *2-5*). The NP-MH and NP units had the lowest values of *Dd* for SU. This contrasts with the

NP-QSR and QSR units, which showed values similar to those reported by (CABALLERO *et al.*, 2020) for the sub-basins of the Josafaz (1.46) and Faxinalzinho (1.28) streams.

The analysis of the SGU emphasizes how the scale of analysis can change the outcomes. The NP/SGU agrees with the SU of NP, where *Dd* is low (SINGH *et al.*, 2019). Nevertheless, for the SGU related to QSR, MH, and their intersection with NP, the floodplain region shows well-drained units according to their natural characteristics. This aspect is only observed when SGU are considered, showing the importance of integrating social and geomorphological aspects in territory analysis.

The highest density of drainage is related to an elevated relief and scarce infiltration, where erosion processes have deteriorated the surface. According to (COSTA *et al.*, 2018), the capacity of infiltration derived from vegetation and low reliefs are prone to low values of *Dd*, which is verified in NP, NP-MH, NP-P, and NP-H.

Table 2-5. Drainage density (Dd) of the units of analysis.

Units of Analysis	Area (km^2)	Length (km)	Dd (km/km^2)
NP	29.28	14.33	0.49
QSR	45.55	73.97	1.62
MH	5.85	5.78	0.98
NP-QSR	27.70	33.44	1.21
NP-MH	10.64	4.89	0.46
NP-P	27.29	13.29	0.49
NP-H	1.63	1.00	0.61
QSR-P	3.29	3.50	1.06
QSR-H	40.71	42.63	1.05
QSR-F	1.55	7.62	4.92
MH-H*	3.08	-	-
MH-F	2.77	9.78	3.53
NP-QSR-P	1.74	1.99	1.14
NP-QSR-H	25.37	25.87	1.02
NP-QSR-F	0.59	3.68	6.24
NP-MH-P *	0.39	-	-
NP-MH-H	9.98	3.32	0.33
NP-MH-F	0.26	1.44	5.54

* There were no identified river channels in these Sociogeomorphological Units (SGU).

2.4.2 LULC Description and Variation

In the evaluated period, the social units of analysis showed a predominant coverage of forest formation (>50%) (Figure 2-5). The forest cover in this region is associated with the Atlantic Forest (Figure 2-6a), which has undergone intense land use changes (CABALLERO; RUHOFF, 2021). The forest formation class in the QSR, NP-MH, and NP-QSR units is near or higher than 90% and can be related to the hillslope regions. The percentages are rather variable for other coverages

and land uses. The grassland formation covers 40–45% of the NP unit, a value which is lower for other units, and can be associated with the plateau region. Furthermore, silviculture increased from 2005, which is a questionable event because it is a national park. Pasture (2–7%) and MAP (13–23%) are represented in the MH unit, which is characterized by being more populated and included in the floodplain region (Figure 2-6b). In general, silviculture cover and other temporary crops correspond to low percentages (<3.5%), except for MH (1–6%).

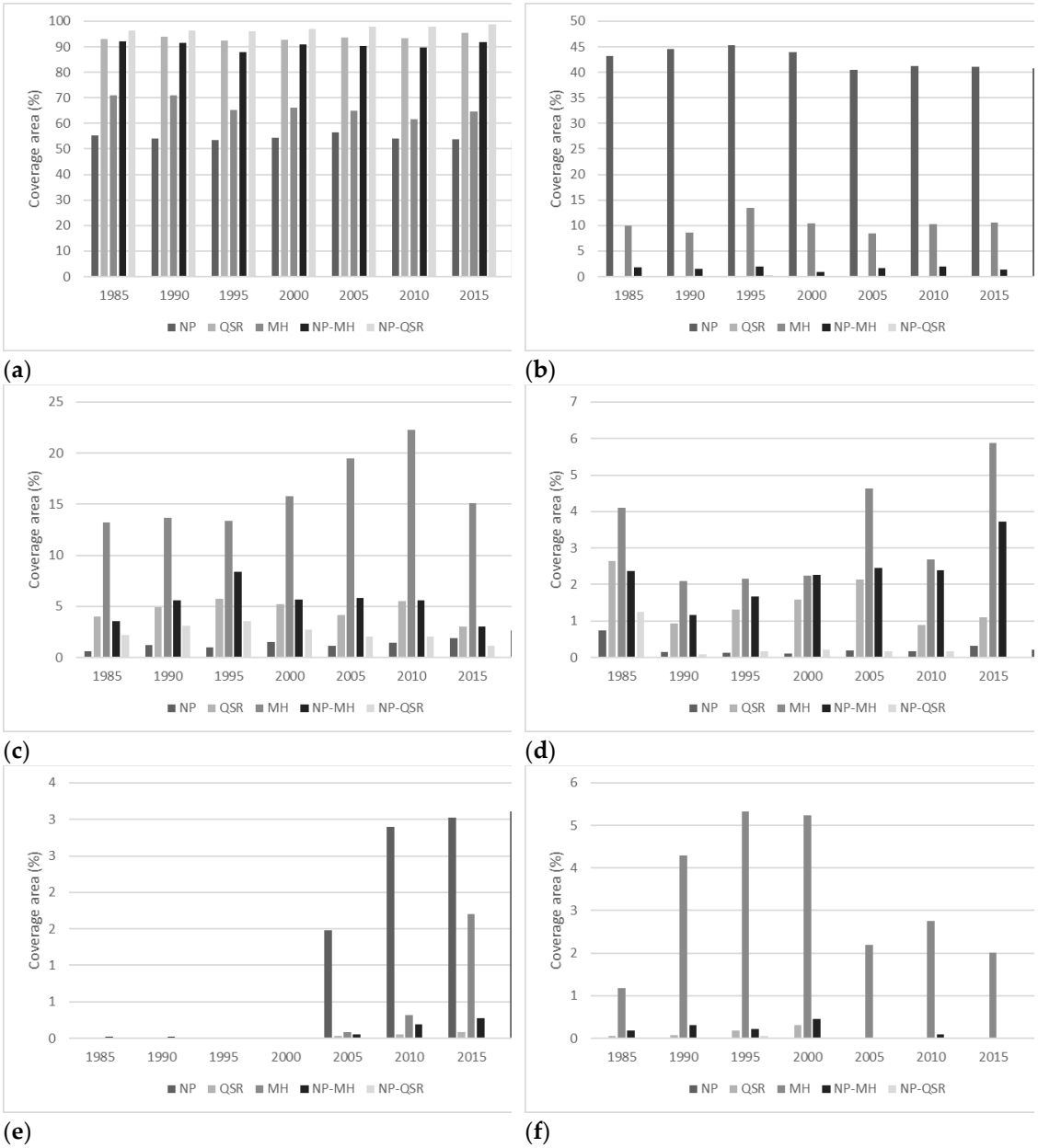

Figure 2-5. LULC in the analysis territory units from 1985 to 2020. (a) Forest formation; (b) grassland formation; (c) mosaics of agriculture and pasture (MAP), (d) pasture; (e) silviculture; and (f) other temporary crops.

(**a**) (**b**)

Figure 2-6. Status of LULC during 2021 in (a) Quilombola community of São Roque; (b) Mãe dos Homens community.

For the units of analysis without intersections (NP, QSR, and MH), the variation in LULC areas in the previous time step varied in order of magnitudes greater than 1.03 ha/year and less than 3.53 ha/year (Figure 2-7).

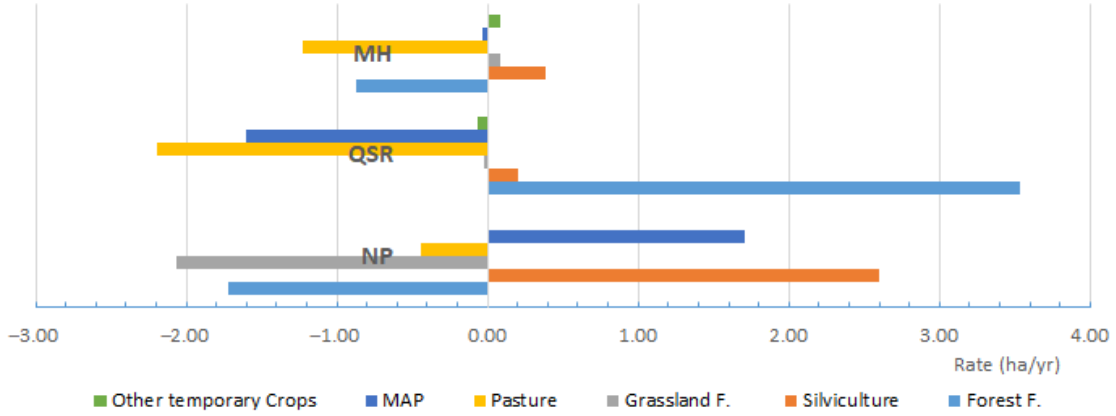

Figure 2-7. Mean variation rate of LULC in rural communities and natural parks from 1985 to 2020.

LULCC in the MH unit show decreased MAP, pasture, and forest formation and increased silviculture, grassland, and other temporary crops. The mean rates of LULCC in MH are lower than in other SU. However, the substitution of natural biomes with agricultural activities is observed, which is a common practice according to (CARVALHO; BATELLO, 2009; OLIVEIRA *et al.*, 2017) . Although other temporary crops have the lowest variation rate of LULC, to the extent of not appearing in NP, this LULC has a representative coverage area in MH compared with other SU. The analysis of QSR demonstrated an increase in forest formation to the detriment of the abandonment of activities of pasture and MAP.

Variations in LULC in the QSR are associated with the departure of residents from the community due to difficult housing conditions (SILVA; GOULART, 2008), such as government abandonment, lack of opportunities, and the occurrence of natural disasters such as floods and

windstorms. At the same time, it is identified that the QSR unit is a region that facilitates the development of forest formation, possibly due to the hillslope conditions too. It is known through personal communication that they do not usually cultivate close to water sources to preserve territory and the landscape.

These ideas about conservation in QSR match the principles of sociogeomorphology. The QSR organized their crops keeping their distance from water resources due to their ancestral beliefs and local knowledge about floods, which was acquired over time. Forest coverage was promoted to avoid strong floods and protect the community. In this way, crop growth can be sustainable and in equilibrium with nature. LULCC result from interactions between humans and nature, so a sense of belonging to landscapes rather than their mere use can be a relevant factor for addressing LULCC according to (WATERMAN *et al.*, 2021). Thus, the co-production of the human–nature system is verified, an idea that can be used in territory management.

In NP, there is an increase in silviculture (2.60 ha/year) and MAP (1.70 ha/year) and a decrease in forest formation (−1.70 ha/year) and grassland formation (−2.06 ha/year). This result is a paradox considering that national parks must promote the afforestation of their areas. However, it is identified that this is an area with low *Dd* and low *S*, which facilitates silviculture and agriculture, practices that may be carried out outside the law. Areas with territorial overlaps between NP and rural communities (traditional and non-traditional) showed LULC variation rates between −1.0 and 1.50 ha/year, which are lower than those of other units (Figure *2-8*).

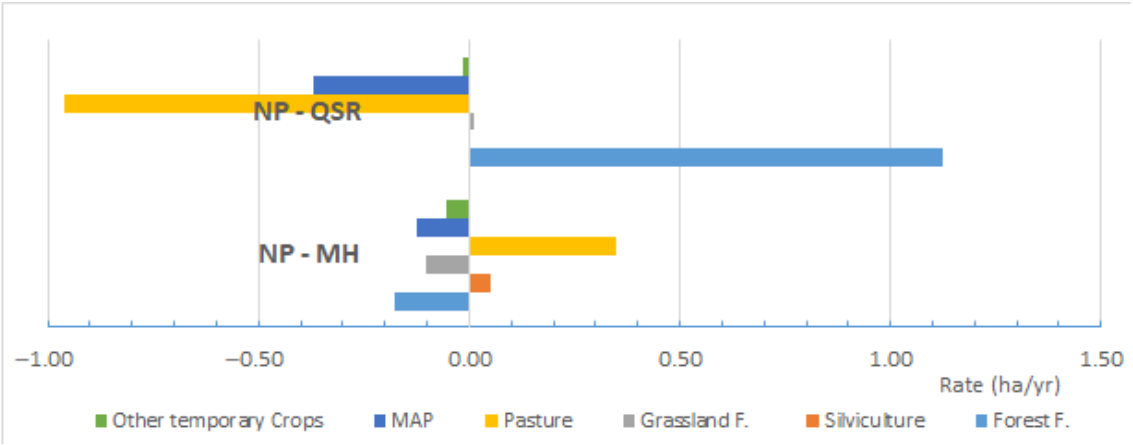

Figure 2-8. Rate of change in intersections between communities and national parks between 1985 and 2020.

The creation of national parks and their delimitation as conservation units have brought some conflicts to rural communities (BENEDETTI; ANJOS, 2021). Therefore, the implementation of land use policies must consider the territorial aspects of the settled communities. The NP-QSR area showed an increase in forest formation (1.12 ha/year) and a decrease in other temporary crops (−0.01 ha/year), MAP (−0.37 ha/year), and pasture (−0.96 ha/year). With these results, the

mission and performance of national parks in QSR to preserve natural territories and stimulate rural and forest formation can be verified (BRASIL, 2012). However, the opposite situation is evident in the PN-MH territory. There was an increase in pasture (0.35 ha/year) and silviculture ($4.90x10^{-2}$ha/year). One of the possible reasons for such a situation is explained if *S* and *Dd* are considered. For the QSR and NP-QSR units, the high *S* values hinder the development of agricultural activities.

This contrasts with the MH unit, where *S* and *Dd* as geomorphometric characteristics enable community survival activities. In addition, the fact that the territory in the QSR has been occupied throughout the years by almost the same families should be considered. In MH, the mixing, departure, and entry of new families have diminished the sense of belonging to the territory (WATERMAN *et al.*, 2021). As previously stated, the QSR was established approximately 200 years ago. However, the community's founders resided longer in the territory on the farms of the plateau region.

2.4.3 Statistical Analysis

2.4.3.1 Statistical Comparison of LULC

In terms of area variation rates, each unit of analysis had at least one point of LULC data with non-normal distribution, except for NP-MH. Hence, non-parametric tests were used for comparison. The Kruskal–Wallis test pointed to an absence of statistically significant differences among the units of analysis (p-value > 0.05).

In addition, the use of the Mann–Whitney test to carry out pairwise comparisons revealed that there were no significant changes in LULC for the different units. This means that area variation rates in the different LULC classes are similar, which points to a balance, whereby one type of land cover increases, and another one decreases to a similar magnitude.

Similar to the variation in area rates, in the analysis of the area of LULC, each unit of analysis had at least one point of LULC data with non-normal distribution, except for NP-MH. Again, it was identified that these areas differed in most cases according to the Mann–Whitney test. Table 2-6 shows the pairwise LULC comparisons whose p-value was greater than 0.05.

Table 2-6. p-values returned by the Mann–Whitney test applied to LULC areas.

Social Unit	LULC Description	p-Value
NP	MAP—Silviculture	0.791
	Pasture—Silviculture	1.000
QSR	Grassland—Silviculture	0.957
	Grassland—Other temporary crops	0.561
	Silviculture—Other temporary crops	0.419
MH	Pasture—Other temporary crops	0.372

Social Unit	LULC Description	*p*-Value
NP-QSR	Grassland—Pasture	0.226
NP-MH	Silviculture—Other temporary crops	0.790

In the NP unit, the lack of differences between MAP and silviculture, and between pasture and silviculture, was verified. These differences persisted when comparing pasture and MAP. These activities indicate that the area of these LULC exists in a different proportion compared to other LULC of the same unit, such as forest and grassland. In the QSR unit, grassland formation, silviculture, and other temporary crops were similar to each other. When this result is compared with Figure 2-5, the information is consistent because there are percentages below 4% across the time period that represent those LULCs (grassland, silviculture, and other temporary crops). In the MH unit, only pasture and other temporary crops coverages were statistically similar. In the NP-MH unit, silviculture and other temporary crops proved to be closely related, to the extent that an increase in silviculture entailed a decline in other crops (Figure 2-8). Furthermore, in the NP-QSR unit, grassland and pasture were similar in area, but the other results were contradictory, as shown in Figure 2-8.

2.4.3.2 Cluster Analysis

Two large groups with more than a 40% similarity in their data were identified (Figure 2-9). Group A (blue) corresponds to the LULC from natural formations (forest and grassland) that are similar in terms of area and geomorphological characteristics such as *S* mean, *Dd*, and the length of river channels. In addition, there is a similarity with the area of territorial unit of analysis. This implies that the delimitation of territorial units such as national parks or the QSR, or even the MH, considers their characteristics to occupy these areas.

Group B (red) refers to MAP, pasture, silviculture, and other temporary crops. In other words, group B is related to anthropogenic activities which are typical of the economic system of the region. In addition, it also had a similarity to mean altitude and maximum slope. This is because the values of *Z* and maximum *S* influence the way to work with land and determine different LULC.

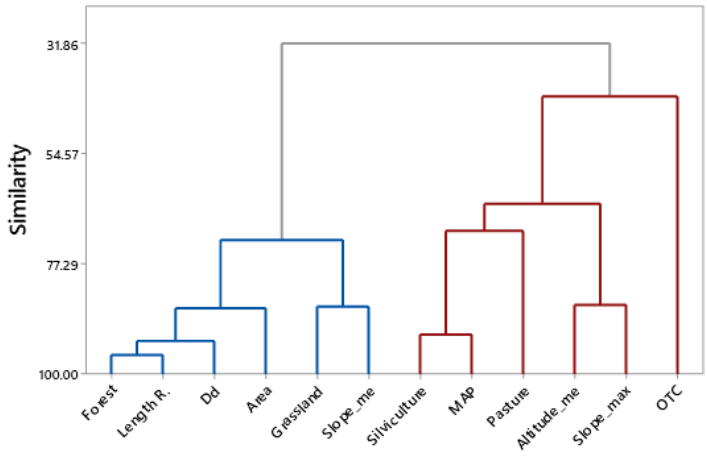

Figure 2-9. Dendrogram to identify similarities between natural and anthropic variables.

Figure 2-9 shows statistically significant results (p-value ≤ 0.10) from the Pearson's correlation test. In group A, which focuses on geomorphological characteristics, the forest is related to the length of the main river (r = 0.922; p-value = 0.026). The correlations between the length of the main river with both *Dd* and the area of the units of analysis were also verified. The correlation found between forest cover and *Dd* contrasts with the one described by (SINGH *et al.*, 2019), who pointed out an inverse correlation between *Dd* and dense vegetation. Extensive forest cover and many caves or *grotas* with water source point creeks are the natural conditions of the headwater of the Mampituba River, which explains the correlation between forest cover and *Dd* in this region. Headwater conditions in the Mampituba Basin include forest cover and mean values of *S*. The SU with high mean *S* values can have a large forest cover area, e.g., QSR, NP-QSR, and NP-MH (Figure 2-5).

In group B, silviculture and MAP showed a statistically significant correlation. Additionally, other temporary crops and maximum slopes were inversely correlated (r = −0.874). This means that crops of different types such as soy can be predominantly found along hillslopes with low S values. This result can explain the activities of MH because this SU has the highest cover area of this LULC and the least *S* between the maximum declivities of SU (Table 2-7). This result may also be derived from the MH-H (SGU), which has the same maximum slope as MH (43.38°). Furthermore, the correlation between other temporary crops and maximum slopes gives an idea about the crops of subsistence of the QSR, which is in the hillslope region. This community has historically occupied this area (KENNY, 2011; SPAOLONSE, 2013), even when many inhabitants were forced to leave the national park territory. Although many others stayed there because they had no other choice, the permanence of the Quilombola community in the region is positive considering that they take care of their environment (PENNA-FIRME; BRONDÍZIO, 2017), since land preservation is an intrinsic feeling of this community.

Table 2-7. Correlation coefficients and p-values between variables.

Group	Variables		Correlation	*p*-Value
A	Forest	Li	0.922	0.026
A	Forest	Dd	0.867	0.057
A	Forest	Slope_m	0.842	0.074
A	Length	Dd	0.860	0.061
B	Silviculture	MAP	0.837	0.077
B	OTC	Slope_max	-0.874	0.053

Some human–landscape interactions are closely associated with natural features, while others depend on community behavior. The findings of this study relate to agricultural activities and depend on the social characteristics of communities. Thus, sociogeomorphological studies in land management help to recognize relevant information derived from social characteristics, especially in traditional communities. As a result of the research findings, attention is drawn to government plans for territory management that consider human–landscape interaction. It is worth noting that due to the different characteristics of all social groups within a community, future land management strategies appropriate to them should be established. When local knowledge is included, it encourages exploration and valorization of ancestral wisdom about land management. Hence, land management policy requirements could include local knowledge and social characteristics. Furthermore, land management policies might include nature-based solutions (PONTEE *et al.*, 2016) that are closely related to local knowledge and human–landscape interactions, which could be considered as a requirement for government action.

2.5 Final Remarks

In the present work, the Quilombola São Roque (QSR) and Mãe dos Homens (MH) communities were analyzed over a period of years in terms of six different LULC classes: forest, grassland, silviculture, mosaics of agricultural and pasture (MAP), pasture, and other temporary crops (OCT). These communities are located in a region where geomorphological units such as plateau, hillslope, and floodplain are identified. Variables such as altitude and slope have been found to boost mass movements and, by extension, influence the use allocated to land covers. Thus, by using social units and geomorphological units, sociogeomorphological units were analyzed, i.e., a sociogeomorphological approach was conducted to comprehend these two rural communities. In the study region, river discharge occurs regularly, possibly due to the high presence of vegetation, especially forests. The QSR community area and its intersection with natural parks

are the units with the longest length of the main river, being two social agents that ensure the preservation of the environment. Here, we highlighted the sociogeomorphology principles where the co-production of the landscape was composed of interactions between geomorphic units and social units.

Some variations in LULC have been identified, such as an increase in forest and a decrease in crops in QSR, as well as decreased MAP, pasture, and forest formation and increased silviculture, grassland, and other temporary crops in MH. In addition, it was observed that there are different responses in the overlaps of natural parks with the communities for each LULC class.

Fifteen classes of SGU were established from the intersection of 5 SU and 3 GU. The SGU allowed for the identification of specific characteristics of the territory and helped explain some interactions between social and natural agents that impact on the landscape. From a holistic point of view, territorial analyses integrating several landscape elements can give interesting information. Thus, the study of SGU and the principles of sociogeomorphology can help government managers make better plans for their territory.

The considered variables were examined through a cluster analysis, which revealed two groups. One group represents the characteristics of the natural environment. The other group accounts for social activities such as agriculture associated with altitude. Thus, it can be seen how, consciously or unconsciously, communities consider natural characteristics for their own development when settling down, demonstrating that this aspect is relevant when thinking about land management strategies. Additionally, subsistence agriculture and forest coverage are found to be strongly related to slope, which proves that even in places with limited accessibility, land can be worked, and forest can be protected, for which there must be a balance with the environment. This is an important aspect to consider in public policies for a better organization of rural communities.

The results show the different responses of LULCC according to communities' features and demonstrate that natural conditions influence the way that communities manage their territory, and this is related to their local knowledge and costumes. This study shows how relevant social activities can be in territory management because there are many points of view. In the near future, the Brazilian government may have to apply various traditional community practices to the integrated management of natural resources, including water resources. Territory management includes natural aspects, so taking care of the territory should mean taking care of the environment and natural resources.

Although the information from the MapBiomas Project was very useful to obtain an idea about LULC, the spatial resolution and the description of LULC was not the best to describe the details

of LULCC in the study area. Therefore, fieldwork is necessary to retrieve details and information directly from inhabitants through, e.g., personal interviews. The present study analyzed only two communities and their overlaps with the national parks; however, there are more communities in the basin area that were not considered. These communities have areas inside and outside of the basin area, so this can be challenging for analysis. Further research in this line should consider expanding the study area to other communities, and reassess the results obtained here.

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3 Enhancing disaster risk management through understanding risk perception: the role of identity in rural communities

This chapter is based on the following manuscript submitted to Natural Hazard Review.

Resources:

GONZÁLEZ-ÁVILA, I. et al. Enhancing disaster risk management through understanding risk perception: the role of identity in rural communities. Natural Hazard Review (Under review – Round 2).

Abstract

Risk reduction strategies are guided by vulnerability and hazard assessments, which must be as accurate as possible. Vulnerability is primarily shaped by social characteristics; thus, the response to disasters may vary across different cultural groups. Furthermore, there are tendencies to research vulnerability just for metropolitan settings. Though there are many rural cases studies worldwide, few ones can be seen in Brazil. The objective of this study was to develop a cross-cultural comparison of the viewpoints of various members of traditional and non-traditional communities dealing with risk disaster management. For that, two communities in Brazil were studied from identity approach. One of the social groups is defined as a traditional community in Brazil by law while the other group is not. We performed in-person interviews to identify the primary vulnerabilities in each location. Quantitative and qualitative interview questions were used and arranged in blocks to distinguish among the various phases of disaster management. The answers were analyzed using frequency analysis and contingency tables, with each community receiving a separate evaluation. A sociogeomorphological analysis was carried out with the collected data, and the findings shed light on how susceptible social groups are. It highlights significant differences (p-value = 0.1) such as length of residence in the community, kind of losses, socioeconomic assistance, psychological preparedness, looking for data and weather forecast sources, and emergency contact. Theories such as the Safe Development Paradox and helpful Traditional Knowledge were observed. These findings point out ways to validate and improve the efficacy of policy actions to be taken in rural disaster scenarios through dialogs. So, interviews are an alternative method to large government databases and conventional information for disaster risk management.

Keywords: household interviews, risk perception, traditional and local knowledge, vulnerability.

3.1 Introduction

Risk can be viewed as a function of hazard and vulnerability (MONTE *et al.,* 2021). In this regard, Disaster Risk Reduction (DRR) strategies involve diagnosing hazards and the steps to deal with external pressures that affect a community livelihoods and well-being. *Vulnerability* is a concept that unifies all the social components of disasters (MONTE *et al.,* 2021), and is therefore not easy to understand. Vulnerability must be studied from multiple perspectives and using several technologies to enrich the studies. According to the framework Methods for the Improvement of Vulnerability Assessment in Europe (MOVE) (BIRKMANN *et al.,* 2013), there are three basic approaches to study vulnerability: exposure, susceptibility, and resilience, with social and natural factors important in assessing vulnerability. According to (BIRKMANN *et al.,* 2013), exposure refers to the degree to which the community is located within the geographic range of a hazard event. Susceptibility refers to the propensity of socially and ecologically vulnerable elements to experience harm. Resilience refers to the ability of a community or social-ecological system to mobilize its resources in response to a recognized hazard. Thus, the need for further development of the interaction between soft and hard sciences is emphasized, with social elements having to play a crucial role in disaster risk management (DRM) (GONZÁLEZ-ÁVILA *et al.,* 2023; HAMIDI *et al.,* 2020).

Based on disaster sociology, the effects of disasters can vary depending on how vulnerable people are. For example, female heads of households, poor people, children, people with disabilities, and indigenous people require different disaster management methods because disasters affect them differently. Social groups establish different values about their surroundings, contributing to their local identity (RAWLUK *et al.,* 2017) and influencing vulnerability. According to BASILE and CAVALLO (2020), identity is composed of tangible (land, natural resources, houses) and intangible (memories, histories) elements. Those elements could be impacted by disasters. The place identity is the one used to specify which aspect of the identity is impacted when disasters happen. According to PENG *et al.* (2020) the place identity is the facet of oneself that establishes a person's unique identity within his or her surroundings through an intricate interplay of conscious and subconscious thoughts, emotions, values, aspirations, choices, abilities, and behavioral inclinations. For instance, VALENCIO *et al.* (2009) found that women's identities are more affected than men's ones when the household is impacted. The authors address that the space within a house is still considered women's space, particularly in rural areas where gender issues are still evident. Thus, in the present study, we aim to research and compare the place identity of rural communities to identify how DRM is shaped.

Although the helpful information for disaster management is usually collected and provided by governments, there are gaps that make vulnerability assessment difficult (MENDONCA; GULLO, 2020), especially in rural areas and from the perspective of place identity. A question then arises: Are there benefits to disaster management from studying rural vulnerability and place identity through face-to face surveys? Several studies investigated ways to improve disaster management. Some of them emphasized face-to-face interviews (HERNÁNDEZ-MORENO; ALCÁNTARA-AYALA, 2017; MENDONCA; GULLO, 2020), while others focused on engaging researchers or decision-makers at the institutional level (LEE, 2016). For example, NIVOLIANITOU and SYNODINOU (2011) conducted interviews with firefighters on technological disasters, and ROUHANIZADEH *et al.* (2020) engaged in dialogues with specialists about post-disaster strategies. However, there is no comparative analysis of how rural traditional and non-traditional communities perceive risk in Brazil. It is important to note that individuals who have experienced those firsthand best describe perceptions of disasters. Therefore, disaster perceptions are unique to each individual and are influenced by their own vulnerabilities when facing the hazard. This analysis of perception construction can be applied to other places worldwide.

Many urban and rural disasters in developing countries, such as Brazil, go unrecorded in large databases because they fail to meet specific criteria, even if they often take place. Consequently, these disasters are disregarded or seen as minor. For example, the International Disaster Database (EM-DAT) records focus on disasters with at least ten fatalities, 100 people affected, a declaration of a state of emergency, or a call for international assistance (CRED, 2023). As a result, developing regional solutions to disaster management issues may be challenging. Local investigations are crucial to discover specific features that other types of research miss. Top-down approaches to vulnerability assessment are well-known to involve the government. In this scenario Safe Development Paradox is built, also well-known as the Levee Effect or Safeti Dilemma (BREEN *et al.,* 2022). In general, these theories mention that people create a sense of security when the government implements structural measures against disasters, but it results in false security since leading to higher losses in the event of failures of the structural safeguards (COLLENTEUR *et al.*, 2015; DI BALDASSARRE *et al.,* 2019). On the other hand, bottom-up approaches stimulate and require community participation (ISIDIHO; SABRAN, 2016; LI; SIVAPALAN, 2020) and increase risk awareness. In this sense, specific features of communities such as local knowledge (LK) become more important and empowering.

In Brazil, traditional peoples (indigenous) and communities such as Quilombola communities adopt four criteria for recognizing themselves: i) ethnic-racial; ii) connection to biome or

ecosystem; iii) identity defined by predominant work activity; and iv) uses of territory and historical circumstances (COSTA FILHO, 2020). According to the National Policy for the Sustainable Development of Traditional Peoples and Communities – PNPCT (BRASIL, 2007), the Quilombola community is defined an "Ethnic-racial group, according to criteria of self-attribution, with their own historical trajectory own historical trajectory, endowed with specific territorial relations, with a presumption of ancestry related to resistance to historical oppression", and it upholds time-honored beliefs and customs. It is sufficient to refer to the previously described regulation in order to identify non-traditional groups; if the community is not named, it is not regarded as traditional in Brazil. In these traditional communities, there are collections of opinions, feelings, stories, and insights about the surroundings of a particular social group, which have been developed over time across generations. These collections are called Traditional Knowledge (TK), while in the case of non-traditional communities, this is referred as Local Knowledge (LK). Local spatial knowledge (LSK), as described by MCCALL and ALVAREZ (2022), is part of TK or LK. Facts and Values are the two main pillars for LSK. According to MCCALL and ALVAREZ (2022), Facts are the local people's technical understanding of things such as soils, flora, and natural resources fully understood by locals but only partially understood by outsiders, while Values represent community's interests and viewpoints that may be in conflict with the "official position". Values also depict how locals and the environment interact (social, physical, spiritual, folklore, and environmental aspects) so that they are related to identity.

Therefore, the objective of the present work was to obtain TK and LK from two different rural communities (traditional and non-traditional) in southern Brazil to understand and connect the risk disaster perception that these communities have. With the appropriate approach, the collected data allowed us to identify each community's risk management culture and gain a comprehensive understanding of them. The primary objective of integrating culture and DRR is to establish the foundation for developing more effective management plans for a mountain system that includes communities with diverse social makeup, as is typical in rural areas of Brazil. IDZIOREK *et al.* (2023) emphasized some issues regarding place attachment, its function in DRR, and the application of anthropological and geographic viewpoints. Since this study is cross-culturally comparative, these issues are covered in this work. Finally, comparing these different communities seeks to highlight the importance of conducting interviews in research.

3.2 Study Area

The study area (193.74 km²) is located in the headwaters of the Mampituba River, with three major tributaries: Josafaz Creek, Faxinalzinho River, and São Gorgonho River (Figure 3-1). Because the Mampituba River acts as a state splitter, the study area is an interstate area in southern Brazil, comprising the states of Santa Catarina and Rio Grande do Sul.

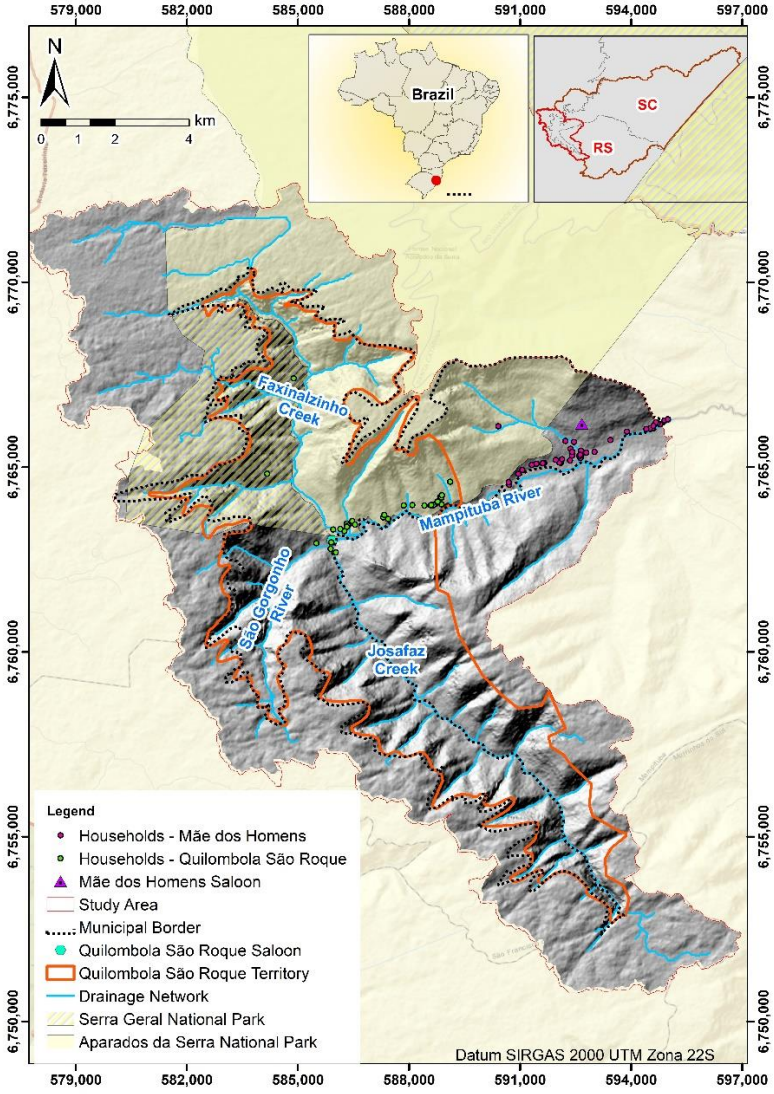


Figure 3-1. Location of the study area in the Mampituba River basin, between the states of Santa Catarina (SC) and Rio Grande do Sul (RS).

The region has a mild mesothermal climate, corresponding to the Cfa type in the lower parts and Cfb in the higher parts according to the Köppen classification. Rainfall in the region is distributed uniformly along a year and varies between 1450 mm and 1900 mm per year (SEMA, 2020). Due to extreme hydrological events, this region has suffered from severe water-related disasters frequently (PAIXÃO *et al.*, 2021). There are several settlements in this region; however, the present

study evaluates two: Mãe dos Homens (MH) and Quilombo São Roque (QSR). The characteristics are outlined for both communities in Table 3-1 (GONZÁLEZ-ÁVILA *et al.*, 2023).

3.2.1 Quilombo São Roque (QSR)

The quilombos emerged in Latin America as an opposition to the slavery system (SILVA; SOUZA, 2022). The QSR community exemplifies this historical structure in Brazil, where some customs have been still practiced recently. The QSR is located along the three major tributaries of Mampituba. In 2003, the Association of QSR was established as an institutional effort to ensure technical studies for the titling of their traditional territory. Over time, several territorial disputes arose between the national park and the QSR (ZILLI *et al.*, 2021), and the QSR fought to restore its rights (IOCCA; FIDELIS, 2020), which encouraged the QSR to establish a more effective social organization for self-representation in court proceedings.

3.2.2 Mae dos Homens (MH)

The MH community is made up of people descended from European immigrants who had reached this region with the support of the Brazilian government (CARVALHO FILHO; MONASTERIO, 2012) and founded a colony. At the time of its founding (1840), pig farming was the most important economic activity only on the left side of the Mampituba River. Later, banana plantations even on the other side of the river provided space to accommodate more families in the community. Due to the need for jobs in the logging industry in the 1950s, the area saw a large influx of settlers. In 1957, the MH inaugurated the first steam-powered sawmill. Today, MH is not demarcated by any geographical area.

Table 3-1. Social characteristics of studied communities.

Community	**Quilombola São Roque**	**Mãe dos Homens**
Type	Traditional	Non-traditional
Start of Occupation	About 1800 [1]	1840~1900 [2]
Ancestors	Enslaved Africans	European immigrant families
Social Organization	• *Grota* system ("Grota" local name to cave). Organizational system. • Social Association formed in 2003 • Around 32 families	• Community • Around 45 families
Delimited area	73.28 km²	No
Economy	Agriculture	• Agriculture •Livestock •Logging
Natural Disasters	• Floods (1974, 1995, 2006) • Storms	• Flood (1974) • Storms

Community	Quilombola São Roque	Mãe dos Homens
Fluvial network	• Josafaz creek • São Gorgonho creek • Mampituba River	• Mampituba River • Facão River
Geoform and relief	• Pedra Branca mountain • Cliffs • Canyons	• Flood Plain • Wavy Relief

[1] Occupation for more than 180 years, according to personal communication. [2] The first couple arrived in 1840 but it was not until 1940 that there was community infrastructure, i.e., a community saloon (LUMMERTZ, 2015).

The communities were analyzed as socio-geomorphological units (SGU) explained by GONZÁLEZ-ÁVILA *et al.* (2023a). Thus, the study area can be divided into 15 SGUs applicable to land management. The SGU is a type of analysis unit that uses geomorphological (floodplain, slope, plateau) and social (communities, national parks) units as a set of analysis units that strengthen the holistic view of the 2030 Agenda (ONU, 2018). The distinct set of environmental conditions, social configurations, settlement processes, and past experiences in both communities could impact the response against disasters and the vulnerability component of risk assessment. In this sense, comparing these two communities could illustrate the weaknesses and strengths that help to improve risk management disasters in rural communities.

3.3 Materials and Methods

3.3.1 Interviews

Fieldwork is essential to identify characteristics of both communities, because technical, transferable and personal skills (PEASLAND *et al.*, 2019) are developed around the disaster. In order to gather data regarding of MH and QSR's perception of risk and the disasters that result from their awareness of natural hazards, in-person surveys including 34 questions were carried out on eight distinct days in 2022. All questions were semi-structured, except for two open questions that were included to obtain spontaneous feedback and to analyze the potential use of these questions in disaster management. The questionnaires were prepared based on the authors' knowledge and questions from previous literature, such as HERNÁNDEZ-MORENO & ALCÁNTARA-AYALA (2017). The questions were clustered into seven blocks (Table 3-2), which were created considering the three stages of planification and DRM (before, during, and after) suggested by CEPAL (BELLO *et al.*, 2020) and the participants' perceptions. Information about demographic features is covered in the first section. In order to identify some experiences and draw lessons from the past, the second section surveyed residents' perceptions of disasters. Institutional issues are addressed in the third section. The following sections discussed topics associated with disasters stages. The questionnaire also included a question about how the

community's surroundings were perceived to identify the feeling of rootedness and understand the place identity of people. It should be noted that, even though Table 3-2 demonstrates an English description, the actual description was in Portuguese and the all the interview was conducted in Portuguese which is used on a daily basis in both the communities.

The sections of questionnaire are classified as topics about three issues in vulnerability: exposure, susceptibility and resilience as stated in the MOVE framework (BIRKMANN *et al.*, 2013). Issues related to experiences with disasters, the location of homes, injuries in previous disasters, the geomorphology of the area, and hypothetical situations are considered as topics related to exposure. To understand the susceptibility issues, observations and questions were asked about construction materials, population level of awareness, illiteracy, time spent in the community, type of community and sense of security. Regarding resilience, they were asked about communication, social network, level of preparedness, recognition of the institution and employment. It also asked about communities' perceptions of their surroundings, seeking to understand the context of each community and promote disaster strategies for the next risk. Point of View section is final section analysis, attempts to present the perceptions of rural communities in a holistic perspective about specific topics that can improve disaster management.

In qualitative interview studies, there are no established standards for assessing sample size compared with quantitative research (MALTERUD *et al.*, 2016). Thus, the sample for each community was determined using the information power model (MALTERUD *et al.*, 2016). The process involved five stages: i) Sample specificity: Both the MH and QSR communities represent the specified target group while also offering variations within the experiences being explored. These communities are in areas characterized by distinct geomorphological units that shape their risk management experiences. ii) Established theory: The interviews draw upon theories related to common disasters in the area. iii) Quality of dialogue: With the introduction of Natural Disaster Research Group – GPDEN from Federal University of Rio Grande do Sul (UFRGS) in the communities in 2021, a robust and transparent communication channel between researchers and participants exists. iv) Analysis strategy: Answers are meticulously analyzed, delving deep into discourse details provided by selected participants. The total representative samples were 31 for QSR and 39 for MH.

To collect data, only one representative from each house was interviewed. However, the perceptions of other family-members and some interventions were allowed to gain wide answers, so it was noted in a space for additional comments in the interview paper. The interviews were considered within the framework of the activities described in the document No. 5.702.024 of the Ethics Committee of the UFRGS. A preliminary review of answers was conducted and then all

responses were classified based on the collected information. Quantitative responses were classified in intervals, while qualitative responses were organized in descriptive classes.

Table 3-2. Questionnaire divided in blocks

Demographic information
Q1. How many people live in the house? Infants (<2 yr.); Children (2 – 11yr.); Adolescents (12-17yr.); Adult Men (18 – 65 yr.); Adult Women (18 – 65 yr.); Elderly Men (>65yr); Elderly Women (>65yr) Educational Level: Elementary School; High School; Technical course; No schooling; Not informed. Occupation: Farmer; Retired; Services; Not reported. * Education and occupation were asked **Q2.** Which community do you belong to? **Q3.** How long have you been a resident of the community? **Q4.** How long have you lived in this house? **Q5.** What motivated you to live there? **Q6.** Would you like to live somewhere else? If yes, why?
Perceptions related to disasters
Q7. Do you feel safe from disasters triggered by natural hazards in this place? Why? **Q8.** Has anyone in the family that lives in this house ever experienced any natural events such as floods, landslides, or windstorms? If yes, which one(s)? **Q9.** Has anyone in the family ever suffered loss because of these events? Which? **Q10.** Do you know about the 1974 flood? **Q11.** Do you know of other natural events in other years? **Q12.** Do you identify any place where events and impacts are recurrent due to landslides, floods, or windstorms? If yes, which one(s)? **Q.13**. Do you and your family feel prepared to act during a flood, landslide, or windstorm? If yes, how? If not, why? **Q14.** Do you and your family believe floods, landslides, or windstorms could affect your home? If yes, how? If not, why? **Q15.** Which would be more problematic for you: floods, landslides, or windstorms?
Institutional recognition
Q16. Are you familiar with Civil Defense? **Q17.** Has Civil Defense ever interacted with the community? If yes, how? **Q18.** Are you enrolled in any social assistance programs the city hall offers?"
Action during the disaster
Q19. Hypothetically, if it rains a lot and the river level rises until it reaches your house, you: Stay at home; Leave the house (where?) **Q20.** If a landslide happens, do you know what to do? **Q21.** How will you be informed if something happens that affects your ability to access the community or the community itself? Cellphone/Call; Instant Messages; Personally; It is not communicated. **Q22.** Do you have a safe meeting place agreed upon with your family/community? If yes, where?
Preparation for disasters
Q23. Do you usually look for weather forecast information? **Q24.** Where do you look for weather forecast information?
Post-disaster action
Q25. To whom do you tell if there is an impact caused by nature?

Q26. Do you know the contact calling numbers of: Ambulance/Emergencies; Firemen; Police; Civil defense **Q27.** If you lose your house, do you have another place to go? **Q28.** How many relatives do you have that live in different houses in the community? **Q29.** When damage occurs due to floods, landslides, or windstorms, who usually makes the repairs, and where do the resources come from?
Point of view
Q30. Do you think it is important to know more about environmental education related to disasters triggered by natural hazards? Why? **Q31.** Do you consider that the occurrence of disasters triggered by natural hazards influences community development? **Q32.** Do you consider that the community has changed the landscape or terrain? **Q33.** Do you consider that natural events have altered the landscape or terrain? **Q34.** Who do you think has been causing major terrain/landscape changes? Community; Disaster triggered by natural hazards; Others
Additional comments (optional)

3.3.2 Data analysis

The responses were classified according to community and processed through frequency analysis and contingency tables. Frequency analysis was based on histograms that were applied to simple questions or questions used to understand the social context of the participants. Sankey diagrams (HANZL *et al.*, 2021) were used as a visualization tool to analyze open-ended questions that cannot be classified into ranges. For example, Sankey diagrams were not used for questions such as Q1, Q2, and Q3, where answers can be classified and frequencies established. Contingency tables were useful for some selected questions associated with data where qualitative variables were present (LÓPEZ-ROLDÁN; FACHELLI, 2015).

In theory, the chi-square test compares the deviation between observed and expected frequencies. In practical terms, there is no exact definition of observed and expected frequencies in the present study, because both communities (QSR and MH) are based on observed data. The chi-square test was used to analyze both communities' responses based on contingency tables constructed from frequency counts. The idea of comparing responses related to the perception of disaster risk is to identify similarities and differences between communities and thereby glimpse the strengths and opportunities for improvement in risk management in each rural community.

The chi-square test compares data and identifies whether the disparity between communities is due to chance or a link between the variables under consideration. A p-value of 0.10 was used to distinguish between statistically significant and non-significant findings. Both groups differ statistically at a tiny p-value (≤ 0.1). On the other hand, groups are not statistically distinct if the p-value is more than 0.1. It is recommended that the data where the difference exists be observed

(ZIBRAN, 2007). Statistical analysis and visualization were done using R (Ihaka & Gentleman 1996).

3.4 Results

3.4.1 Demographic information (Questions 1-6)

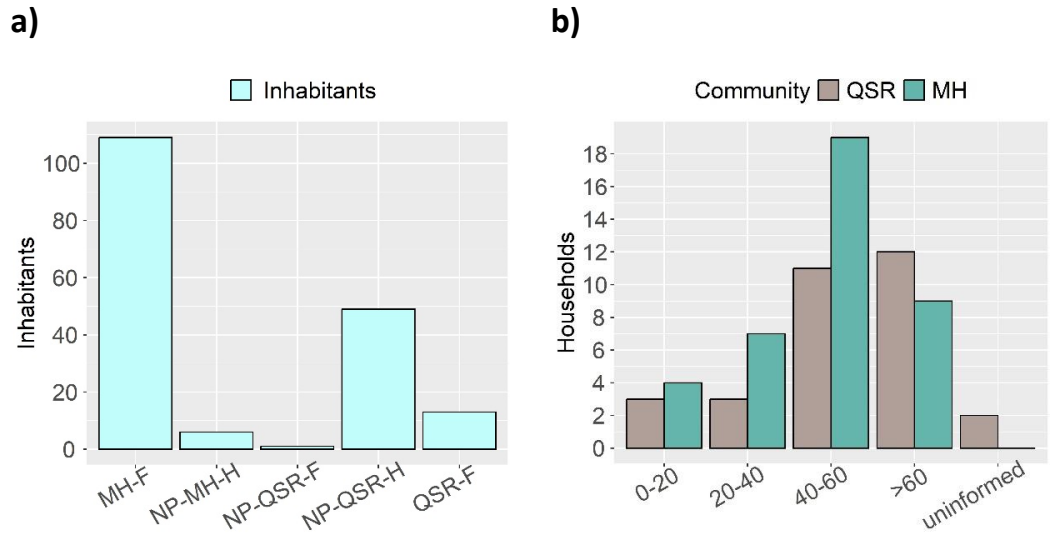
Total 31 out of 32 households in QSR and 39 out of 45 households in MH were interviewed. The demographic information results in 63 QSR inhabitants and 115 MH inhabitants. The frequencies in the age groups are similar between both communities (χ^2 = 7.41, p-value = 0.28), where men and women adults represented the most people in both communities (59% for QSR and 52% for MH). The quantity of older adults in QSR (n = 13 inhab.) and MH (n = 28 inhab.) differ considerably; however, these differences were not statistically significant since they represent 21% for QSR and 24% for MH. People who are old enough to labor in the crops cause the high frequencies in the QSR age groups (adolescents, women and men adults, and older adults). The age group quantities in the communities indicate the lifestyle in each community. In MH people perform specific services in the vicinity, such as Praia Grande Municipality, while in QSR people work in agriculture. The average of inhabitants per house interviewed is two and three in QSR and MH, respectively.

There are 15 SGUs in the study region (GONZÁLEZ-ÁVILA *et al.*, 2023), only five of them are populated (Figure 3-2a). Regarding MH, only one surveyed household (n = 6 inhab.) lives in the intersection of the national park and hillslope region (NP-MH-H). Most of MH people (n = 109 inhab. – 38 households) live in the floodplain region (MH-F). Most QSR residents (n = 49 inhab. – 26 households) live in the national park, QSR, and hillslope intersection (NP-QSR- H). The remainder of the population is distributed between the floodplain region (QSR-F) with four households (n = 13 inhab.) and the floodplain and national park intersection (NP-QSR-F) with one household (n = 1 inhab.). Thus, we consider that MH is more strongly connected to the floodplain area and QSR is more strongly connected to the hillslope region. Additionally, the talks indicate that the QSR has relocated their homes from the riverine due to flooding, demonstrating their awareness of the potential risks. This objective evidence suggests that the QSR has taken measures to reduce the impact of flooding on their homes.

The time length during which the respondents have lived in the community is shown in Figure 3-2b. An amount of 11 households, each with respondents who have lived in QSR for 40 to 60 years (with a mean age of 50 among the interviewees), were surveyed. Additionally, 19 households who have lived in the MH for the same period that QSR were surveyed, with a mean age of 55 years. Most of the MH community (31 households) has lived in their current homes for

more than 11 years, while the vast majority of the QSRs (18 households) have lived in their current homes for less than ten years (Figure 3-2c), showing a statistically significant difference in demographic behavior (χ^2 = 18.60, p- value = 0.00). It is demonstrated that the duration of the infrastructure residences in QSR is shorter than that of MH. This difference may be related to construction materials and techniques, site-specific considerations, and environmental conditions in the surrounding area. These factors can either increase or decrease vulnerability.

There are several motivations to live in these places according to each community (Figure 3-2d). The people of MH have chosen to live in this location because many of them were born, owned property, or got married there. The three main reasons why the QSR people chose this location are road access or life quality, land ownership (financial), and the emotional and cultural attachment that the community and its members represent due to being a traditional community. Most people in both the communities are comfortable with their environment. A total of 23 households in QSR and 29 in MH affirm that they do not want to leave their communities (Question 6), with only a few answers expressing a desire to move out of the community (8 QSR and 10 MH households). Despite some social differences between the communities, it seems that the above-mentioned reasons maintain the inhabitants' desire to remain in the region. The roots that these two communities maintain with their environment should be taken into account in DRR strategies to avoid increasing vulnerability, for example, when it comes to relocating floods victims.



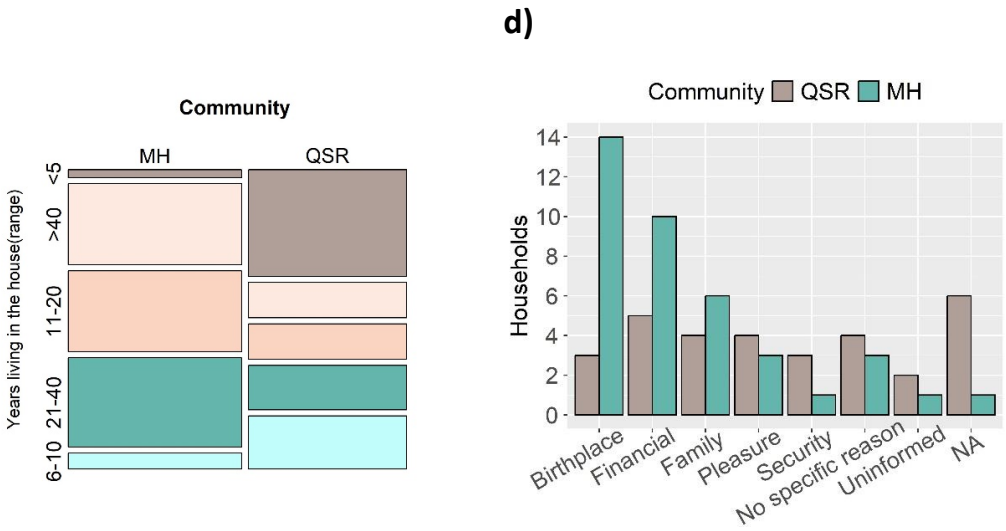


Figure 3-2a) SGU in the study area; b) Q3 – How long have you lived in the community?; c) Q4 – How long have you lived in this house?; d) Q5 – What motivated you to live there?.

3.4.2 Perceptions related to disasters (Questions 7-15)

The residents in both communities were similarly divided between those who believe that they are safe from disasters caused by natural hazards and those who are not. Only two QSR participants did not answer the Question 7. The statement suggests that the inhabitants of these two households may be uncertain about their safety in the face of natural hazards due to a lack of education on the matter. In response to Question 8, there was more than one disaster affecting people, confirming the occurrence of multi-hazard events. Most of residents in the two communities asserted that they were flooded. Hail and windstorms were the other two phenomena mentioned most frequently in the interviews. It should be noted that MH residents named more phenomena in this question, as the total number of reported disasters was 52, whereas QSR mentioned 35 (Figure 3-3a).

In both communities, the residents of the study area have suffered losses because of floods, landslides, hail, and windstorms. We looked at the different types of losses that have happened in this regard in the past (Figure 3-3b) and found a statistically significant difference ($\chi^2 = 9.60$, p-value = 0.05). While MH residents described losses primarily related to crops and rooftops, the QSR responses were similarly distributed among several options (crops, farm animal, furniture, house, rooftops). The 1974 flood (Question 10) and others in this block of questions were used to investigate and appraise historical experiences with disasters caused by natural hazards. Most of residents in both communities claimed to have heard of the 1974 flood. Only three houses in QSR and one in MH stated that they were unaware of this major flood.

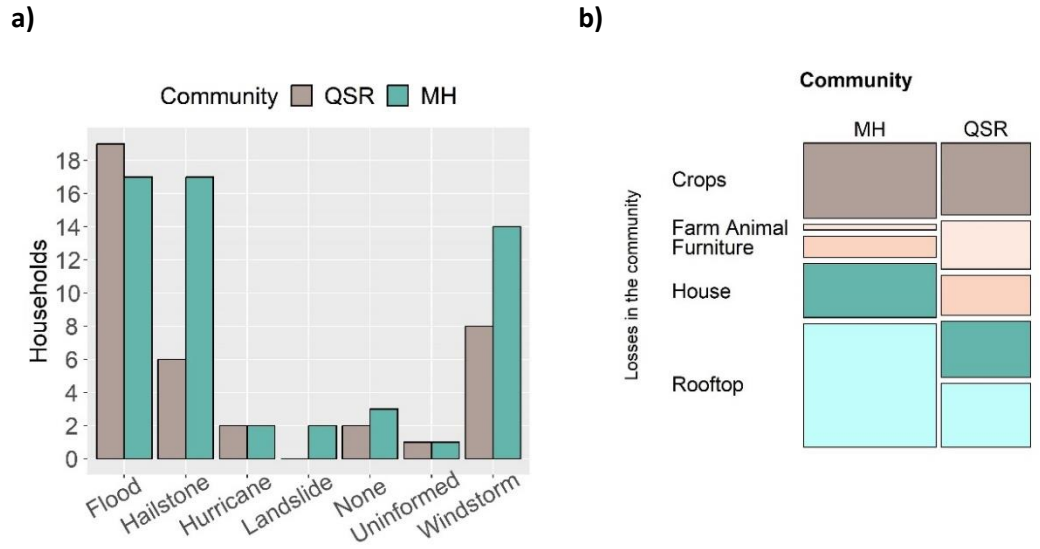


Figure 3-3a) Q8 – Has anyone in the family that lives in this house ever experienced any natural events such as floods, landslides, or windstorms? If yes, which one(s)? * Uninformed answer means -No response; b) Q9 – Has anyone in the family ever suffered loss because of these events? Which?

The interviewees were free to answer Question 11 according to their past disaster experiences, so many points of view were identified, and some key-words were emphasized in Figure 3-4a. The paragraphs below provide some key points about Question 11. In both communities, flood and windstorm disasters were considered common events. QSR inhabitants affirmed that windstorms occur every year, issue well-known in function of their occupation (agriculture). Other disasters, such as landslides and cyclones, were mentioned without details. Even landslides were mentioned only by MH.

Several dates for past disasters were mentioned but it is important to emphasize that the 1995 flood (on the Christmas evening) was frequently mentioned in both communities. Residents of MH informed that the excessive rain had caused land instability and landslides, creating a natural dam that pushed back the Facão River. When the dam broke, flood occurred. This natural process was mentioned several times in conversations with both communities. Due to the frequent mention by MH, which is a downstream community, the flood impact on the MH was more notable than in QSR. The oldest flood year was 1914 and was mentioned by a man of QSR who highlighted that his grandfather had told him about it. Thus, the oldest data on flooding was obtained by oral transmission, characteristic of traditional communities. This highlights the importance of encouraging this culture of dialogue in the rural community.

In response to open-ended questions about other disasters, MH residents mentioned that landslides can occur even in flood zones. In the past (1950), hillslopes in the MH area were deforested, leading to common landslides. However, after the intervention of IBAMA, which is

the Brazilian Institute for Environment and Renewable Natural Resources, residents reported that landslides were no longer as frequent. Despite living in a hillside area, QSR inhabitants did not mention landslides as a hazard. This finding may be because their houses are far from drainage channels, commonly recognized as a potential cause of mass movement. Also, they never deforested in the same proportion as other communities, so instability in the soil was rare. This care for the environment is typical of traditional communities. Both communities mentioned wind-related disasters but did not provide specific dates. The concept of natural events such as windstorms is widespread among crop workers, because it is one of the primary threats they must prepare for.

The majority of the two communities did not report recurrent risk areas (Question 12). For 7 interviewed households in MH, living near the river is more dangerous. The most hazardous locations in QSR are the caves (*grotas* in Brazilian Portuguese) (4 households) and the slopes (4 households). MH identifies natural processes that threaten the flood plain, while QSR associates these threats with slope processes. Currently, QSR does not consider the riverbanks to be hazardous locations because it has located its houses far from the riverbank in its self-management of the territory. Thus, the influence of geomorphology on risk perception can be clearly observed.

Question 13 examined how people perceived their level of disaster preparedness (Figure 3-4b). The most common answer from both communities was unpreparedness for a disaster. Communities require more education and preparedness regarding disaster-related issues. Empirical information can be acquired collectively, but there is a need for increased government presence to improve disaster preparedness. Identifying the DRM planning stages that require attention is essential. Emphasis should be placed on preparing for disasters before, during, and after they occur in these communities. It is essential to consider each community's distinct socioenvironmental conditions. Personal dialogues between social groups and policymakers are crucial. According to observations in interviews, conversations about disasters with the residents of the communities lead to a specific event such as a flood or windstorm. Thus, in many cases, their responses focused on this. Even though some people answered that they could shelter in place or feel prepared, they provided few details.

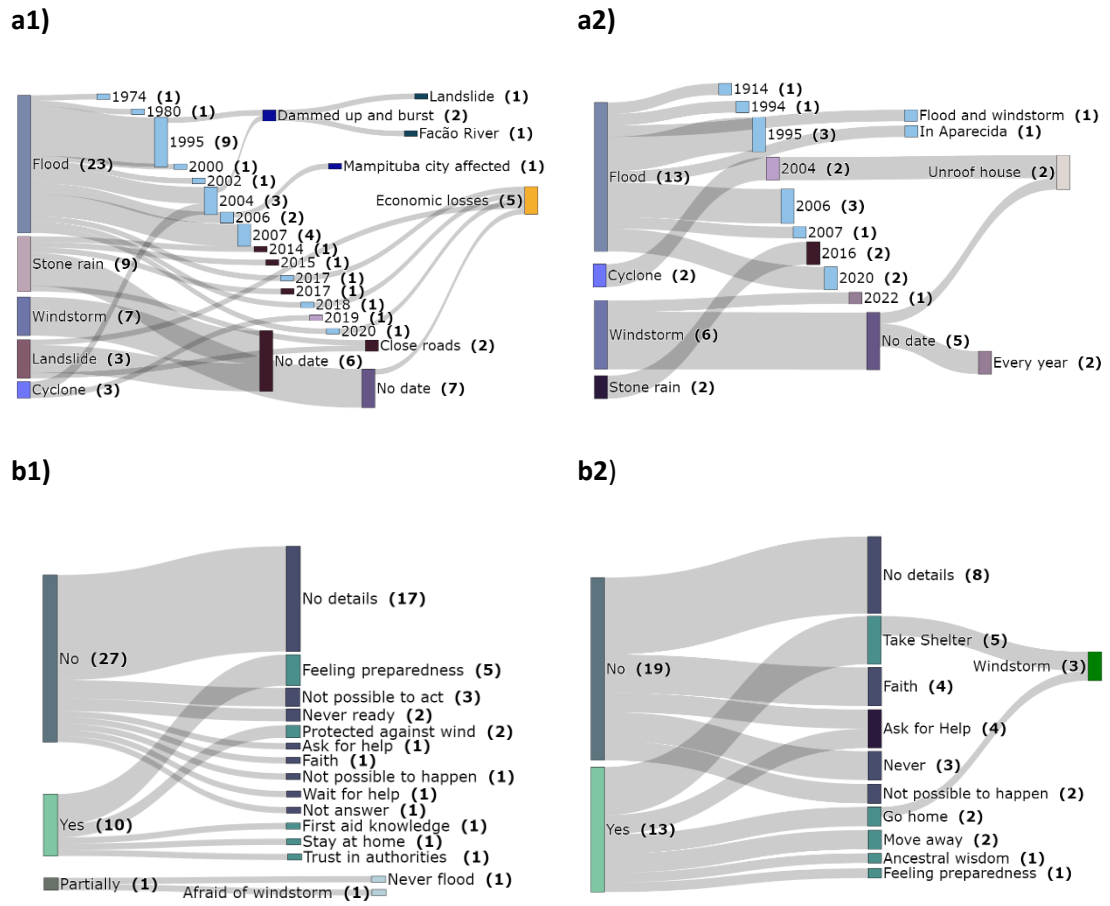


Figure 3-4. a) Q11. Do you know of other natural events in other years? (a1) MH and (a2) QSR; b) Q.13 – Do you and your family feel prepared to act during a flood, landslide, or windstorm? If yes, how? If not, why? (b1) MH and (b2) QSR.

Most people in both areas (16 households in QSR; 30 households in MH) are aware that disasters triggered by natural hazards can harm their homes (Question 14). Although landslides and floods are common in the region, windstorms are the natural hazard that cause the most distress to local populations (Question 15). The canyon's geomorphology channels the region's winds, which can significantly impact homes, particularly those on slopes or built without technique or weak materials. While the community has been able to cope with floods and landslides by moving out of vulnerable areas over the years, wind-dependent phenomena are more difficult to predict.

3.4.3 Institutional recognition (Questions 16-18)

In Brazil the Civil Protection and Defense Organization performs various roles, including sending alert messages in the event of a storm, flood, or landslide threat. According to the answers to Question 16, civil defense is a familiar term for most respondents. However, when the interaction between communities and Civil Protection and Defense was asked, the QSR affirmed that they had no connection or decided not to inform (Figure 3-5a). On the other hand, the communication between MH and Civil Protection and Defense has an established place in the community;

however, details were few and they claim that the institution only visited them after the disaster. In addition, nine of the houses surveyed in MH were unable to answer the question. In this sense, there is a lack of preparation for the institutional initiative is evident, so resilience capacity is low.

We clustered government-sponsored financial and social support as social assistance for interviews. Among the essential programs are *Bolsa Familia* and the Social Assistance Referral Center - CRAS (BRASIL, 2023b). Question 18 reveals that most people in MH do not receive this type of support. A statistically significant differences ($\chi^2 = 4.57$, p-value = 0.03) between the number of households in each community receiving social assistance. While the QSR community receives a more significant percentage than the MH community (Figure 3-5b), some homes have chosen not to participate in the *Bolsa Familia* program or CRAS. Not participating in social assistance programs implies that families don't have the social vulnerability characteristics that the government has established to accept them into the program. Therefore, in the event of a disaster, the economy of QSR will be more affected due to the vulnerability of its inhabitants, resulting in a lower capacity for recovery compared to MH.

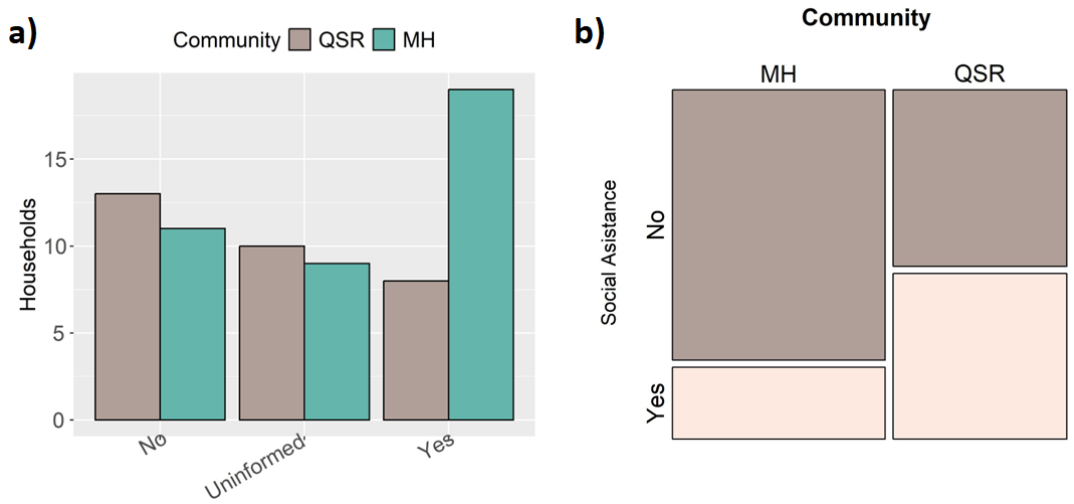


Figure 3-5a) Q17 – Has Civil Defense ever interacted with the community? If yes, how?; b) Q18 – Are you enrolled in any social assistance programs the city hall offers?

3.4.4 Action during the disaster (Questions 19-22)

The analysis of hypothetical situations with rising river levels and the resulting reach of houses (Figure 3-6a) shows statistically significant differences ($\chi^2 = 17.32$, p-value = 0.00) in the response of residents between the communities (Question 19). This illustrates how different populations perceive risk differently and the necessity for various risk management strategies. Despite the fact that "leaving home" and "go up the hillslope" were two recurring answers in both communities, several other answers were given. The statistical difference could be explained by

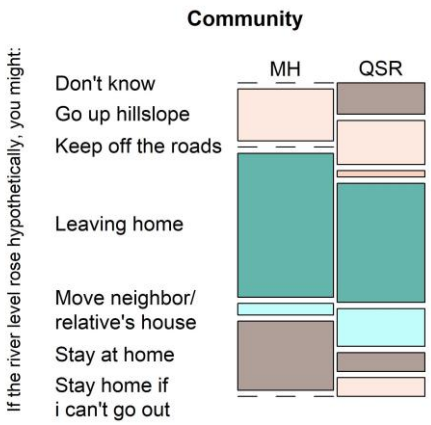
QSR providing more options to answer the question. The answers - “I don't know what to do”, “keep off the roads” and “stay at home if I can't go out” - were only mentioned by QSR. Other reasons that may explain the difference include reactions such as “moving to a neighbor or relatives’ house” and “staying at home”. QSR in this case emphasized the feeling of being overwhelmed by relatives and neighbors’ safety, addressing the solidarity. In MH, more people than in QSR emphasized that they could stay at home if water levels rise, even if it reaches their house, addressing trust in structural measures.

Figure 3-6b shows how inhabitants could deal with landslide disasters. The responses to the Question 20 highlighted that the communities lack awareness of the actions to be taken. Most of MH inhabitants' answers were: “to leave the house or run”, “I don't know what to do”, or “I don't think it will happen”. The answers of the QSR were: “Leave the house or run”, “I don't know what to do” and “find a safe place”. MH may have doubts about the occurrence of this disaster because they live on a floodplain area, unlike QSR living in a hilly area recognizes the possibility of such events.

Furthermore, residents of both communities confirmed that voice-to-voice (in-person) communication is the most widely used means of communication during a disaster event (Figure 3-6c). After voice communication, in MH, there is a high level of trust in telephone and cell phone calls made via mobile or landline. In QSR, communication through devices is a disadvantage as climatic conditions can cause light and internet failures and make communication difficult.

The Question 22 asked about the existence of a safe meeting place and 24 households from each community confirmed that they did not have a single meeting place. A few responses from both communities pointed to the community saloon and relatives’ homes as meeting places (Figure *3-6*d).

a)



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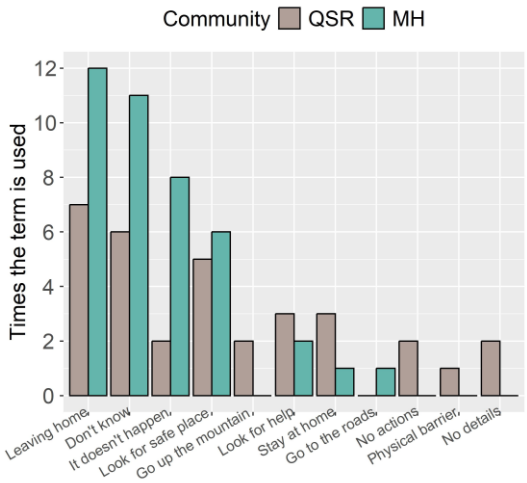

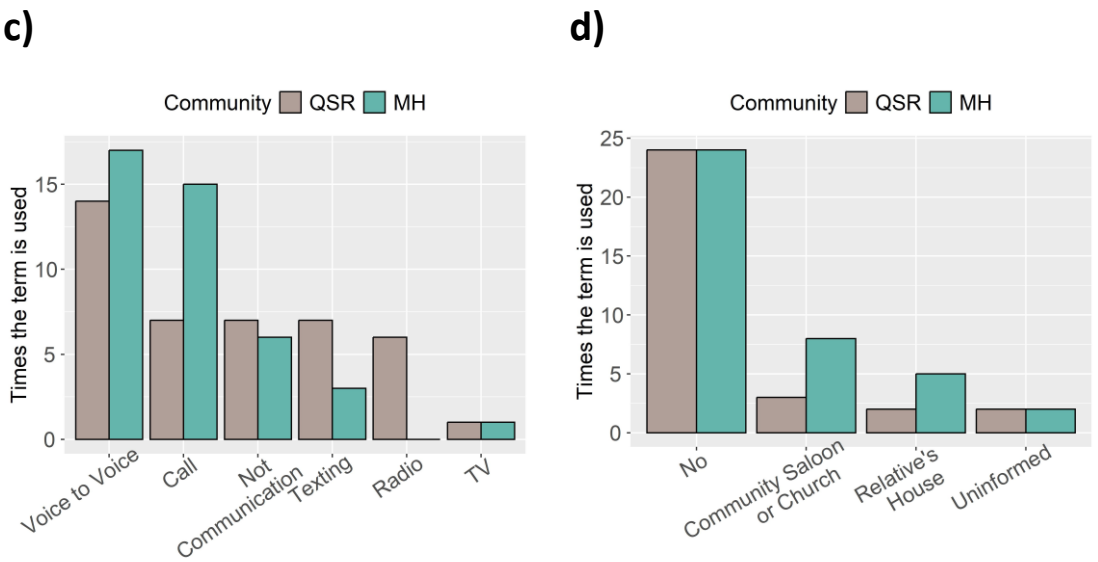

Figure 3-6. a) Q.19 – Hypothetically, if it rains a lot and the river level rises until it reaches your house, you: ; b) Q.20 – If a landslide happens, do you know what to do? ; c) Q.21 – If an event occurs that damages access to the community and/or the community itself, how will you be notified? ; d) Q.22 – Do you have a safe meeting place agreed upon with your family/community? If yes, where?

3.4.5 Preparation for disasters (Questions 23-24)

Question 23 verified the existence of statistically significant differences (χ^2 = 12.07, p-value = 0.00) when searching for information on climatic conditions. Figure 3-7a shows that most of MH respondents look for weather forecast information to prepare their routines. In QSR, many residents do not seek this information because they rely on LK and/or do not rely on information systems. Figure 3-7b shows that MH people check weather forecasts on more advanced devices such as mobile phones, where QSR people look to television and radio for information as these are the primary means available for this community. The type of source consulted for information can vary in sophistication depending on the purchasing power of each household. Therefore, most QSRs choose traditional and economical means of communication, such as radio or television, that do not rely on internet coverage or more advanced technologies like smartphones.

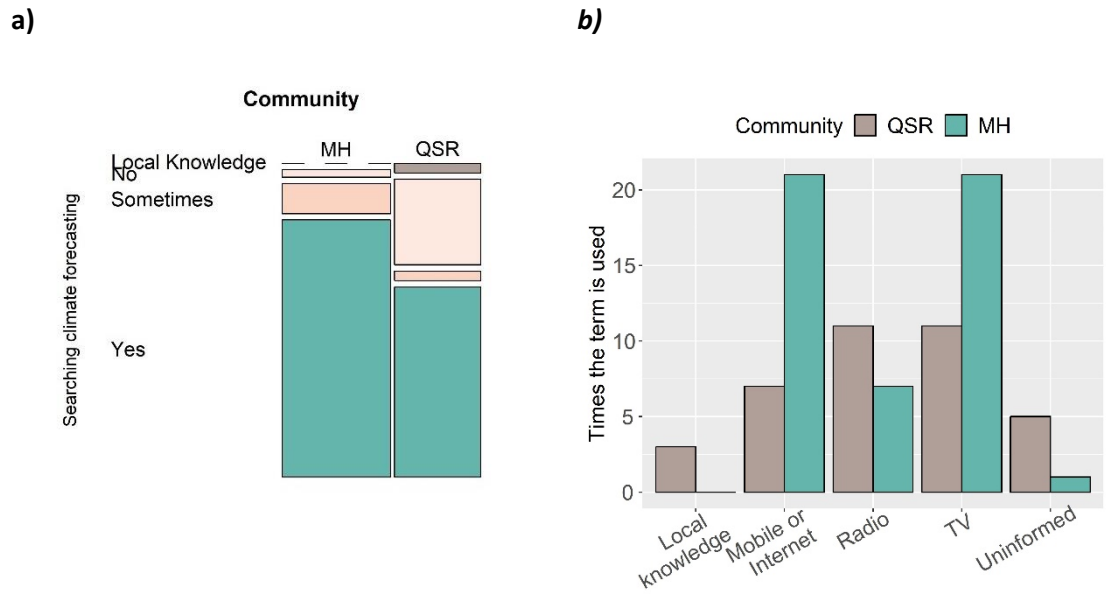

Figure 3-7. a) Q.23 – Do you usually look for weather forecast information? ; b) Q24 – Where do you look for weather forecast information?

3.4.6 Post disaster action (Questions 25-29)

Question 25 revealed a statistically significant difference ($\chi^2 = 8.93$, p-value = 0.06) in primary post-disaster contact communities. Figure 3-8a shows "neighbor" as the main answer in MH, while in QSR, there are various answers. It is important to emphasize that "Leaders" was an option that MH people did not consider. Because of QSR's internal dynamics and ancestral culture, the leader's function is thus more prominent in the traditional community. It is noteworthy that QSR has been constituted as an association since 2003, and as such, it may inherently instill in its members' the proper conduct for various circumstances.

Additionally, MH relies more on civil defense interventions than QSR. The Question 26 shows that both communities are very vulnerable, because most people do not have the phone numbers for emergency services such as fire departments, police, and health centers. Some rely on their cell phone to have the numbers saved by default or only have one number, usually a city hall number.

Question 27 reflects the economic vulnerability of communities regarding having another house to use as shelter. In MH, 25 households reported having no other place to live in disaster situations, while 14 families reported that they had. In the QSR, 16 households reported having no other house to use as shelter, and 15 people reported that they had another one. Therefore, unlike in QSR, most people in MH have no other refuge in case their home is affected. Although many families in the two communities have no other housing options of their own, most of them have between 1 and 5 relatives' houses to go to in case they become homeless. It was said that the

ancestors of both communities were related to each other, so that today there are still many second and third relatives.

Figure 3-8b shows that MH typically pays for the damage caused by disasters triggered by natural hazards. Half of the people in QSR can cover the damage, while the rest needs financial support to restore their routines. In some cases, both communities utilized external and internal resources. However, the QSR community requested more external resources to repair their homes than the MH community. The economy of several QSR households relies on social assistance, as discussed in Question 18. The Question 29 reinforces the economic vulnerability highlighted in the previous section (question 18). It is important to remember that the magnitude of the disaster increases when the community's capacity to recover its functioning is low. Therefore, QSR would need more resources to resume its activities.

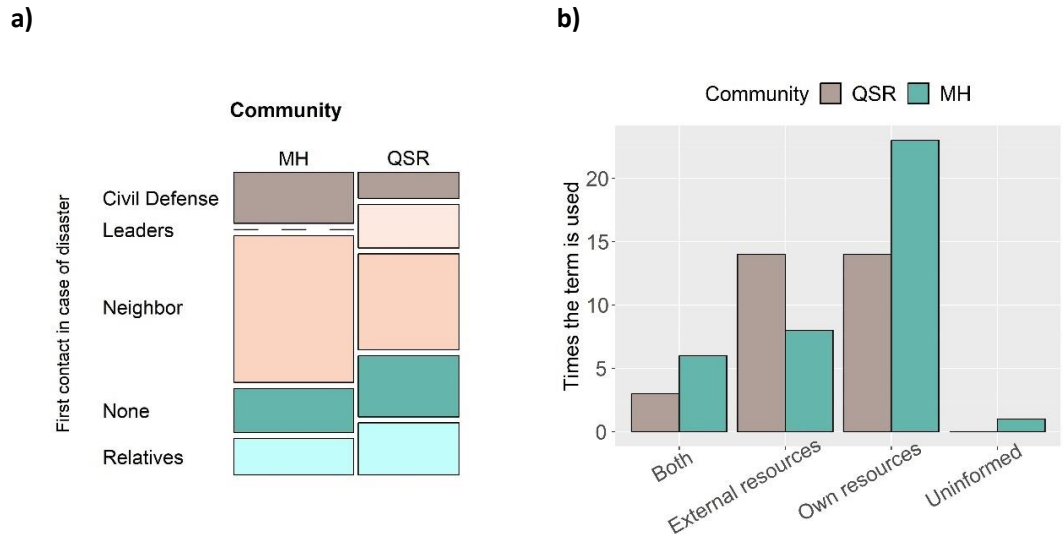

Figure 3-8a) Q25 – To whom do you tell if there is an impact caused by nature?; b) Q29 – When damage occurs due to flooding, landslides, or windstorms, who usually makes the repairs and where do the resources come from?

3.4.7 Point of view (Questions 30-34)

The perception of the environment was examined with the Questions 30 to 34. Environmental education related to disasters triggered by natural hazards (Question 30) is important for most residents of both communities (QSR = 28; MH = 33). Others agree that it is partially important, are unsure, or respond that it is irrelevant. Therefore, providing technical knowledge to the community is crucial for the inclusive management of public resources. Most of the two communities agree with that disasters triggered by natural hazards disrupt the daily lives of both communities (Question 31). However, some people of both communities disagree with the disruption of daily lives or are unsure how to respond (QSR = 14; MH = 14). Figure 3-9a shows the perspectives of both communities regarding whether they have influenced the landscape

around them. For the residents of MH, the perspective seems to be divided. However, for QSR inhabitants there are more people who believe that they have had no impact on the environment. Even though a large portion of the QSR area is inside conservation units, they still view themselves as non-aggressors of the environment because of their traditional agricultural methods, attachment to and respect for the land, and use of locally obtained materials in construction. Moreover, the majority of respondents believe that disasters triggered by natural hazards can change landscape appearance (Figure 3-9b).

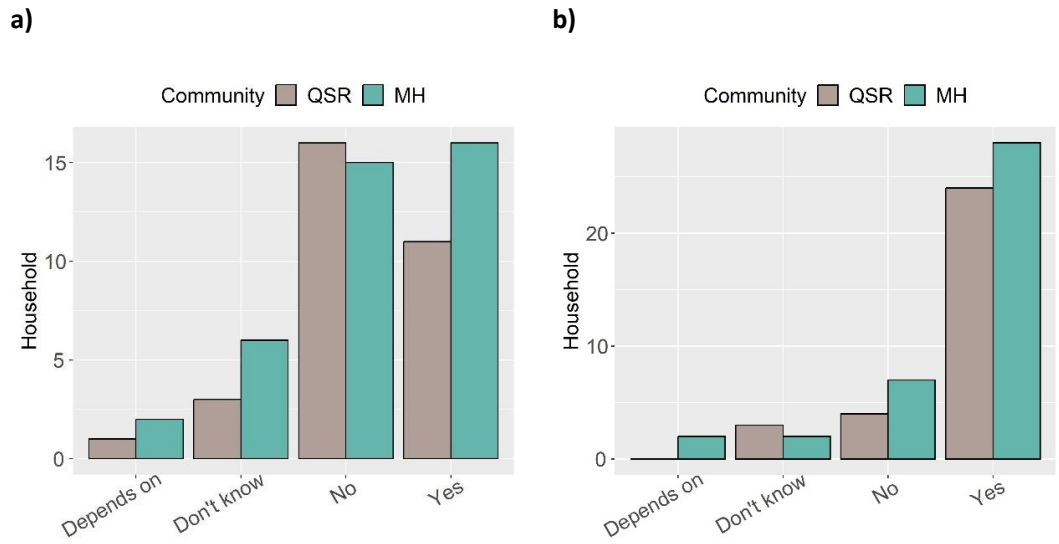

Figure 3-9. a) Q32 – Do you consider that the community has changed the landscape or terrain?; b) Q33 – Do you consider that natural events have altered the landscape or terrain?

3.5 Discussion

The study area is characterized by floodplains and hillslopes, which significantly influence the communities due to natural processes that increase communities' exposure hazards. Then, QSR and MH serve as landscape modifiers. The sociogeomorphological approach provided valuable insights into the vulnerability of social groups since it considers the geomorphology in which each community is located. MOULD *et al*. (2018) mention that these insights can be gained from interpersonal dialog, as we did through our interviews. Restoration river management is similar to DRM in that natural processes are involved, and natural resources are manipulated by humans. For example, VIGLIONE *et al.* (2014) emphasize the important role of settlement processes in flood dynamics. Likewise, we verified that QSR and MH settlement processes influence management territory nowadays. People who live within these ecosystems develop close relationships with their surroundings. Therefore, researchers, managers, and policymakers must

consider social-natural interactions, so sociogeomorphology approach calls for the integration of different points of view.

The interviews reveal that the QSR faces challenges in maintaining their homes within their territory (Figure 3-2c) due to limited resources, insufficient information on safe locations, and a lack of opportunities to avoid territorial conflicts with national parks as other traditional communities according to BOHN and GROSSI (2018). These difficulties affect the place identity as defined by PENG *et al.* (2020), making people deeply rooted in the territory more vulnerable during disasters. Additionally, it was observed through personal dialogues that disasters affect the houses, means of subsistence, and income of QSR. At the same time, MH typically experiences damages to their homes rather than their means of support (Figure 3-3b). Therefore, QSR is more susceptible than MH. These challenges reflect the differences between two communities in terms of the state of the economy, culture, institutions, physical fragility, susceptibility, and the lack of capacity to anticipate. All of these factors are framed within the MOVE framework.

It was observed that QSR people have lower income than the MH community, which can be affirmed by seeing the building material of houses and techniques which are weaker in QSR. Many houses in QSR are wooden buildings, while in MH bricks are the standard materials. Therefore, when storms and floods affect the houses, QSR is more vulnerable to damage to its assets than MH (HAMIDI *et al.*, 2020). In addition, some QSR residents receive social economic assistance (Figure 3-5b) and require external resources after a disaster (Figure 3-8b), which are associated with low incomes (PEACOCK *et al.*, 2014). Thus, the analysis was carried out according to observation and indirect questions and not on the basis of a specific income value, which can give a false evaluation of the economic situation. Recognizing the participation of the surveyed population in social assistance programs provides insight into the economic or social vulnerability of each household. This helps to avoid establishing income values that may vary between societies. For instance, in Brazil in 2024, the minimum wage is 260 euros per month (AGÊNCIA BRASIL, 2024). To be eligible for the *Bolsa Familia* program, families must have a maximum income of 40 euros per month (BRASIL, 2023b). This amount is significantly lower than the poverty limit considered in Europe in 2023, which is 800 euros per month (LIBERDADE, 2023).

Most of respondents in both communities have lived in the same area for more than 40 years (Figure 3-2b), which can have advantages and disadvantages regarding disaster and risk awareness. First, living in the same area for a long time allows QSR and MH to better understand natural processes such as floods, landslides, and storms. Then, the studied communities are more resilient and adapt to such natural hazards when LK or TK is employed, as observed by CUATON

and SU (2020). For instance, when comparing the two communities, it is evident that QSRs have reorganized the location of their homes in response to past flood events. As a result, there are now few homes with high exposure to flooding. In contrast, MH residents seem confident that their homes will withstand the floods that occur every year. This suggests that QSRs are more aware of flood risks and better self-management practices. The disadvantage is that the QSR and MH sometimes view standard the frequency of natural events, so even essential preparedness is not a priority. Thus, preparedness competes with other concerns, as DEEMING (2008) discussed. The previous statements were identified with Questions 12, 13, and 20. Therefore, a questionnaire must consider questions with a similar aim to obtain several information resources that could be cross-checked between them as developed in this study and observed in others such as MCCALL and ALVAREZ LARRAIN (2022).

Research incorporating LK can document and translate this wisdom into information accessible to stakeholders outside the community, including the scientific community. In Brazil, ALMUDI and SINCLAIR (2022) studied the perception of hydroclimatic events in rural communities, and SANTOS *et al.* (2023) mapped native seed banks along a specific region in Bahia. However, studies conducted in Brazil using LK or TK in the context of natural disasters are scarce. In this sense, open-ended questions helped to elicit information from LK deeply rooted in the communities (QSR and MH) in a disaster context. For instance, weather forecasts from government sites do not apply right to the QSR area, so they prefer to rely on TK passed down through generations, which differs from MH. Obtaining this information can contribute to natural process readiness and DRR; however, this information is not always useful to the communities, context well described by PHILLIPS; MORROW (2007). Some communication problems detected in QSR, such as the credibility of information systems, the loss of importance of warning messages, and the isolation of the community call into question possible protective measures. Therefore, future risk management strategies for QSR should prioritize environmental education (e.g., reading meteorological reports) and other methods to incorporate TK to prevent disasters.

Technological communication in QSR has some limitations compared to MH. The QSR residents acknowledge that energy and internet services are affected during floods or hailstones and prefer voice-to-voice communication (Figure 3-6c). They also emphasized that the location within the canyons provides difficult signal coverage, so they prefer not to rely on telecommunication. Then, typical warning messages cannot be an effective measure for QSR. This effect can also be seen in the discussion about the search for forecasts, as mentioned before. According to Scolobig et al. (2012), risk awareness is higher among individuals who previously experienced a flood, lived in

isolated areas with higher risk, or had lower trust in local authorities. This could explain the QSR's different responses compared to MH (Figure 3-7a and Figure 3-7b), whereby QSR prefers to rely on TK or not look for weather information, increasing their adaptation capacity. Additionally, it was noted that QSR relocated their homes after past floods, even though both communities had houses in the floodplain, indicating greater awareness and resilience than MH. Thus, engaging in dialogues with the communities to locate the ancestors' damaged houses could increase the risk awareness and enhance flood hazard mapping accuracy by identifying hazardous areas based on past flood events.

The role of religion in preparation is described in AYEB-KARLSSON *et al.* (2019), documented by BONGO *et al.* (2018) for indigenous peoples and by PENNA-FIRME and BRONDÍZIO (2017) for traditional communities .This influence on beliefs on disaster management and the role of religion in preparation are observed in several QSR answers based on TK (Figure 3-4b). Some people from the two communities think preparedness is unnecessary because they rely on faith to stay safe. They kept thinking that they would be saved by God no matter where they were or that they would escape unharmed because they had done nothing wrong to warrant punishment. Thus, these beliefs should be considered when developing policies, as it is crucial for communities to make sense of actions in the face of a potential disaster. The LSK and facts described by MCCALL and ALVAREZ (2022) were observed in supplementary answers in QSR. For example, some of QSR argued that observing the behavior of insects and animals (ants and birds) and cloud formation provides some clues about the weather at any moment.

The difference in social networks between MH and QSR became clear when hypothetical situations were analyzed (Figure 3-6a and Figure 3-6b). In an emergency, seeking out friends or family members is typical of QSR (Figure 3-8a), as it is a behavioral pattern that results from culturally embedded values about the importance of family (PHILLIPS; MORROW, 2007). Although solidarity is expected during disasters (FUREDI, 2007) and, therefore, may be present in both communities, this response is more common in communities where solid social relationships exist. Additional comments reveal a pattern of solidarity and unity within the QSR community, possibly stemming from their history of resistance against the slave regime and their organization into Quilombola associations from 2003. In contrast, the community of colonizer descendants (MH) tends to prioritize individuality. Supportive and united communities have a superior disaster response and recovery capacity and can even carry out collective disaster preparedness activities.

Community leadership is crucial for community representation and decision-making in DRM (ZAMISA; MUTEREKO, 2019). Thus, the community's vulnerability decreases when trained

leaders are present (MAHMUD *et al.,* 2020; NATIONAL RESEARCH COUNCIL, 2015). In QSR, community leadership is naturally activated in emergencies, and these leaders generally initiate the chain of calls to emergency response entities. In contrast, leadership may be less decisive in MH, as the social structure and resource management depend on the Praia Grande municipality. In emergencies, each household in MH individually calls the mayor's office to report an emergency. This can overload the emergency response networks and cause collapses increasing vulnerability. Thus, the QSR social network is an advantage over MH in the context of risk management.

The results highlighted place identity and LK as useful tools for DRM in rural areas. The interviews provided some information that cannot be found in government databases because the communities studied are small, and their data if hard to find on official sites. As HERNÁNDEZ-MORENO and ALCÁNTARA-AYALA (2017), TRUEDINGER *et al.* (2023), and VALENCIO *et al.* (2009) mentioned, interviews are painstaking works that support to understand the social dynamics necessary for scientific analysis in DRM. While interviews are a common type of work, the DRR's integration of these and their findings as an operational tool is their most significant constraint. In QSR, lack of confidence in institutions such as civil defense was notable, while MH demonstrated a greater interaction with this institution. The Civil Defense institutions at its three levels (municipal, state, and federal) must do more preventive measures in rural areas (Figure 3-5a), because communities do not know the institution's actions very well. The responses obtained here from QSR respondents coincided with the unequal institutional treatment noted by VALENCIO *et al.* (2009), which can be attributable to isolation (SCOLOBIG *et al.,* 2012). As for MH, its inhabitants affirm that Civil Defense acts after a disaster, but preventive measures are absent, for example, environmental education, help to creation Defense Community Nuclei (NUDEC), promote with government elaboration of mapping participative risk (i.e Practical Application – Appendix). Thus, there is an opportunity to improve institutional management strategies to be more inclusive with vulnerable communities, including holistic views (UNDRR, 2015). Protection and Civil Defense, a national organization, has supported the NUDEC creation (LUCENA, 2005), a collection of neighborhood volunteers willing to collaborate with the Municipal Coordination of Civil Defense (COMDEC). The interviews conducted in the rural communities under study indicate that there is potential for the formation of NUDECs consisting of MH and QSR. By improving the ability to prepare for, adapt to, and recover from disasters, the deployment of NUDECs is a vulnerability solution that enhances resilience. The two communities' empirical knowledge and prior disaster experiences would aid in developing more context-appropriate measures considering technological and economic restrictions, sense of

attachment, and historical of unfavorable events, for example. Compared to unorganized rural communities, QSR's association structure offers an advantage for deploying these organizations (NUDEC) against disasters. Additionally, it would build a dialogue bridge—which is currently lacking or nonexistent—between the communities (MH and QSR) and the COMDEC. The ability to conduct preparedness and mitigation actions, establish disaster response methods, build resilience, improve recovery, and reduce risk—all of which contribute to addressing the five stages of DRM—is made possible by the presence of a space and prominent leaders in this field. In this case, science such as sociogeomorphology can be very useful since interactions among social units such as neighborhoods, communities, or economic regions and natural conditions such as floodplains, mountain processes, climatic conditions, and ecosystems are considered. Thus, there is a co-produced system where both (social-natural) are considered as cause and consequence of modifications of that system.

Since the interaction of natural processes with the failures of societal structures causes disaster, the tactics for dealing with these situations vary depending on the natural hazard type and the amount of community awareness (WHITMARSH, 2008). Past experiences in both communities, such as the 1974 flood or yearly windstorms, have stimulated awareness about disasters, as argued in general by SCOLOBIG *et al.* (2012) , however it is not enough. For both communities, the government's drainage improvement near access roads generates a sense of security regarding floods. The population hopes that the flow goes to the river, as it should. Therefore, the population does not prioritize increasing skills related to non-structural measures, confirming the 'safe development paradox' mentioned by BREEN *et al.* (2022). Thus, the concern feeling (Figure 3-3b) may diminish due to trust in the municipal services that manage the risk (BREEN *et al.,* 2022; COLLENTEUR *et al.,* 2015; DI BALDASSARRE *et al.,* 2019) or due to time passing (VIGLIONE *et al.,* 2014). Although communities have awareness, it is difficult to see the connection between awareness and preparedness (SCOLOBIG *et al.,* 2012) as residents reported being unprepared (Figure 3-4b). Both communities agree that natural processes frequently occur in this area, but underestimation of natural phenomena or lack of preparation could make disasters severer. Therefore, as AGHAEI *et al.* (2018) and CANLAS and KARPUDEWAN (2023) mentioned, education on DRR, such as including multi-hazard assessment concepts in the first levels of education, collective and individual training to act in case of emergency and identification of places prone to natural hazards can be essential to avoiding diminishing risk perceptions.

Both communities recognized that education in risk management is essential for their communities as disasters disrupt daily life and cause material hardship (Question 30). Thus, we

identified the willingness of rural communities to receive technical information that facilitate integrative approaches to DRM can be applied (VANELLI *et al.,* 2022). Community perceptions of environmental impacts vary (Figure 3-9a). In MH they knew that their past activities, such as logging, were very harmful to the environment. They mentioned that the National Park's intervention was beneficial. In contrast, QSR affirms that they did not damage the landscape as they used the land according to their TK, confirming why traditional communities are known as Green Collectives (PENNA-FIRME; BRONDÍZIO, 2017). Additionally, QSR highlighted the abstract values that the country holds for them, such as place meanings (SALCIDO *et al.,* 2023) and Values (MCCALL; ALVAREZ LARRAIN, 2022). Furthermore, both communities agreed that disasters triggered by natural hazards can strongly change the landscape, as occurred with the 1974 flood and subsequent events (Figure 3-9b). In this sense, the perceptions of multiple threats (SULLIVAN-WILEY; SHORT GIANOTTI, 2017) were confirmed.

3.6 Conclusions

The results obtained with the interviews permitted capturing personal experiences and obtaining information on disaster perception in two rural areas with TK and LK. Interviews were considered an appropriate way to have a primary source of information for DRM. Interview development and analysis highlighted the benefits of understanding the context in which communities face risks. Understanding community dynamics helps to identify the vulnerability conditions such as exposure, susceptibility, and resilience necessary to implement suitable DRR strategies. However, some limitations refers to the field research and personal interviews consume much more time and resources. The interviewer should have experience in social activities and be empathetic and must not overlap technical knowledge with TK and LK. The questionnaire should be strategic to obtain information that can be cross-checked to ensure the consistency of responses. Questions that are too open or unstructured can dilute the goal of the questionnaire. Although a certain amount of freedom can be enriching to obtain more authentic answers, great attention must also be paid to the structure of the interviews. Hence, it is strongly recommended to conduct semi-structured surveys for disaster management.

It is widely recognized that people's perceptions of risk can vary and may be influenced by their social environments. Therefore, this study observed variations in exposure, susceptibility, and resilience conditions between communities. The study offered benefits to risk disaster management by examining rural perceptions of risk through surveys that consider place identity. Thus, it is essential to conduct regular studies to establish an unbiased and comprehensive history or monitoring system. Vulnerabilities were identified considering the social and natural context.

Significant differences in DRM were identified between the two communities. Place identity was a significant factor that affected QSR more than MH when a disaster occurred. The short time length of the house from QSR addresses the higher rate of rotation than MH, which increases vulnerability in QSR. Communication means are different among communities since the resources and set of geomorphology conditioned communication. So, these factors modify the risk awareness of communities.

The safe development paradox was verified in both communities, so it requires improved risk preparedness against it. Windstorms and floods harm both communities. Since these incidents are occasionally seen as common occurrences, moving houses in accordance with their experiences was the first step in the adaption process, but there was lacking in technical expertise specifically for wind-related disaster. As such, the local government must handle this as a multi-hazard and provide education about the disaster. Organizations such as civil defense and local government has the potential to integrate into the social networks of both communities in the prevention phase by implementing force groups like NUDEC.

The communities can integrate the risk reduction measures as long as it makes sense for them and it be suitable to their context. In this way, DRR measures will be efficient. The studies of identity-related cultural aspects, interactions with the environment, beliefs, TK and LK and behaviors are a valuable resource for expanding the universe of vulnerability. Census data has long period of update so it is insufficient to accurately reflect social interactions, especially for unstructured or small communities. In this sense, integrating therefore, combining this type of questionnaire into with the census data process can be beneficial for rural areas. Discussing logical directions with the community in hazardous situations is critical to saving lives. For instance, asking about where the best place to stay in floods or whom to call when a disaster occurs are simulated situations that are useful as mental exercises to identify flaws in community decisions. In this case, stimulating the discussion allows for a more participatory approach to strategy development and the delivery of appropriate results to the community. Furthermore, future research should complement this integration process by implementing activities on participatory maps to provide tools in the community-based DRM. Therefore, additional sociogeomorphological approach studies must be conducted in tandem with risk hazard education to maintain data updates and track changes in risk perception.

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4 Attributes influencing the flood risk perception in rural communities

This chapter is based on the following manuscript that will be submitted to International Journal of Disaster Risk Reduction.

Resources:

GONZÁLEZ-ÁVILA, I. et al. Attributes influencing the flood risk perception in rural communities.

Abstract

The study area is the Ampuero municipality, Spain, where face-to-face interviews were conducted to get insight into flood risk perception and how it is influenced by the degree of development of rural areas, for which the results were compared to those obtained in rural areas from another country. The study was carried out from a sociogeomorphological standpoint, using geographic information resources that also enabled visual comparing the perceptions captured with flood risk maps from hydraulic models. It was identified that the development level influences all stages of disaster risk management. In addition, the sociogeomorphological approach highlights priority areas for the response phase and reveals gaps that can be closed with disaster education. Furthermore, several guidelines were described for proposing appropriate disaster risk management strategies for rural communities. Based on these guidelines, the gap between flood risk perception and management will be minimized.

Keywords: Perception, Flood risk management, Household interviews, International comparison, Sociogomorphology.

4.1 Introduction

Risk perception represents the accumulation of external stimuli and their respective interpretations to which each individual is exposed. In the context of Disaster Risk Management (DRM), perception is a kind of action to understand and manage the human factor to reduce risk and, therefore, influences the (in)safety behaviors that an individual assumes. Two paradigms can be cited to understand the perception of disaster risk (BIRKHOLZ *et al.*, 2014): the constructivist (DAKE, 1992) and the rational (KATES, 1971). Both paradigms are not mutually exclusive and can be used to understand risk perception. The former paradigm refers to the stimuli exerted by the social context on the individual's actions in a threat situation. For example, explaining and acting on catastrophic events according to a particular religion. The media strongly influence the constructivist approach. The second paradigm is based on an individual cognitive process in which preventive or defensive actions arise from the mixture of stimuli that the threat exerts and a priori knowledge. For instance, the costs-benefits analysis of residing in a

landslide area and the subsequent decision-making process, which may align with what is considered rational.

The culture about risk is shaped by individual and collective experiences, histories, beliefs, relationships, and understandings, as stated by BIRKHOLZ *et al.* (2014) for the case of floods. However, there are few studies that compare risk perception across cultures (LEE *et al.*, 2015; SIEGRIST & ÁRVAI, 2020). In this sense, the interaction of several environmental, social, and economic elements in a specific geographic space modifies people's perceptions and impacts their behavior. In the present study, the risk perception can differ between urban and rural environments, even within communities of the same type, by varying degrees of socioeconomic development. So, the adequate analysis of these elements requires a holistic-overviewing effort. In light of the considerations above, we present the following research question: RQ1 – How do different levels of development in rural areas influence people's perceptions of flood risk and how they manage floods?

Several studies focus more on risk management in urban areas (RANA *et al.*, 2021) than in rural communities. By following constructive and, therefore, artificial standards, urban areas tend to create homogeneous landscapes with similar problems. For example, undersized drainage systems in the face of increasing population density. On the other hand, rural areas predominantly depend on processes governed by nature, and these areas are also molded by social dynamics, challenging territorial management. Rural areas are, therefore, relatively heterogeneous with diverse problems. Therefore, we decided to focus on rural communities. A further challenge in studies of rural environments is that human activity is changing natural landscapes at an accelerated pace, making it difficult to delimit rural areas. According to LOHMANN & LOHMANN (2008), rural areas can be described as non-metropolitan regions or residual areas that are not urban. Historically, agricultural output was linked to rural areas; however, in the present, rural areas are utilizing other services to support their resources, such as tourism, recreation, industry, and residential care, so agricultural services are only one of the available choices.

BIRKHOLZ *et al.* (2014) mentioned that the main gap in disaster management lies in the interface between risk perception and DRM. To diminish this gap, the present study considers the externalities of the landscape in rural communities that shape the behavior of the studied population and considers the natural environment in which it develops. This approach allows us to establish a sociogeomorphological analysis (GONZÁLEZ-ÁVILA *et al.*, 2023b) for DRM. Thus, the second research question is formulated as follows: RQ2 – What are the valuable and advantageous results of using a sociogeomorphological approach for flood risk perception

analysis? It is therefore desired that by responding to this question, we will be able to illustrate the integration of different points of view in DRM analysis and to provide guidance on strategies applicable to rural communities facing flood disasters.

Capturing the perception of flood risk through interviews allows obtaining a wealth of information in order to establish more effective strategies for DRM as MENDONCA & GULLO (2020) did in the landslide-based study. Thus, there is one more question for discussion: RQ3 – How can suitable measures for managing flood risk be proposed and integrated in rural communities? In light of the questions above and in accordance with SIEGRIST & ÁRVAI (2020), who proposed recommendations for future research, we present an investigation and demonstrated the circumstances in which a higher level of knowledge or significant cultural differences result in disparate responses based on the perceptions and that influence flood risk management. For this purpose, the study area is Ampuero, a municipality in the province of Cantabria in Spain. The characteristics observed there correspond to a rural community in a developed country. The information captured comes mainly from a questionnaire adapted from GONZÁLEZ-ÁVILA *et al.* (submitted) for a developing country, so comparing aspects of rural communities with different degrees of development can be feasible.

4.2 Study Area

The Ampuero municipality (32.2 km^2) is located in the eastern part of the Autonomous Community of Cantabria, Spain (Figure 4-1). It is closely connected to the eastern Cantabrian coast and the upper valley of the Asón. The study area is in the floodplain of the Asón River, specifically in the lower river's basin, and corresponds to Ampuero's floodplain. The mean elevation in the study area is 11 meters above the sea level. The geology of Ampuero belongs to the Quaternary (Holocene) alluvial overburden, composed of silts, clays, sands, and gravel (AYUNTAMIENTO AMPUERO, 2018). The climate in Ampuero follows the typical pattern of the Cantabria Mountain region. According to the Köppen-Geiger climate classification, it is the Cfb temperate climate with a dry season and moderate summer temperatures. The monthly mean precipitation vary from 93 to 114.6 mm (ANCELL & CÉLIS DÍAZ, 2012; MITECO, 2020).

Ampuero has a population of 4,455 inhabitants – (INE, 2023). The municipality has 24 population entities serving as a residential and tertiary services center (GOROSTIZA, 2015). The shift in economic activities results from de-agrarianization processes that began in the 1980s. Ampuero has demonstrated a departure from Cantabria's traditional rural geographic model, which involves abandoning of agrarian spaces. Instead, there has been a geographic redistribution

(DELGADO VIÑAS, 2014) whereby the municipality mostly consists of commercial, industrial and residential areas (Figure 4-1).

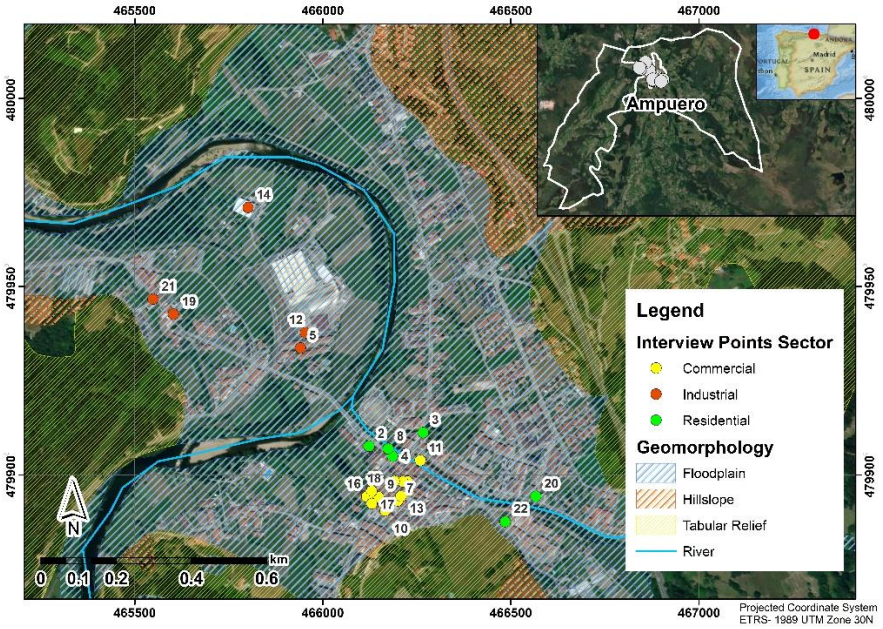

Figure 4-1. Study area and interview points for Residential, Commercial and Industrial sectors in the floodplain in Ampuero

Records of flooding in the Asón River date back to 1582. On August 26, 1983, a discharge of 728.56 m^3/s was recorded in the Asón River, resulting in the death of one individual in Ampuero. In this event, the precipitation was approximately 180 mm in one day exceeding monthly mean precipitation. On January 31, 2015, the Asón River reached a critical level of 1,200 m^3/s, flooding the Industrial Park (Marrón) in Ampuero. The flooding reached a depth of 1.70 m in the industrial warehouses. The last heavy flood occurred on November 29, 2021, with precipitation reaching 222 mm in 48 hours (BÁRCENA-ODRIOZOLA & GARMENDIA-PEDRAJA, 1999; GORDÓN, 2017). Given the prevalence of flooding in Cantabria, the government approved the Special Civil Protection Plan for the Autonomous Community of Cantabria against the Floods Risk–INUNCANT (GOBIERNO DE CANTABRIA, 2010) in 2010, including Ampuero as one of the main hotspots in the region in these terms.

Currently, the Asón River restoration is in execution. It involves structural measures that outflow water, the recovery on both banks of some flood plains for public use, the cleaning of vegetation, and the removal of some breakwaters. The government will finish the project in the summer of 2025 (GOBIERNO DE CANTABRIA, 2023). On the other hand, the guidance for adaptation to floods by MITECO (2020) for the Marrón park in Ampuero contains a wealth of information on structural measures that can be taken. However, it is not enough to reduce the losses due to floods. The document presents a few non-structural strategies, including the recommendation to

become familiar with the INUNCANT plan, identify emergency numbers, have a self-protection plan, and take out property insurance. Consequently, there is a call to attention regarding potential gaps in flood risk management involving non-structural measures in Ampuero that will be examined in this study.

4.3 Materials and Methods

4.3.1 SIG resources

Data regarding the Ampuero flood mapping was obtained from the Cantabrian Hydrographic Confederation (CHC) for return periods of 10, 100, and 500 years (CHC, 2014). The geomorphology utilized in the study aligns with the Geomorphology Map of the Autonomous Community of Cantabria, which is presented at a scale of 1:25,000 and corresponds to sheet number 036-3. The Land Use and Land Cover map is derived from high-resolution mapping conducted between 2017 and 2020. The geomorphology and land information were obtained from the website of the Cantabria Government (https://mapas.cantabria.es/).

4.3.2 Interviews

To investigate the perception of flood risk and awareness in Ampuero's floodplain, the study area was divided into three sectors: Commercial, Residential, and Industrial (Figure 4-1). The Commercial sector is the municipality's central zone, where most community services are concentrated. These include the mayor's office buildings, restaurants, banks, pharmacies, supermarkets, and other similar establishments. The Residential sector comprises grouped housing apartment buildings. In these buildings, the first floor generally corresponds to a garage, and the houses are on the second floor. The Industrial sector is home to mechanical workshops and Teknia which is a factory manufacturing metal and plastic components for the mobility industry. Teknia employs many inhabitants of Ampuero, so it is essential to the municipality's economy. The division was made in this way to facilitate grouping different zones into homogeneous social activities: services, housing, and industry. Hence, the study employed a sociogeomorphological approach which jointly considers these social activities and geomorphological features (floodplain area) as units of analysis. This approach was proposed by GONZÁLEZ-ÁVILA *et al.* (2023b).

Face-to-face interviews with 27 semi-open questions were conducted on three days in 2023. The applied questionnaire (Table 4-1) is an adaptation of the interview used in similar previous studies (CARVALHO *et al.*, 2023; GONZÁLEZ-ÁVILA *et al.* submitted; GONZÁLEZ-ÁVILA *et al.*, 2023a) and modified according to authors' knowledge. Using a similar interview in

two different study areas will allow comparisons and discussions related to socioeconomic characteristics that influence DRM.

Most people in Ampuero were interviewed at their workplaces rather than at home, which is unusual. Nevertheless, it is at the workplaces where the interviewees spend most of their time. Only one representative from each local was questioned to gather statistics. Nonetheless, records of related people's opinions of the interviews were kept as additional comments. A preliminary review of answers was conducted and then all responses were classified based on the collected information. Quantitative responses were classified in intervals, while qualitative responses were organized in descriptive classes. The interviews were permitted within the framework of the activities described in the document CEID2023_10 of the Ethics Committee of the Valencian International University – VIU.

Table 4-1. Questionnaire divided in blocks used in the present study

Sense of belonging
Q1. How long have you lived in this house? Q2. What motivated you to live there? Q3. Would you like to live somewhere else? If yes, why?
Perceptions related to flood disasters
Q4. Do you feel safe from flood disasters in this place? Why? Q5. Has anyone in the family that lives in this house ever experienced floods? If yes, which one(s)? Q6. Has anyone in the family ever suffered loss because of these floods? Which? Q7. Please, mention any flood you remember. Q8. Do you identify any place in Ampuero where floods events and impacts are recurrent? Which one(s)? Q.9 Do you feel prepared to act during a flood? If yes, how? If not, why? Q10. Do you believe floods could affect your home? If yes, how? If not, why?
Institutional recognition
Q11. Are you familiar with Civil Defense? Q12. Has Civil Defense ever interacted with the community? If yes, how? Q13. Are you enrolled in any social assistance program offered by the city hall?
Action during the disaster
Q14. Hypothetically, if it rains a lot and the river level rises until it reaches your house, you: • Stay at home; Leave the house (where?) Q15. How will you be notified if a flood event causes damages in the community? • Cellphone/Call; Instant Messages; Personally; It is not communicated. Q16. Do you have a safe meeting place agreed upon with your family/community? If yes, where?
Preparation for disasters
Q17. Do you usually look for weather forecast information?

Q18. Where do you look for weather forecast information?
Post-disaster action
Q19. To whom do you tell if there is an impact caused by nature? Q20. What is the number to call in an emergency? Q21. Do you have temporary shelter? Q22. When damage occurs due to floods, who usually makes the repairs, and where do the resources come from?
The perception that the community has of its surroundings
Q23. Do you think it is important to know more about environmental education related to flood disasters? Q24. Do you consider that the occurrence of flood disasters influences community development? Q25. Do you consider that the community has changed the landscape or terrain? Q26. Do you consider that floods have altered the landscape or terrain? Q27. Who do you think has been causing major terrain/landscape changes? • Community; Floods; Others

4.3.3 Sample Selection

Firstly, three sectors in Ampuero's floodplain were chosen as sample sites due to their proximity to the Asón River and the recurring floods in this municipality. According to INE (2023), there are 3,231 households in the entire municipality, so we proceeded to estimate the total number of homes or workplaces that would be within the sectors of interest (flood area). Based on the housing density in Ampuero, a total of 339 houses were estimated for the area of interest. Next, the sample size of 77 with an error acceptance value of 10% was determined using Simplified Yamane's formula as explained in LIU *et al.* (2018). This formula is expressed by:

$$n = \frac{N}{1+Ne^2} \tag{4.1}$$

where n is the sample size; N is the total number of households; and e is the error acceptance value. Most of the sampled households were selected using a random sampling technique, and according to the availability of households. Some places seriously affected by flood disasters were selected based on the advice of local people. Also, this sample size was divided over all three sectors.

The theoretical sample size is well suited for quantitative studies, but since this study is qualitative, this calculation is only a guide. According to the information power model (MALTERUD *et al.*, 2016) and what is observed in the field, a lower number of interviews can be considered satisfactory if a convergence of responses is observed.

4.3.4 Data analysis

The responses were arranged according to the sectors: Commercial, Industrial, and Residential. Contingency tables were used to arrange the data and identify significant differences among

sectors (LÓPEZ-ROLDÁN & FACHELLI, 2015). The Fisher's Exact was used to compare the deviation between pair of sectors. A significance level (p-value) of 0.10 was adopted for this purpose. A p-value below this level, in the Fisher's Test indicates that there is evidence to suggest that the response of inhabitants is associated with the sector where they work or live. Consequently, it can be concluded that the responses may differ depending on the sector. Conversely, a p-value above the significance level suggests that the responses may be similar among sectors. It is recommended that the data are observed in cases where a difference is identified (ZIBRAN, 2007), so that the responses having statistically significant differences were further analyzed through histograms. Statistical analysis and data visualization were carried out R (IHAKA & GENTLEMAN, 1996).

4.4 Results

4.4.1 SIG resources

According to the Hydrographic Confederation of Cantabria (CHC), the study area has flood maps for a return period of 10, 100, and 500 years (CHC, 2014) as shown in Figure 4-2. The sociogeomorphological division indicates that the Industrial and Commercial zones of Ampuero are situated near or within the flood area for three return periods. Conversely, the area classified here as residential is at risk when considering the 500-year scenario. The Industrial area has already reached a flood level of 1.7 m, which was also observed during the 2015 flood event. The flood maps produced by CHC (2014) appear to accurately depict the flooding scenario in Ampuero.

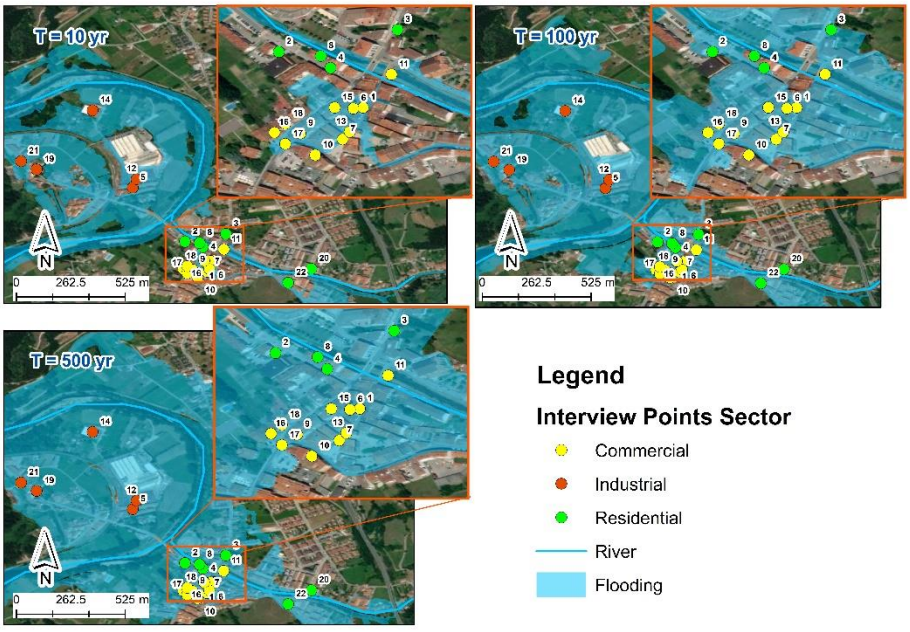

Figure 4-2. Localization of interview point and flood mapping for return period of 10, 100, and 500 years in Ampuero

4.4.2 Interviews

4.4.2.1 Sense of belonging

The Industrial and Commercial sectors are predominantly occupied by workers, while few interviewees also work in Residential neighborhoods. The majority of interviewed people in Residential have lived there for over 50 years, while those in Commercial and Industrial sectors have lived there for 10 to 30 years (Q1). Most of those surveyed prefer to live and work there due to the high regard for quietness, which is linked to both life quality and tranquility in the three areas (Q2-Q3).

4.4.3 Perceptions related to flood disasters

The respondents' responses to previous questions have been mostly similar. However, when queried about their safety perception in the face of flood risk (Q4 - Figure 4-3a), the three distinct sectors within Ampuero's floodplain exhibited notable differences (Figure 4-1). Even though all respondents indicated that they or members of their family had experienced flooding (Q5), there was no consensus regarding the safe feeling. The Test's Fisher results revealed a significant difference between the Commercial and Residential sectors with a p-value = 0.049 and between the Industrial and Residential sectors with a p-value = 0.080. Thus, neither the Commercial sector (73%) nor the Industrial sector (80%) feel safe, while the Residential feels more assured about flood situations. The main losses reported are goods and equipment from the Commercial and Industrial and personal property from Residential neighborhoods (Q6).

The psychological damages were acknowledged only in the Commercial sector. The most memorable flood was that of 2021 (Q7), which was the last of significant proportions. Several respondents indicated that the depth of water in various sectors reached 0.7 m. Other floods mentioned were the one that took place in 2015, which was more damaging than that of 2021, and the 1978 flood, which resulted in one fatality.

The Commercial (43%) and Industrial (50%) recognize themselves as areas with frequent impacts due to flooding (Q8 - Figure 4-3b). Commercial areas were mentioned at specific points as main commercial streets and the access road to Ampuero. For the Industrial sector, names such as the industrial park of Marron, sports fields, and the surroundings of the train rail were mentioned. For the Residential sector respondents, the Industrial Park is the most impacted area in Ampuero. This perception explains the statistically significant difference (*p- value* = 0.033) in the pairwise comparison of Commercial-Residential. The Bullring infrastructure located in the Residential sector was mentioned as a frequently impacted zone.

The Commercial perception of being prepared for a flood is the highest among the three (Commercial-Residential *p-value* = 0.098; Commercial-Industrial *p-value* = 0.063) (Q9 - Figure 4-3c). Merchants say that they are prepared because they elevate their goods to avoid economic damages. Other comments from the residents of Ampuero are that they use pumps to drain the water from their properties, monitor the river, carry out self-management through voice-to-voice communication with neighbors, and put barriers on their properties. Those who feel unprepared say that flooding is uncertain when there is a high tide, snowmelt, and rainfall at the same time, once the water gushes from the ground and the toilet. Trust in the government and resignation from the situation are also mentioned. Despite the subjective sense of preparedness, it is widely acknowledged that the workplace or the home (where the interview occurs) are susceptible to flooding (Q10).

4.4.4 Institutional recognition

Q11 indicates that, despite the absence of a Civil Protection head office within the municipality, the emergency unit is nevertheless well-known to respondents. Typically, Laredo, a nearby municipality (13 min by car – 11 km of distance), provides support for emergencies in Ampuero. The Commercial and Residential sectors exhibit a comparable perception of the interaction between people and civil protection (Q12). This perception can be divided into two categories: a positive perception of the interaction and a negative perception of the interaction. Most respondents from the Industrial already affirm the absence of civil protection work. This sector is one of the most flood-problematic and economically crucial for Ampuero. So, more priority and resources are expected in disaster prevention and response. At the same time, respondents from the three sectors were unsure whether flood assistance programs exist in the municipality. Also, many respondents affirmed that this kind of program does not exist (Q13).

4.4.5 Action during the disaster

During flood events, respondents in the Commercial sector exhibit significantly different behavior from those in the Industrial and Residential areas (Q14 - Figure 4-3d). Those in the Commercial sector tend to evacuate after securing materials susceptible to damage. Respondents in the Industrial sector are divided between staying on-site or evacuating. The machinery and equipment in the Industrial sector cannot be elevated as they are in the Commercial area. Instead, barriers are used as recommended in MITECO (2020). Respondents in the Residential area mostly remain at their homes or workplaces.

The primary means of communication for flood notification is through verbal communication among neighbors, local police, or fire brigades (Q15). While some respondents mentioned the use of messaging, it is not a widely used medium, and even this type of communication is not

mentioned in the Residential area. The absence of early warning system alarms by governmental entities is also highlighted.

Although respondents do not have a designated meeting point, the exposure to flooding in the Commercial and Industrial sectors has led to self-management (Q16). In contrast, respondents in the Residential region do not see the need for a safe meeting point as they have not had to use such strategies. Although the area is not highly prone to flooding, it is important to increase awareness and preparedness as it is located in a flood plain.

4.4.6 Preparation for disasters

Most respondents habitually search for weather or river level information (Q17). Most people in Commercial and Residential consult mobile app information (36% and 67%, respectively). The confederation's website (CHC) is also a primary source of information for the Industrial sector. However, in the Industrial sector, a high percentage (40%) of the respondents do not consult any source (Q18 - Figure 4-3e).

4.4.7 Post-disaster action

The insurer is responsible for receiving reports of flood damage to properties in all areas of Ampuero (Q19) and to give resources to fix damages (Q22). However, respondents in the Residential and Commercial areas also tend to report damage to their neighbors.

- The emergency number for the entire European Union is 112, which triggers medical, police, and calamity systems (Q20). The Commercial and Industrial gave some negative answers to this question without mentioning the emergency number that they use. One reason for this may be that some floods are not considered emergencies, as people already know how to respond based on past experiences.

According to the respondents, temporary shelter is not considered a useful measure for DRM related to flooding in Ampuero. They affirm that the shelter is unnecessary due to the magnitude of the previous damages caused by floods (Q21 - Figure 4-3f). A statistically significant difference for Commercial-Residential (p-value = 0.03) is identified. Respondents from the Commercial (73%) and Industrial (60%) sectors expressed uncertainty regarding the existence of a shelter designated by the municipality. At the same time, those from the Residential stated that there are no shelters (83%). The communication gap about shelters highlights the importance of defining a point or providing guidance for these vulnerable groups.

4.4.8 Perception about the surroundings

The concept of environmental education aimed at mitigating flood risks is widely accepted by respondents from the Residential sector who have experienced fewer disasters (Q23). Although respondents from the Commercial and Industrial sectors mostly agreed with the environmental

education initiative, expressed some skepticism about the usefulness of awareness-raising as a strategy for DRM. This is due to the fact that it is not a tangible structural strategy and is not widely disseminated among the population.

Respondents from the Residential and the Commercial agree that floods harm the village's development (Q24). Meanwhile, respondents from the Industrial have differing opinions despite this sector is constantly threatened by flooding.

Most respondents mentioned that the development of Ampuero has not significantly altered the landscape. However, about half of the Residential respondents affirmed that Ampuero's development altered the landscape (Q25). A number of respondents indicated that the proposed alterations will be subsequent to the implementation of the structural measures defined in the government's project against floods (GOBIERNO DE CANTABRIA, 2023).

The respondents indicated that floods do not typically impact the landscape. However, some respondents from the Commercial sector reported temporary changes in the surrounding landscape when floods occur (Q26), due to tree trunks and debris left behind.

The Industrial sector closest to the river has kept relatively the same landscape since its consolidation in 1994. While the Commercial and Residential areas have experienced some developments, the overall tendency for the city is to have a minimal impact on the landscape (Q27).

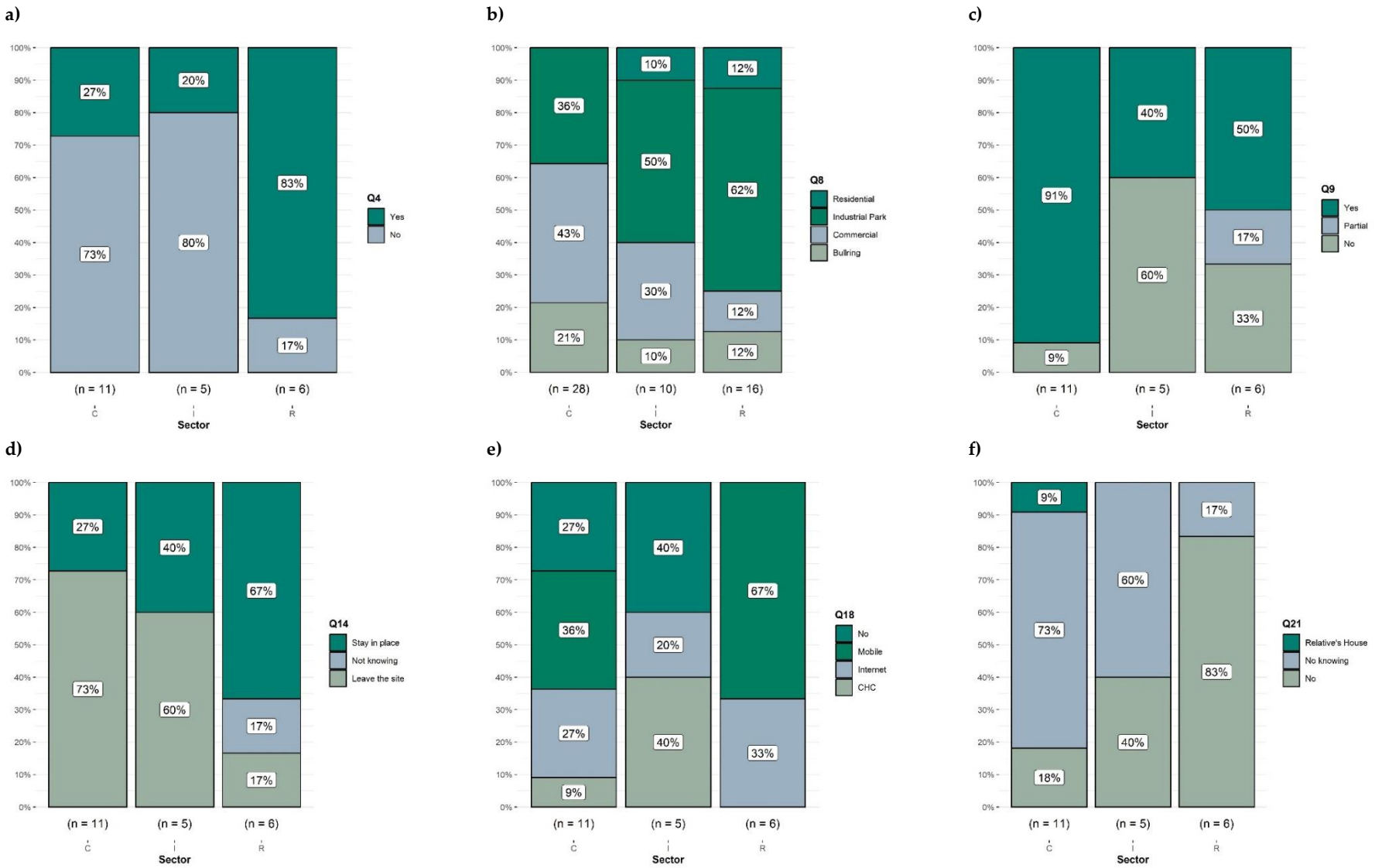

Figure 4-3. Responses comparison among three sectors: a) Q4. Do you feel safe from flood disasters in this place? b) Q8. Do you identify any place in Ampuero where floods events and impacts are recurrent? c) Q.9 Do you feel prepared to act during a flood? d) Q14. Hypothetically, if it rains a lot and the river level rises until it reaches your house, you: Stay at home; Leave the house (where?). e) Q18. Where do you look for weather forecast information? f) Q21. Do you have temporary shelter?

*Letter **C** means Commercial Sector; Letter **I** means Industrial Sector; Letter **R** means Residential Sector.

4.5 Discussion

Here, the research questions (RQ1 , RQ2, and RQ3) listed in the introduction will be answered, and comparative comments will be made between Ampuero and other Brazilian rural communities (Mãe dos Homens – MH and Quilombo São Roque – QSR) from previous studies that, apart from minimal variations, used the same questionnaire (CARVALHO *et al.*, 2023; GONZÁLEZ-ÁVILA *et al.*, 2023a). For this comparison, the main characteristics of the Brazilian communities are presented in Table 4-2.

Table 4-2. Characteristics of Quilombola São Roque community and Mãe dos Homens Community (adapted from GONZÁLEZ-ÁVILA *et al.*, submitted).

Description	Quilombola São Roque	Mãe dos Homens
Community	Traditional	Non-traditional
Knowledge	Traditional	Local
Delimited area	73.28 km²	No delimitation
Fluvial network	• Josafaz creek • São Gorgonho creek • Mampituba River	• Mampituba River • Facão River
Geoform and relief	• Pedra Branca mountain • Cliffs • Canyons	• Flood Plain • Wavy Relief
Natural Disasters	• Floods (1974, 1995, 2006) • Storms	• Flood (1974) • Storms
Ancestors	Enslaved Africans	European immigrant families
Start of Occupation	About 1800 [1]	1840~1900 [2]
Social Organization	• *Grota* system ("Grota" local name to cave). Organizational system. • Social Association formed in 2003 • Around 32 families	• Rural community • Around 45 families
Length of residence in the same house	Short time	Long time
Economy	• Agriculture • Pensioner	• Agriculture/Livestock •Logging • Pensioner
Leadership presence	Yes	No
Hosting of social assistance programs	Strong	Weak
Construction characteristics of the house	First-floor wood-made houses	First-floor brick-made houses
Main Roads	One unpaved road	One unpaved road
Time/distance to the nearest downtown	40 min by car - 21 km	20 min by car - 12 km
Technological Access	Limited Radio/TV	Limited TV/ Smartphone
Prevention - Looking for weather forecasting	Not usually - Not rely on information system	Usually – Preparation for routines

[1] Occupation for more than 180 years, according to personal communication. [2] The first couple arrived in 1840 but it was not until 1940 that there was community infrastructure, i.e., a community saloon (Lummertz, 2015).

4.5.1 Risk perception according to the level of development (RQ1)

The Ampuero municipality is characterized as a rural community in the European context (CĀNE, 2021); however, when compared to the MH and QSR communities, there are several differences associated with the development level.

In the case of flooding, the Brazilian communities would opt to leave home or go up the mountain according to their local knowledge, while the Residential sector of Ampuero mentions that they would stay in place. This behavior difference may haves to do with the level of development and the type of housing. In a Brazilian case, single-family houses with one floor and light construction materials are common. In Ampuero, the first floor of the house is used as a garage and the house itself is on the second floor. Until now, the water hardly reaches that height and neither impacts the belongings of the house. The restriction of access to and from the homes in Ampuero when a flood occurs should also be considered an impact on the normal functioning of the community, although it does not put the lives of the residents at risk. The disruption of the normal functioning of the community can be defined as a disaster (MONTE *et al.*, 2021). Recalling that Ampuero's Residential sector is in an area with a lower susceptibility to flooding. However, in a flood plain geomorphology, attention should be paid to the exposure to which these inhabitants/workers are exposed. It implies lack of education and disaster orientation.

The economic activities in both Brazilian and Spanish communities present stark contrasts. Rural community economy in southern Brazil depends on agriculture (LACERDA *et al.*, 2020), while Spain's community benefits from a diverse economy, particularly the secondary and tertiary sectors (CĀNE, 2021). These differences generate economic disparity among rural communities with different levels of development. This issue can be confirmed in the study when respondents mentioned losses associated with flooding. In Ampuero, losses are primarily related to merchants' products, industrial machinery, and personal belongings. In contrast, QSR and MH communities suffer from crop damage and housing destruction. Thus, the inequality rooted in developing rural communities increases future disaster vulnerability (CAPPELLI *et al.*, 2021) compared to developed rural communities. For Brazilian communities, floods represent an obstacle to their development meanwhile in Ampuero flood impacts are not perceived as impediments to progress. This difference might be attributed to the time and resources available during the recovery phase. In developing communities, recovery time is longer, and resources are limited, which affects the return condition to regular community activities and influences their development.

Access to information determines how communities deal with DRM. Commercial and Industrial respondents in Ampuero demonstrated a greater trust in weather forecasting available on the internet and electronic devices, and also an understanding of how to access and interpret digital resources such as flood modeling and river levels, offered by CHC. This indicates a higher sense of preparedness for flooding. As XU *et al.,* (2020) observed, the media, in particular television, radio, and mobile phones, can influence perceptions of disaster risk. Consequently, merchants and industrialists in Ampuero have higher flooding awareness and a more accurate understanding of its potential severity and likelihood. However, residents are not aware at the same level due to the disaster education gap. This contrasts with Brazilian rural communities, where information access may be more limited, which is opposite to the effective Disaster Risk Reduction (DRR) education strategies described by AGHAEI *et al.* (2018). In contrast to Brazil, the Spanish institutions responsible for this information disseminate it throughout the entire country. Thus, the Brazilian communities lack the required training to manage this type of information due to limited technological access. The level of community development influences access to information and how the inhabitants respond to it in a disaster context. Consequently, communities with enhanced access to information can construct a better perception of risk based on their previous experiences, community context (constructivism paradigm), and a priori knowledge (rational paradigm), making better decisions in the face of a disaster.

Access to the physical space is also a crucial factor in determining how communities conduct DRM. In Ampuero, respondents from the Commercial sector identified locations susceptible to flooding with relative ease. These sites are characterized by being access roads or by offering some services to the community. In case that the inhabitants of Ampuero require any service, they can go to nearby municipalities (13 min by car - 11 km). In contrast, respondents from the QSR and MH sectors identify locations associated with natural features such as hillsides, riverbanks and *grotas* (cavities in slopes or hills produced by rainwater). These communities have only one unpaved access road. When it collapses, people in these communities are isolated. In addition, accessibility to QSR is difficult because it is a remote community (~40 min by car to the downtown).

Disaster preparedness and response in communities with physical access limitations, as observed in Brazilian communities (GONZÁLEZ-ÁVILA, *et al.,* 2023), require self-management. For instance, QSR relies on and communicates relevant facts to its community leader, while MH respondents look for their neighbor or warn the mayor's office (GONZÁLEZ-ÁVILA, *et al.,* 2023). However, this is not the case in Ampuero, which has good road access conditions and after a flood, the first step they take is to notify the insurance company. Notably, in Ampuero, all the

interviewees have flood insurance, which is uncommon in Brazilian rural communities. Thus, the inhabitants' self-management and self-efficacy in Ampuero may not be stimulated given the confidence of the inhabitants in the role of the response entities. Thus, the coping capacity and cooperative neighborhood responses described by PENG *et al.*, (2020) are uncommon in the studied municipality.

Additionally, as CEJUDO & NAVARRO (2019) described, European rural communities tend to become uninhabited. Hence, a number of people living in Ampuero today are there only for the weekend or have a job associated with the industrial park, which avoids community interaction and affects the social fabric. Thus, the logical process to act in a disaster is already established for each community, where self-efficacy could be an advantage for rural communities in developing countries.

Ampuero's inhabitants are educated to call 112 in an emergency since it is an emergency contact number within the European territory. This fact differs from developing countries like Brazil, where the emergency contact number is not centralized for all the country. In rural communities, the scenario is worse. Centralizing emergency response in a single contact number makes it easier for the population to memorize and use. Moreover, unifying response efforts in a single entity can save economic and human resources and improve their efficacy. These aspects could make the difference between developed and developing countries in terms of DRM in the response stage, where developed countries are at an advantage.

4.5.2 Sociogeomorphological approach for risk perception analysis (RQ2)

The fieldwork allowed the identification of floodplain characteristics in Ampuero, as confirmed in Figure 4-1. The sociogeomorphological analysis focused on the three identified sectors of Ampuero, so that the use of sociogeomorphological units can assist in the identification of gaps in flood risk management help in the administration of resources for DRM. In this case, the industrial and commercial zones were found to be two priority places to be addressed by DRR practices focused on emergency response and early warning systems. The Industrial sector currently needs more guidance from the government or aid agencies. In the event of flood, this region is one of the first to be affected, leaving less time to execute activities. As a result, they strongly rely on early warning systems or pre-established actions for their execution as described in MITECO (2020). Early warning of disasters can become essential in places where local geomorphology favors flash floods, such as the mountainous basins in QSR (GONZÁLEZ-ÁVILA *et al.*, submitted). The response time is shorter in these areas, because there is no time to secure belongings, which is done in Ampuero. Conversely, the residential area needs a better understanding of the floods in the vicinity. Thus, sectors within the same municipality showed

significant differences in how they act in the face of floods conditioned according to the geomorphology around. Consequently, one of the advantages of using the sociogeomorphological approach in the analysis of risk perception is that it can be used in different contexts even for developed and developing countries (CARVALHO *et al.*, 2023; GONZÁLEZ-ÁVILA *et al.* 2021; GONZÁLEZ-ÁVILA *et al.*, 2023a).

Regarding the role of the sectors in modifying the landscape, none believe they have had a notable influence on the landscape. However, attention is drawn to the fact that the landscape not only refers to the visual aspect but also to landscape services, as DARVISHI *et al.* (2022) mentioned. A respondent at the Industrial sector affirms that high tide, snowmelt, and high rainfall are physical factors that trigger flooding in Ampuero. Thus, settling in floodplain areas, insufficient drainage, and problems built from social activities are stressed when natural processes are intensified. Then, the landscape functions are modified depending on its composition or alterations, as DARVISHI *et al.* (2022) described. However, Ampuero is unaware of its intervention in the functionality of Ampuero's floodplain landscape.

The interview, in conjunction with the consultation of the flood maps, revealed that flood perception and hydraulic simulations in Ampuero are aligned. According to FORRESTER *et al.* (2015) and SANDERS *et al.* (2020) the combined use of dialog and mapping tools improves the validation of participative processes. In the present study, this combination was relevant to understanding the role of memory in disasters, and it was confirmed that the 2021, 2015, and 1978 events were the most remembered ones due to their severity. Thus, the events that caused the most significant economic losses and human lives are remembered very well in Brazilian communities (GONZÁLEZ-ÁVILA *et al.*, Submitted). However, nowadays it is difficult to remember the details of past disasters once memory decays with time (SONG *et al.*, 2021). Thus, derived from the present study there is a call for disaster education sessions to emphasize the importance of understanding that all studied areas in Ampuero, regardless of whether they belong to the Commercial, Residential, or Industrial sectors, are in a floodplain. Hence, the community has several degrees of exposure to flood hazard. Disaster education also includes keeping alive the memory of past experiences and disasters. Furthermore, such actions could assist in land-use planning policies to avoid construction at places susceptible to natural hazards.

4.5.3 Establishing risk reduction disaster measurements for rural communities (RQ3)

In order to establish DRR measures, it is essential to conduct a comprehensive diagnosis of the community situation. This involves identifying the interacting social and physical factors, with a

particular focus on identifying hazards and elements vulnerable to the hazard (sociogeomorphological approach).

There is a lack of clarity regarding the existence of a database that explicitly addresses risk perception worldwide. Then, Ampuero's databases do not reflect the inhabitants' perception of flood risks. This is understandable given that risk perception is a cultural construct (ADOMAH BEMPAH & OLAV ØYHUS, 2017; SANDERS *et al.,* 2020), requiring qualitative research with this type of information. The interviews and guided dialogue developed in this study have yielded valuable information, including insights into the community's needs and priorities in the context of flood disasters. Thus, qualitative research is a suitable start to improve DRM.

Ampuero's inhabitants show attachment to the community due to quality of life. Thus, they justify staying and rebuilding in the same flood-hazard area. In these three compared communities (Ampuero, QSR, and MH) a feeling of rootedness for their space is identified, which does not depend on economic development conditions. Feeling of rootedness is also documented by TRUEDINGER *et al.* (2023) in Germany, where factors such as home ownership status, degree of attachment to the area, and the belief that such extreme events occur very rarely are mentioned. These motives are also observed in Ampuero's inhabitant's conversations. Despite the interviewees mentioned that removing some settlements and relocating critical infrastructure may be effective risk-reduction strategies, many individuals still choose to rebuild in the same exact location. TRUEDINGER *et al.* (2023) also describes this logical sense when German people were interviewed as Spanish people in Ampuero. Then, government orientations must be based on holistic studies and effectively communicated considering the degree of attachment of inhabitants.

Most of Ampuero's respondents are unaware of the psychological impacts that can occur after floods, although there is a significant amount of literature on the psychological impacts of disasters (ALEXANDER, 2005). This scenario also is observed in GONZÁLEZ-AVILA *et al.* (submitted) for MH and QSR communities. In Ampuero, as floods are frequent in the study area (floodplain), the government should pay specific attention to affected groups such as merchant. Both industrialists and merchants present a high degree of helplessness in the face of a disaster, which can be explained by the absence of government actions. This perception of helplessness is described in MORGADO (2020). Consequently, implementing programs designed to provide conjunct economic and emotional assistance in the wake of floods could be a suitable measure for rural communities. This program could be umbrellaed by other social assistance programs, as Brazilian communities have (BRASIL, 2023).

The post-disaster call chain in Ampuero begins from the affected inhabitants to the insurance companies. The responses to the interview stressed the absence of leaders in the community, which differs from the traditional rural communities in Brazil. Community leaders play a pivotal role in rural communities in developing countries (ATANGA, 2020; GONZÁLEZ-AVILA *et al.*, submitted). Consequently, the present study underscores the necessity and relevance of ascertaining the role of local leaders in DRM in rural communities in developed and developing countries. Furthermore, it is recommended that the leaders are integrated into developing DRR strategies, as proposed by ATANGA (2020).

Ampuero has seen that flood mapping information is available to stakeholders. Thus, CHC information helps to reduce institutional vulnerability, as described in the vulnerability framework of BIRKMANN *et al.* (2013). The diagnosis of access to information and understanding of the hazard for rural communities allows managers to establish more objective DRR actions. For Ampuero, access to digital resources available through the CHC is evidenced, which helps to determine whether people are in an emergency. Not all countries have this information, and not everyone can access and interpret the data. According to MEECHANG *et al.* (2020), technology should be perceived as valuable and easy to use so that everyone can be confident with it. Thus, the technological and knowledge limitations in rural communities should be assessed. Although many people in Ampuero are familiar with CHC information, its widespread use should be encouraged. It is noteworthy that there was a lack of prevention activities on the part of civil protection in Ampuero, which was also noted in rural communities in Brazil (GONZÁLEZ-AVILA *et al.*, submitted). Thus, access to information of water-level in rivers, flood-prone areas, weather forecasts, emergency numbers, and shelter information is a required resource for developing prevention and mitigation strategies, which civil defense and protection entities and government managers in rural communities may implement.

The perception of how communities see themselves as modifying agents or not of the landscape is important, as it reflects their awareness of possible natural phenomena that may represent a hazard as observed in the responses of Ampuero's inhabitants. Prior knowledge helps in the elaboration of educational strategies that should be addressed, specifically in matters of disasters as described in the theory of mental maps in SCHOLZ *et al.* (2014). It was observed that the inhabitants of Ampuero are little aware of their role in modifying the landscape. They, in turn, emphasize their confidence in the government's project, which they believe will put an "end" to flooding in the region. (GOBIERNO DE CANTABRIA, 2023). However, it is very dangerous for the Ampuero's population to rely on structural measures without accompanying DRR education, since floods in a floodplain region never "end". It is therefore recommended to generate a change

in the mental model of the community based on a participatory approach as advised by SCHOLZ et al. (2014). These authors highlight the adverse effects on populations that rely solely on structural measures, as is the case of Guaiba basin in Brazil, which has a system of dams that failed in the May 2024 event due to a lack of maintenance (PONTES, 2024). In this event the state government was not prepared for a proper response which increased the risk of the affected people. This reported effect is the Safe Development Paradox (BREEN; KEBEDE; KÖNIG, 2022; FUSINATO et al., 2024) and always has devastating effects when disaster strikes.

Other issues on which DRR education in rural areas should focus are the definition of safe meeting points and temporary shelters. Ampuero's inhabitants, believing that extreme events are rare, see these prevention strategies as unnecessary. This gap in the acceptance of extreme events is commented on by TRUEDINGER *et al.* (2023). In the Brazilian communities, the population is not familiar with these strategies (GONZÁLEZ-ÁVILA Submitted). Then, the present study stresses that meeting points and temporary shelters should be identifiable from flood mapping and should be easily accessible to users as advised by MEMBELE *et al.* (2022). By defining these spaces, risk prevention is increased, and consequently flood resilience is strengthened in these communities.

4.6 Conclusions

The sociogeomorphological approach divided the Spanish municipality of Ampuero, located in a floodplain, into three sectors (Commercial, Industrial, and Residential), revealing gaps in DRM. The division in sociogemorphological units considers natural and social attributes, applicable in diverse contexts globally. The qualitative research identifies physical factors and contributing to flooding and community preparedness indicators in Ampuero's floodplain, aiding risk perception assessment. This tailored approach facilitates targeted DRM strategies for the municipality. For instance, industrial and commercial zones require enhanced emergency response and early warning systems, while the residential area needs better flood understanding. The analysis emphasizes the need for government or aid agency support in high-risk sectors like the Industrial sector, where response time is shorter.

When comparing the response of a rural community in a developed country with that of rural communities in a developing country, it is observed that there are vulnerabilities independent of economic resources and the development degree. Among the common problems, there are the need for more prevention, poor disaster education, absence of disaster counseling from the government, lack of early warning systems, and the undefinition of meeting points and shelters. In communities with limited resources (in developing countries), recovery and rehabilitation

times are longer, and access to DRM information is more restricted. In developed countries, insurance in flood zones, centralization of the emergency response number, and better access to technology and information systems are essential. In contrast, in developing countries, the social network and local knowledge can be essential.

The measures for managing flood risk in rural communities can be proposed and integrated adequate when community engagement is stimulated. As the community involves all stakeholders' inhabitants, workers, industrials, policy-makers, and local government, so cooperative actions among all stakeholders need to be taken. Integrating local knowledge and technical information is necessary to propose better DRR measures, so local leadership involvement in DRM stages and improvement in community access to sophisticated information systems is required. The government is required to guide the processes of prevention, mitigation, response, and recuperation actions, reinforcing skills such as self-management and self-efficiency. The government also should address land planning in parallel with integration of psychological support in DRR efforts. Regardless of economic development, communities should prioritize disaster response plans based on historical experiences and proactive measures, rather than solely relying on infrastructure projects. Continuous disaster education is crucial for effective disaster risk management in rural areas.

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CHAPTER 5

5 Practical Application, Conclusions, and Recommendations

5.1 Practical Application

This section presents a Technical Note published on the website of the Hydraulic Research Institute of the Federal University of Rio Grande do Sul[1]. This Technical Note results from a participatory mapping activity with the Quilombola São Roque community, located between Santa Catarina and Rio Grande do Sul states, which shares territory with the Aparados da Serra National Park (PNAS). During this activity, the community was made aware of the dangers of floods and landslides that affect the region due to its geomorphology. An analysis was conducted in which the participants expressed their perceptions of the HAND results on flood susceptibility map which had been presented to them. This result becomes even more relevant when the PNAS required the GPDEN the data resulting from the activity as a tool to reduce the risk to the population (Appendix). The park management must establish agreements with the community for the occupation of the territory, given that it is a conservation unit.

The activity demonstrates the importance of including risk perception in disaster management. The application of the sociogeomorphological approach in this scenario is highlighted. Floods and landslides influence community organization, and the community decides to reorganize itself to reduce the risk associated with these natural phenomena.

5.2 Conclusions

The sociogeomorphology principles were the framework for this PhD dissertation. Combining social units and geomorphological units, sociogeomorphological units were defined to analyze the rural communities in Brazil and Spain.

Brazilian communities consider natural characteristics for their development when settling down, demonstrating the relevance of this aspect in land management strategies. LULCC are set according to the natural features of the surroundings of communities, for example, slope and altitude conditions. Then, it is indicative that natural conditions influence how communities manage their territory. For instance, in high slope and altitude areas there is an increase in forest and a decrease in crops in Quilombo São Roque (QSR). Meanwhile, in Mãe dos Homens (MH), characterized by its flatness and low altitude, there has been a decrease in forest formation, along with an increase in silviculture, grassland, and other temporary crops. Also, social activities coproduce the landscape, for instance, the QSR community area and its intersection with natural parks constitute the units with the longest length of the main river. Then, these two social agents

[1] https://www.ufrgs.br/iph/nota-tecnica-mapeamento-participativo-em-prevencao-de-desastres-relacionados-a-agua-estudo-de-caso-de-comunidade-quilombola-sao-roque-na-divisa-entre-rio-grande-do-sul-e-santa-catarina/

play a crucial role in ensuring environmental preservation. Thus, these co-productions relationships are linked to their local knowledge and customs. The PhD dissertation underscores the importance of social activities in territory management, highlighting the perspectives diversity.

It is observed in QSR (Brazil), MH (Brazil), and Ampuero (Spain) that the community's response to a disaster is shaped by the human, financial, institutional, and cognitive resources at its disposal. Therefore, qualitative research is a valuable starting point for improving DRM and necessary to sociogeomorpholgical studies. In DRM the sociogeomorphological analysis approach reveals gaps associated with social activities. This approach helps to understand community dynamics and identify the vulnerability conditions considering exposure, susceptibility, and resilience. A sociogeomorphological approach identifies priorities for the establishment and implementation of suitable DRR strategies. The approach addressed sectors within a community according to priorities. These priorities consider both the perceptions of the community and the natural characteristics of the environment. Understanding the community's risk perception aids in developing targeted educational strategies on disaster preparedness. Thus, the sociogeomorphological approach to DRM can be used in different contexts for both developed and developing communities.

The comparisons between the risk management of different rural communities showed focal points that allow us to see the usefulness of the type of analysis carried out here. When comparing communities in Brazil, the following were identified: i) place identity was a significant factor that affected QSR more than MH when a disaster occurred; and ii) the short time length of the house from QSR addresses the higher rate of rotation than MH, which increases vulnerability in QSR. On the other hand, building infrastructure to reduce hazards in communities will affect risk perception and thus people's vulnerability. Especially if it is not accompanied by disaster awareness. In addition, economic activity in the tertiary and secondary sector in a developed country generates higher income than the primary sector in a developing country. Therefore, the losses generated are associated with these activities, and defining losses in economic terms tends to emphasize major economic losses, without adequately considering the breakdown in community functionality.

Communication is a key factor in DRM. Communication means are different among communities since the resources and set of geomorphology conditioned communication. So, these factors modify the risk awareness of communities. Communities in developed countries have better communication infrastructure, which represents a disadvantage for developing communities. Limited access to information decreases risk perception, so better-informed people will have

better cognitive tools to make decisions (rational paradigm), and these decisions will be shaped by the social context (constructivist paradigm). In communities with more uninformed individuals, the perception that there is no real risk is greater.

Local leadership involvement and access to systems information can help propose measures since it integrates the local knowledge and systems of information more sophisticated. An advantage of developing communities may be the performance of their social leaders, who help to provide guidance in the absence of the state or emergency response bodies. In contrast, developed communities present less self-efficiency and self-salvation, as these skills are not practiced and there is a high reliance on government entities. In addition, many rural areas in Spain are now depopulated, leaving a weakened social fabric.

The safe development paradox was verified in all communities, so it requires improved risk preparedness against it. Windstorms and floods are occasionally seen as common occurrences in the studied areas. Usually, communities prioritize disaster response based on past experiences and trust on infrastructure projects to address disaster issues rather than proactive measures. Though moving houses as an adaptation measure is thought within communities, the inhabitants are lacking in technical expertise. Thus their experiences are the main criterion to decide when disaster occurs.

The implementation of questionnaires and participatory activities in the three communities faced limitations because the members' participation is influenced by the relationship and trust established between the interviewer and the participants. In addition, executing these activities demanded long time and was conditioned by the participants' agendas. The experience of the interviewer or leader in participatory activities was crucial, as they motivated participants to share the information needed to improve disaster management.

It is essential to consider that the terms and language used to describe disasters vary according to culture, which represents a limitation that the interviewer must address before applying any questionnaire or activity. The qualitative results obtained from these questionnaires and activities represented a challenge regarding organization and processing due to the lack of standardization in the responses, which is normal when collecting open-ended responses.

In addition, it is crucial to recognize that the questionnaires capture information at specific points in time, and, given the changing dynamics of the communities, this information can quickly become obsolete. For this reason, we strongly recommend maintaining constant communication between the community and disaster risk management entities by creating groups such as Community Nucleus of Civil Protection and Defense (NUPDEC).

5.3 Recommendations

DRM should pay attention to vulnerability-related information. It was demonstrated in the dissertation that the representativeness of vulnerability factors is better understood through qualitative studies. Thus, it is recommended to strengthen databases and field research with this kind of data. Future research should complement this integration process by implementing activities on participatory maps to provide tools for community-based DRM. Therefore, additional sociogeomorphological approach studies must be conducted in tandem with risk hazard education to maintain data updates and track changes in risk perception. The results of the dissertation showed that there is a big gap in disaster prevention and preparedness regardless of the degree of economic development. Thus, it is recommended to carry out education on multi-hazard and disaster issues in different spheres of society.

Based on the gaps identified here, future research could be developed on how it is possible to fill these gaps in joint action between the community and risk management agents, for example, improvement of communication management, inclusion of disaster education courses in school curricula, mapping of susceptible areas, among others. Although the emphasis on risk perception in this work was centered on communities, other future lines of research could include the perception of entities associated with risk management such as the mayor's office, civil defense, firefighters, among others. Future research could expand the analysis of stakeholders to include rural communities and additional traditional groups such as indigenous people, *riberinhos*, *quebradeiras de coco*, among others, in order to evaluate other social characteristics that influence disaster risk management.

The government policies should be grounded in holistic studies and communicated effectively, taking into account the residents' attachment to their community. The government is required to guide the processes of prevention, response, mitigation, and recuperation actions, reinforcing skills such as self-management and self-efficiency. Integrating social leaders into these efforts like rural extension organizations should be a priority. Providing both economic and emotional support in the aftermath of a disaster is a suitable measure for assisting rural communities. Also, access to information about river levels, flood-prone areas, weather forecasts, emergency call numbers, and shelter locations is essential for developing prevention and mitigation strategies in a government. These resources should be utilized by defense and civil protection entities, as well as government managers, to enhance resilience in rural communities. Additionally, census data has a long period of update so it is insufficient to accurately reflect social interactions, especially for unstructured or small communities. In this sense, combining this type of questionnaire with the census data process can be beneficial for rural areas.

Appendix

Mapeamento Participativo em prevenção de desastres relacionados à água: Estudo de caso de Comunidade Quilombola São Roque na divisa entre Rio Grande do Sul e Santa Catarina

Introdução

Entre as atividades desenvolvidas no GPDEN a prevenção de desastres relacionados à água é uma das principais linhas de atuação. Para tal fim são utilizadas ferramentas de gestão como o mapeamento de áreas de risco de inundações e deslizamentos, por exemplo. O mapeamento com diferentes cenários se configura como um instrumento que ajuda na tomada de decisões por parte dos gestores, sendo um tipo da medida não estrutural. Esse instrumento pode ser menos custoso comparado com as medidas estruturais. No entanto, a construção dos mapas de perigo é realizada geralmente por equipes com conhecimento técnico avançado que negligencia a percepção do perigo dos moradores do local em estudo.

Em 2023 foi realizada uma atividade de mapeamento participativo com a comunidade Quilombola São Roque localizada entre os estados de Santa Catarina e Rio Grande do Sul. Essa comunidade possui grande parte do seu território dentro do Parque Nacional de Aparados da Serra. Esse parque funciona como unidade de conservação. Assim, ao longo do tempo e ocupação do território ancestral, a comunidade tem se deparado com alguns conflitos territoriais. Hoje o relacionamento entre a comunidade quilombola e os parques é amigável e há uma melhor articulação e organização dentro dos territórios.

A comunidade encontra-se em uma região de encosta e planície aluvial, caracterizada por apresentar processos naturais como inundações e movimentos de massa. Assim, os processos geomorfológicos em conjunto com as atividades sociais da comunidade são suscetíveis a concretizar um desastre. Frente a dita situação o GPDEN realizou atividades de reconhecimento em campo e diálogo com as comunidades com o objetivo de entender melhor os perigos aos quais a comunidade está exposta. A atividade foi desenvolvida dentro de um enfoque sociogeomorfologico bem como baseado nos Objetivos de Desenvolvimento Sustentável (ODS – 2030). Nota-se que a maior descrição sobre a sociogeomorfologia encontra-se em González-Ávila et al. (2023b).

Mapeamento Computacional

Para identificar áreas suscetíveis à inundação na comunidade, utilizou-se o modelo topográfico *Height Above the Nearest Drainage* (HAND) proposto por Rennó et al. (2008) e Nobre et al. (2011). Este é um modelo topográfico simples que consegue representar manchas de inundação em locais onde o monitoramento hidrológico é insuficiente. O dado de entrada para a presente análise foi um Modelo Digital de Elevação (MDE) de 1 m de resolução espacial.

Com base nos resultados de entrevistas realizadas em 2022 a 31 casas encontradas na comunidade (González-Ávila et al., 2023a; Carvalho et al., 2023), foram estabelecidos intervalos de suscetibilidade à inundação para a área de estudo: alta (0 – 2,33 m), média (2,33 – 4,66 m) e baixa (4,66 – 7 m). Valores acima de 7 m foram classificados como não suscetíveis a inundação, conforme observado em campo e analisado nos dados obtidos. O mapa resultante se mostra na Figura 1.

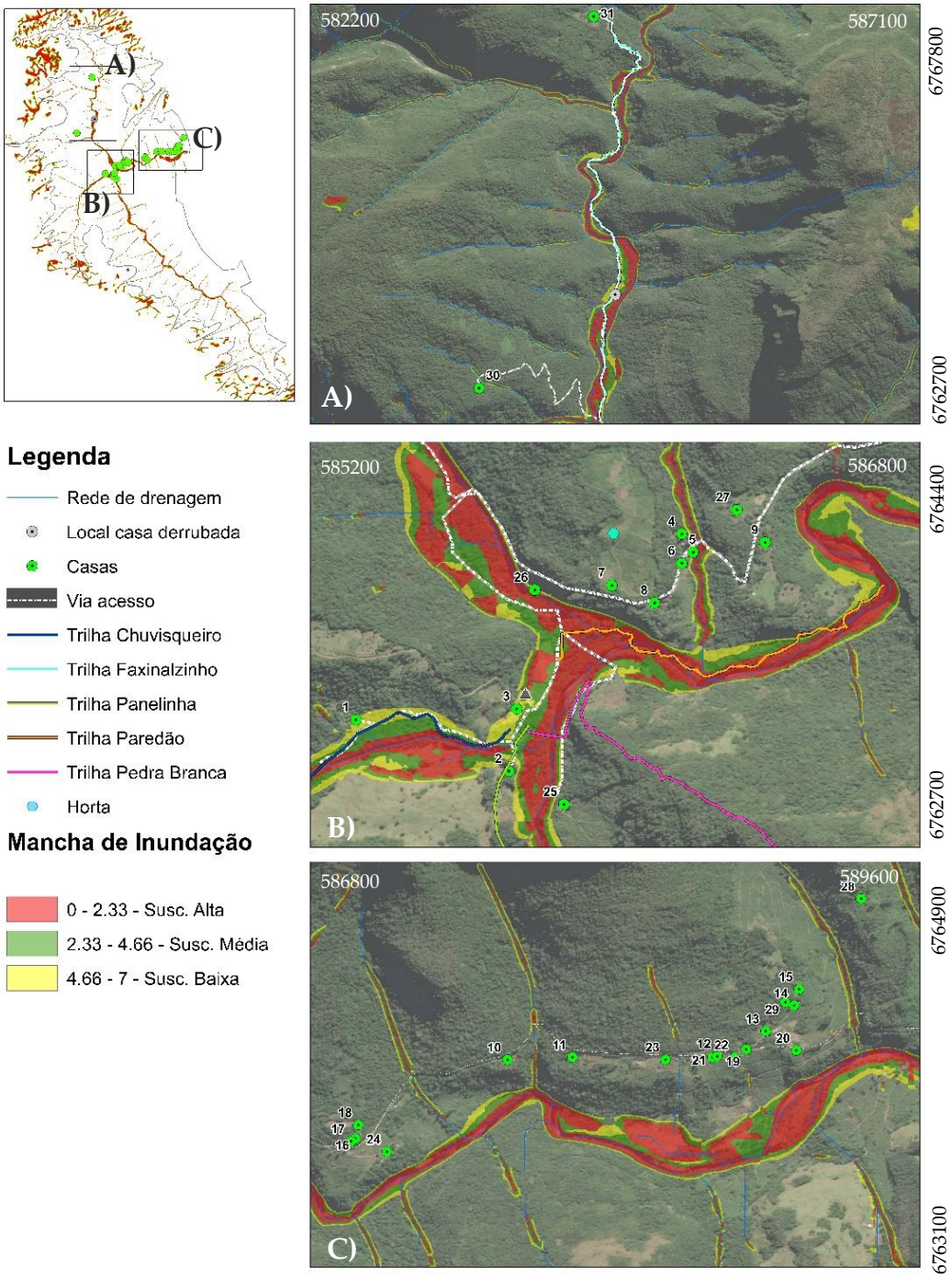

Figura 1. Mapeamento de suscetibilidade à inundação na comunidade São Roque

Mapeamento Participativo

A partir do mapa da Figura 1 foi realizada a explicação do mesmo para a comunidade onde houve a participação de 22 pessoas. Entre as 22 pessoas 7 pertenciam à Comunidade Quilombola São

Roque e o restante são estudantes da escola da comunidade quilombola, sendo que todos os participantes conhecem a região. Foram abordados temas como manchas de inundação, identificação de pontos potencialmente perigosos e potencialmente seguros. A partir de um mapa tamanho A0 como descrito na Figura 1, foram dadas 6 orientações para os participantes com o intuito de melhorar o mapa obtido pela simulação topográfica (Figura 2)
As orientações ou solicitações informadas aos participantes foram a seguir:

a) A localização da sua casa está dentro, perto ou fora da mancha de inundação?
b) Quantas vezes a atual casa foi afetada por inundação? (Caneta/ escrever no mapa)
c) Reconhecem as trilhas na comunidade?
d) Usaria as trilhas como modo de evacuação? Sim _ Não _ , por que?
e) Você concorda com a informação? O que modificaria?
f) Locais que comumente se inundam e que não foram identificados no mapa dentro da mancha de inundação (Caneta/ escrever no mapa)

Figura 2. Atividade com a comunidade

As respostas foram registradas conforme a Tabela 1. Embora as respostas sejam diversas, destaca-se a aceitação do mapa por parte dos quilombolas conforme as respostas à pergunta “e”. As respostas da pergunta “f” foram diretamente escritas no mapa pelos participantes e depois foram georreferenciadas pelos pesquisadores.

Tabela 1. Respostas dadas dos participantes a diferentes casas

Casa	Perguntas				
	a	**b**	**c**	**d**	**e**
03	Significativamente perto	0. No periodo que eu moro não. Em 1974 sim	Sim	Sim	Sim
08	Fora	0	Não precisam, estão longe das trilhas	Não	Semelhante o mapa com a realidade. Grotas
15	Razoavelmente perto. Reconheço que é perigoso por inunação e deslizamento	0	Sim	Sim	Sim
17	Fora	0	Não conheço	Não	-
25	20 metros fora do rio	0	3	Sim	Não a casa é no morro mais longe do rio
Casa 30 QSR	Fora. No entanto, o salão comunitario é perigoso (perto de casa 3), inundação pode atingir	Inundação nunca, porém o vento já atingiu minha casa	Sim	Sim. Utilizaría faxinalzinho para sair para a serra. Trilha pedra branca é de difícil acesso.	Bem elaborado

Na Figura *1*b se registra que há uma região de moradores antigos (entre casa 30 e 31) a qual foi atingida pela inundação de 1974. Na Figura1c, é discutida a inundação do salão comunitário em 1995. Foi identificada uma vivenda acima da Horta. Foram informadas duas mudanças de vivenda correspondente a casa 08 e uma nova casa perto das casas 04,05, 06. Na Figura 1c há identificação de 3 regiões perigosas: i) Perto a casa 25, ii) perto das casas 04,05, 06 - Grota alta que tranca o acesso (Figura 3), e iii) perto da casa 26.

Figura 3. Grota Alta que passa pelo acesso à comunidade

Na Figura 1d há identificação de dois grotas: Grota Dona Oliria-Teixeira e Grota Feia. A Grota Feia quando eleva seu nível fecha o acesso. A casa 10 está em uma condição perigosa por estar em uma encosta muito íngreme, enquanto a casa 20 é suscetível a deslizamento. Também foi identificado um morador novo, entre casa 11 e 23. O mapa resultante com as modificações mencionadas anteriormente se apresenta na Figura 4

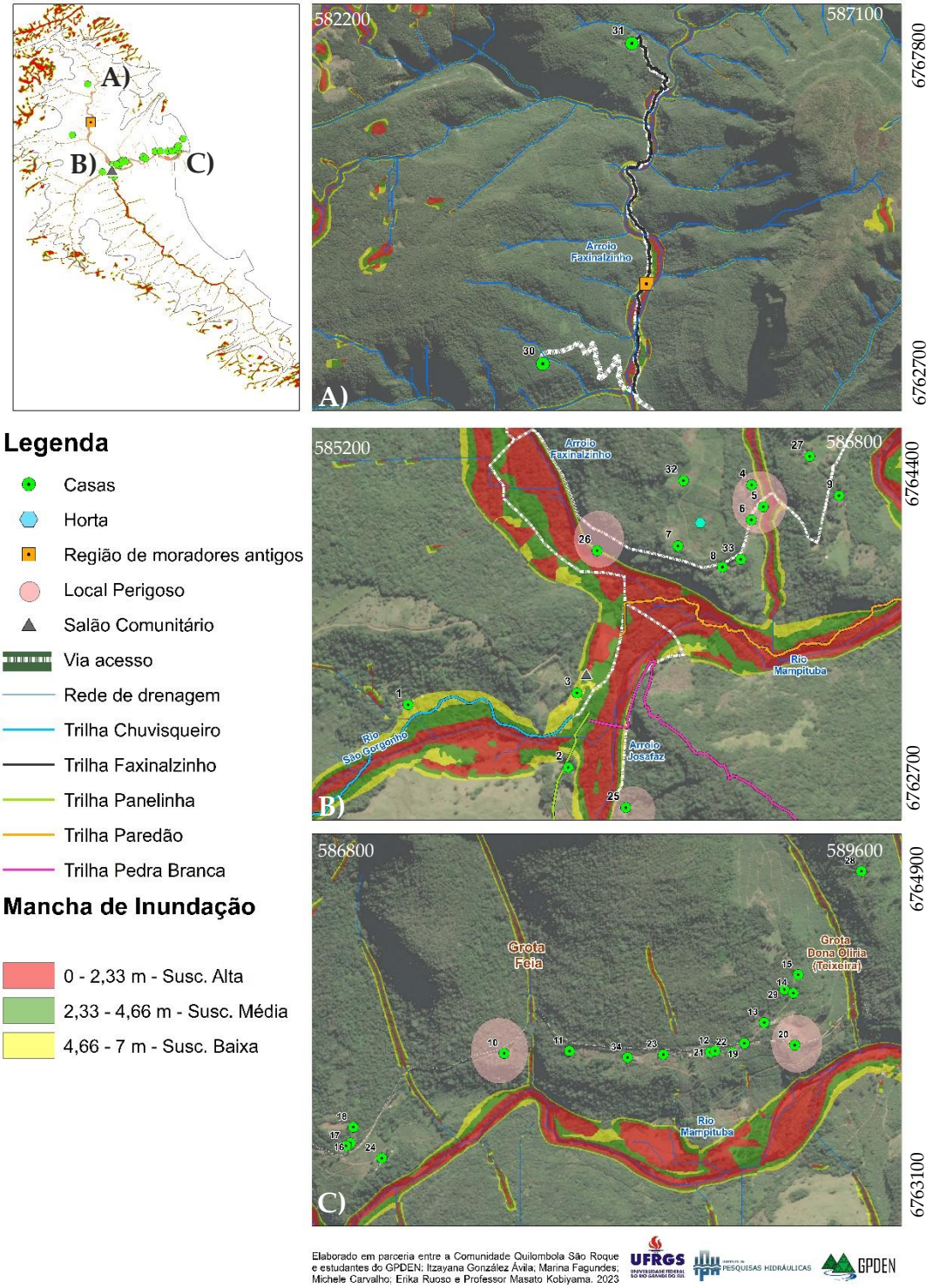

Figura 4. Mapeamento participativo de suscetibilidade à inundação e identificação de locais perigosos e seguros na Comunidade São Roque.

Considerações Finais

Durante a ocorrência dos desastres relacionados à água no Rio Grande do Sul em 2024, houve a solicitação da gestora do Parque Nacional de Aparados da Serra, aos pesquisadores do GPDEN, onde ela pediu fornecimento dos dados digitais e a relação de casas e moradores em situação de perigo, conforme identificado no mapeamento participativo. Em resposta, o GPDEN decidiu publicar a presente Nota Técnica para registrar a solicitação, junto com a análise e importância desta solicitação. O pedido de realocação das pessoas em risco foi realizado pela comunidade, uma vez que eles conseguiram perceber o risco, dados seus conhecimentos locais e nossa atividade de sensibilização. A solicitação dos gestores do Parque buscava detalhes do nosso estudo para fornecer fundamentação científica para a realocação de alguns quilombolas. Destacamos que qualquer modificação nas moradias dentro da unidade de conservação deve ser justificada, visando minimizar o impacto no ecossistema, igualmente considerando a segurança das pessoas das comunidades tradicionais que ali residem.

Por último, esta Nota demonstra que a participação da comunidade na gestão do risco de desastres é essencial para o desenvolvimento de estratégias adequadas à realidade local. A participação comunitária evidencia o empoderamento na gestão do risco, estimulado a partir do nosso estudo.

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