

Coping the recurrent flood risk in Antananarivo City: Societal impacts based on the KJ method and approach by feedback from previous studies

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Abstract

This study aims to assess the vulnerability of the community and its resilience to flooding. The approach on feedback from the previous studies on flood risk in Antananarivo city in combination with the KJ method is chosen as a methodology. The passage of tropical storm ANA in January 2022 demonstrates that 1) flood risks often occur in the city, but public perception of the risk remains low. 2) several studies have assessed the flood risk in Antananarivo city; however, those studies were not valorized by the Government and the different entities in charge of the disaster risk reduction. 3) the findings of the KJ method highlight that the physical factors and human factors were identified as the main issues for managing the flood risk in Antananarivo city.

The water level of the Ikopa River increased by over 37.5m in January 2022 which demonstrated the flood event in the city. This study outlines that the ability to adapt to a natural disaster for the local population first depends on their standard of living, especially in economic terms while for local authorities, it is manifested in numerous adjustments. This study recommends the local Government to take the flood disaster as a priority and provide training to the vulnerable community.

Keywords: Antananarivo city, adaptive capacity, flood risk, resilience, vulnerability.

Introduction

Flooding is one of the major risks facing many countries around the world as well as Madagascar²⁰. Previous studies demonstrate that extreme weather events caused by climate change with socio-economic development will continue to exacerbate these challenges in the future.⁴

Globally, the number of people directly or indirectly affected by flooding could triple by 2030.²⁵ Urban flooding events have become a topical issue in the 21st century and have caused significant damage and fatalities all over the world.¹⁰ Stakeholders face various challenges in managing urban institutional and developmental activities due to the existing pressure on the sustainability of urban areas.

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Madagascar is a flood-prone country with a history of widespread and repeated floods that cause loss of life, substantial damage to property and infrastructure and loss of crops and land.¹⁶ The average annual direct loss due to flooding is \$13 million in Madagascar.⁵ The central highland of Madagascar was hit by flood and landslide due to the passage of tropical storm ANA in January 2022. The city of Antananarivo, the capital of Madagascar, is one of the areas at risk of flooding caused by heavy rain and cyclones. Several studies have investigated the issues of flooding, agglomeration, urbanization and community vulnerability in Antananarivo city.^{6,16-19} Those studies highlight that poverty, corruption, rapid urbanization, development of informal settlements, poor planning and infrastructure are the main drivers of flooding in Antananarivo city.

It has been reported that urban floods affect some of the most vulnerable communities and have a high social, economic and ecological impact on the city.⁸ Vulnerability refers to the degree to which a population is susceptible to and unable to cope with hazards and stress including the effects of climate change.¹² The concept of vulnerability implies a measure of risk associated with the physical, social and economic aspects and implications resulting from the system's ability to cope with the resulting event.¹³ Relatively few studies focus specifically on why the population is unable to cope with the recurrent flood risk and how different population groups have survived. Therefore, a study related to the recent flooding and the coping capacity of the community remains to be addressed.

This study aims to strengthen the disaster resilience of flood-prone communities in Antananarivo city, the capital of Madagascar. In particular, this study will examine two main research questions:

- Why the population in Antananarivo city is unable to cope with the flood risk as the city has been suffering from its effects for many years? Why do not people take lessons from their past flood experiences?
- How the findings from this study can be used to enhance the resilience of the city and translated into action by the government?

Study area

The city of Antananarivo (Figure 1), the administrative capital of Madagascar, is located in the central highlands

(elevation between 1439 m to 1235m). The city's area is about 92 km², divided into 6 districts and subdivided into 192 Fokontany. Situated on twelve laterite hills and alluvial plains, the city is drained by three rivers Ikopa, Sisoany and Mamba¹. Antananarivo city has a population of 3209933 inhabitants, with an average population density of 34,89 inhabitants per km² and an average annual growth of 3.01% from 1993 to 2018.⁷ The city receives an average annual rainfall of 1300mm, of which 90 percent is concentrated in the rainy season. The city of Antananarivo is characterized by an oceanic climate with temperate summers and dry winters.

Material and Methods

In this study, we investigate the vulnerability of the households in Antananarivo city and their livelihoods towards the passage of the tropical storm ANA on 22 January 2022. The approach by feedback from the previous studies on flood risk in Antananarivo city in combination with the KJ method was developed by a Japanese ethnologist Jiro Kawakita and it is chosen as a methodology to conduct this research. The literature review is essential to properly understand other researchers' findings and recommendations to solve the flood risk issues in Antananarivo city. It is also necessary to review the concepts of vulnerability, resilience and especially resilience-building activities, which are actions related to mitigation, preparedness and response activities. A detailed review of previous studies was used to understand better the situation of flood risk in Antananarivo city and to draw lessons.

The KJ Method was developed as the affinity diagram by Jiro Kawakita in the 1960s. The KJ method was developed

because of difficulties in interpreting ethnographic data in Nepal. This method is a problem-solving tool and is a group or individual decision-making method.¹¹ It includes four aspects: a problem-solving model, qualitative data formulation and analysis tools, a new type of field research concept and method and teamwork concepts for creativity.²³ The KJ method involves four essential steps: label-making, label grouping, chart-making and written or verbal explanation.²² Through the brainstorming process, the problem becomes clear and specific.

The KJ method has universal applicability and management decision-making processes that can be utilized in all societies throughout the world to implement social and economic development.²¹ This method helps categorize and organize much fragmented uncertain information into logical cohesive groups as in figure 2. The KJ method was used to develop insight into flooding in Antananarivo city and the relationships that caused this issue, to evaluate the link between vulnerability and resilience.

Results and Discussion

Results of the approach by feedback from previous studies: The importance of academic literature on the notion of resilience is indicative of the increasing importance of natural hazards and disasters in academic debates and scientists. Recently, many researchers have conducted a study on vulnerability to flooding in Antananarivo city as presented in the table 1. The case studies illustrated in table 1 revealed that Antananarivo city has been prone to flooding for many years. Heavy rain caused by cyclones is the main cause. These studies accentuate two important issues: urbanization and the low perceptions of the population.

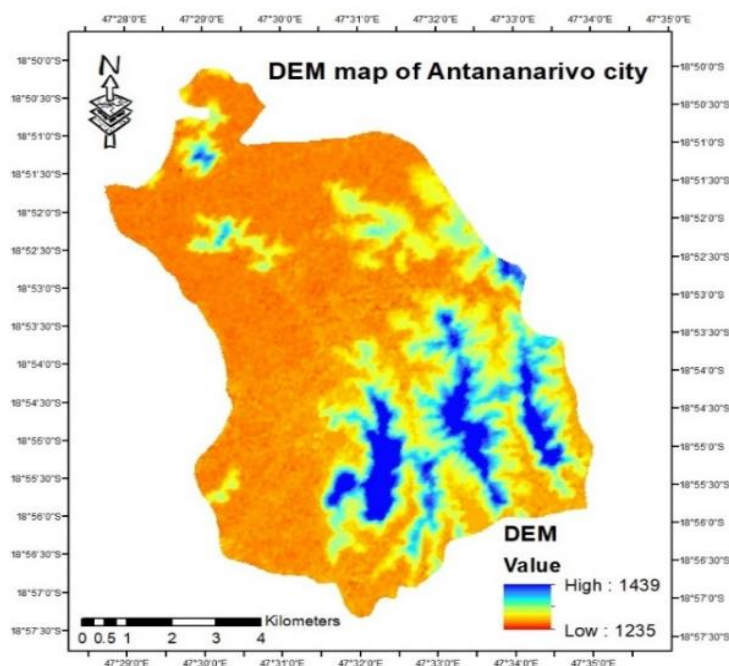


Figure 1: DEM map of Antananarivo city
(Source: Authors)

Table 1
Feedback from the previous studies on flood risk in Antananarivo city

Authors	Thesis title	Main objectives	Findings	Recommendation
Ramiaramanana and Teller ¹⁶	Urbanization and Floods in Sub-Saharan Africa: Spatiotemporal Study and Analysis of Vulnerability Factors—Case of Antananarivo Agglomeration (Madagascar)	To carry out a spatiotemporal analysis of the agglomeration of Antananarivo	<ul style="list-style-type: none"> -Urbanization leads to increased exposure of populations and constructions to floods. -32% of the population of the Antananarivo agglomeration lived in flood-prone zones in 2018. -Urban expansion was intense from 399 ha in 1953 to 3675 ha in 2017. -In 2017, 23% of the buildings in the agglomeration were in flood-prone zones. 	Better integration of flood risk management in spatial planning policies thus appears to be an essential step to guide decisions to coordinate the development of urban areas and drainage networks sustainably, considering the vulnerability of the population living in the most exposed areas.
Razafimanantsoa ¹⁹	Risk Management in Rural Areas: Case of Flooding in the Rural Municipality of Tanjombato, District of Antananarivo	To measure the vulnerability of the local population exposed, with its property, to the risks of flooding and to come up with some suggestions for amending flood management by reducing the risks.	<ul style="list-style-type: none"> -Flood risk management involves several actors, of which the local population plays an important role. -The low areas are the most exposed. Ambohimantrika and Ankeniheny, two Fokontany qualified as flood zones. -The perception of the inhabitants of Tanjombato on the scourge is weak. -The ability to adapt to a natural disaster for the local population first depends on their standard of living, especially economically, while for local authorities, it is manifested by numerous developments. 	<ul style="list-style-type: none"> -Land use planning and development of a plan for the Rural Municipality of Tanjombato are suggested. -Public policies must be highly visible for risk management to be effective. -The study suggested the control of urbanization, empowerment of the population, prohibition of illegal construction, rehabilitation of the main channels for the evacuation of wastewater, reinforcement of the protective dykes on the left bank of the Ikopa; consideration of irrigated areas and improve the drainage system.
Randrianarimanana ¹⁷	Wild urbanization facing the risks of flooding in the urban Municipality of Antananarivo: Case of the Antohomadinika III G Hangar district	To contribute to the reduction of the negative impacts of flooding and to explain the difficulty of the neighborhood in the face of the risks of flooding caused by spontaneous urbanization	<ul style="list-style-type: none"> -Wild urbanization is characterized by the uncontrolled growth of houses due to the acceleration of the number of roofs, the development of the individual backfilling system and the anarchic occupation of the marshland. -Wild urbanization is characterized, also by badly structured urbanization. The houses are built without landscaping. They are in disorder, contiguous to each other and even built on drainage channels. -Urbanization is inseparable from urban amenities. In our case, the infrastructure is inadequate and in poor condition. These promote flooding in the quarter. 	<ul style="list-style-type: none"> -The reduction of the urbanistic factors is essential for the case of Antohomadinika III G Hangar. -Urban planning reforms must be undertaken. -Economic solutions are necessary and the most important thing is the awareness of the population.

Rakotomalala ¹⁵	Contribution of the development of hydro agriculture to strengthen community resilience facing the flood » Case of the Fokontany Andrefandrano, bordering the Ikopa river at the height of the Rural Municipality of Tsiarafy	To highlight the technical inputs of hydro-agricultural development to structure the community's resilience to flooding shocks	-The hydro-agricultural development has protected the factors of resilience, despite its technical limitations in its protective action. -The links between the hydro-agricultural development and the resilience of the rural community to flood are determined by the contribution of the structural capacities of the structures.	-The rural community is endowed with the technical ability to rebound after the shocks. -The capitalization of lessons learned and the development of good practices in flood prevention in rural areas are recommended.
Solofontanaina ²⁴	Analysis of face vulnerabilities at installation risks in the fokontany Soavimasoandro - Ve arrondissement and fokontany Ambaravarankazo and Ampefiloha ankeniheny - Vie arrondissement, Antananarivo city.	To analyze the vulnerability to floods in the Fokontany Soavimasoandro, Ambaravarankazo and Ampefiloha Ankeniheny, urban Municipality of Antananarivo Renivohitra.	-The Fokontany Soavimasoandro and the Fokontany Ampefiloha Ankeniheny, Ambaravarankazo is more vulnerable in terms of geography because it is in a low plain and soil type swamp and rice field, on the other hand. -50% of the houses are built along the dike and 30% are made of planks and bags, which means that it is physically vulnerable. -75.7% of agricultural production is more economically vulnerable as harvest time has fallen into the hurricane season.	-In the medium term, raising people's awareness of short-cycle cultivation and off-season/off-season market gardening, then the implementation of short-cycle rice cultivation. -Sensitization of the target population to leave the lower zone and secure their property and in the long term, development and maintenance of waterways: cleaning, recalibration.
Razafindrakoto ²⁰	The resilience of dwellings to flooding in urban areas: the case of Andohatpenaka, a district of the city of Antananarivo	To show, using a field survey of the low area of Antananarivo that the vulnerability of households to flooding is of academic interest as far as the study of vulnerability is concerned	-A close relationship exists between vulnerability or resilience to disasters and socio-economic development. -Most of the houses in the area under study do not meet construction standards to withstand floods. -Population growth and lack of an urban plan led to the settlement of low-income families in areas exposed to flooding or other hazards. -Poor infrastructure is one of the major vulnerability factors for certain types of hazards such as cyclones, floods and earthquakes.	The development or modification of construction standards or norms following a disaster must be done in consultation with the affected population and the competent authorities.
Andrianasolo ³	Anarchic urbanization flood aggravation factor: Case of the Andohatpenaka district	To study the relationship between land ownership, urbanization and flood risk of three fokontany in Andohatpenaka district.	-The district is the scene of anarchic and precarious urbanization with an increased occupation of non-constructible areas without a concrete sanitation plan, while it is in a flood zone. -The population lives constantly in water and	To improve these living conditions, it is important to first solve the water drainage problems and to make the population responsible for the maintenance and upkeep of the existing infrastructures.

			<p>humidity during the rainy season.</p> <p>-Every year, families have not yet recovered from the last rainy season until the next one arrives.</p>	
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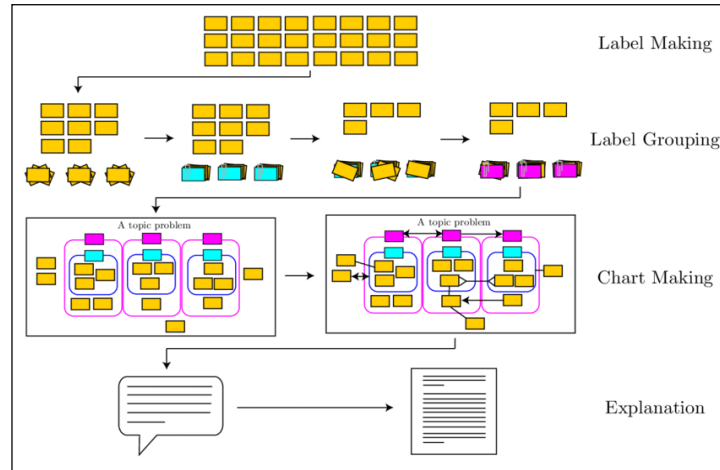


Figure 2: A sample of the whole KJ Method process²³

Concerning the urbanization of the city of Antananarivo, several planning documents were developed but were never well respected. This has led to a loss of control over the management of construction, resulting in the proliferation of precarious illegal housing in various flood-prone areas exposing its inhabitants to the great risk of flooding.² The anarchic and rapid urbanization of the site only amplifies the risk factors of flooding resulting in the modification of the hydraulic operation due to the embankments. This urban anarchism also fails to consider the risks in the implantation because the economic pressure on the soil is quite irresistible which increases the risk of damage. However, the vulnerability of these areas to flooding is not only a matter of land use but also has social and organizational aspects.

Indeed, most of the populations living in these localities are extremely fragile and vulnerable societies and the damage caused by the flood is heavy financially.⁴ In the absence of material and financial means, the poor live in flood-prone areas without respect for the town plan or building standards and build houses that offer no security in the event of a disaster. On the other hand, concerning the situation of the infrastructures, the unprotected canals, the damaged protection infrastructures and the irresponsibility of the inhabitants, all these elements feed the fragility and weakness of the population's capacity to adapt in the Antananarivo Urban Municipality.¹⁷ Most of the important infrastructures are weakened by the lack of periodic or post-disaster maintenance and rehabilitation.

Regarding the perception of risk, it is determined by the responses to be adopted in prevention and behavior during the impact of the disaster. The flood is perceived in a very diverse way by the population of the capital. There are differences in the perception of flood risk between areas in

the study area. Residents in "at-risk areas" take the floods each year as usual and refuse to leave their homes to move to safer places despite the risks and bad weather for fear of their property being stolen. They do not have the financial means to move elsewhere. Poor people do not always have a choice about where they live. They end up living in flood-prone areas because those are often the most undesired areas, having low cost of living.

Moreover, people have cultural ties to where they live, so they refuse to move. They are even more vulnerable because they live in areas at risk. Thus, the capacity to adapt declines with the economic situation. It refers to climate variability as a cause. This vulnerability explains the low perception of flooding that goes with the inferiority of adaptive capacity. Residents of these flood-prone areas cannot help but suffer the loss caused by flooding. In addition, the lack of political will on the part of the public power slows down development at all levels as the degradation of civility stifles the progress of progress. Most of the town's municipality has poor flood risk management.

For some people, anchoring them to customs and ancestral philosophies prevents them from advancing the belief that disasters are the "destinies of God". While the inhabitants in the 'low-risk areas' have another glimpse of the flood. Their perception of flood risk is low, as it represents a type of periodic event. The case displays a few dots in the frequency range.

In other words, the low frequency of flooding in certain areas of the city results in a low perception of the dangers of this hazard by residents. Moreover, the perception of authorities in low-risk areas is lower than the population.

Flooding is a disaster that does not often affect the communal space. As a result, it does not present itself as the primary concern addressed by the authorities. Urbanization-induced migration is also the cause of this flooding¹⁹. Overall, the literature reveals that the city of Antananarivo is vulnerable to the risk of flooding caused by heavy rain which is exacerbated by issues of urbanization and the low perceptions of the population.

KJ-Method

The KJ-method is a popular problem-solving creativity technique in Japan that was used to analyze the main cause of floods in Antananarivo city during the passage of tropical storm ANA and to propose an effective solution. Tropical storm ANA worsened a series of floods 4 days before impact and caused a new rise in water levels, landslides and the collapse of houses in Antananarivo city. On the night of January 17 to 18, 2022, torrential rain fell on Antananarivo, causing a sharp rise in water levels in the river Ikopa (Figure 3). The graph demonstrated that the water level increased during the rainy season from November to April.

It was found that the water level reached a peak (over 37.5m) from January to March (cyclone season) and from December 2018 to June 2022. The water level was about 37.69m during the passage of tropical storm ANA which caused a severe flood in the city. Tens of thousands of houses were damaged, some collapsed under the weight of the litter of water that fell in few days. Victims found themselves trapped. Bridges have collapsed over flooded rivers, carrying away cars and their occupants. The floods also washed away livestock and drowned fields, destroying the livelihood of some residents.

130,000 people were forced to leave their homes. Managing the risk of flooding in Antananarivo city is complicated due to several issues. Those issues are grouped into three main factors (Figure 4): natural, physical and human.

Social vulnerability: The heavy rain has made several households homeless overnight. According to the BNGRC, 35,262 displaced people were spread over 63 accommodation sites. Figure 5 illustrates the photo of people affected by tropical storm ANA who stayed at different shelters. The photos proved that women, children, the elderly and people with disabilities were the most vulnerable. Local authorities decided to transform public places into emergency shelters such as schools, city halls, gymnasiums, churches etc. However, some households preferred not to go for fear of catching COVID-19 in a crowded space and leaving their home vulnerable to burglars and the elements. On the contrary, some households with low income preferred to go to the shelter because this is the only way they can receive help from the Government. It is important to note that the households who have lost their homes and property, do not have insurance. This situation makes recovery difficult for them.

It was found that the lack of an early warning system and late transmission of information were due to the overlap of responsibility of the local authorities (Fokontany, Municipality, District). People blamed the local authorities and Government on the media (Television and radio) for not taking care of them. It is known that floods occur every year in Antananarivo city but all residents have unequal resources (power, education, income and mobility) to take lessons from their past flood experience.

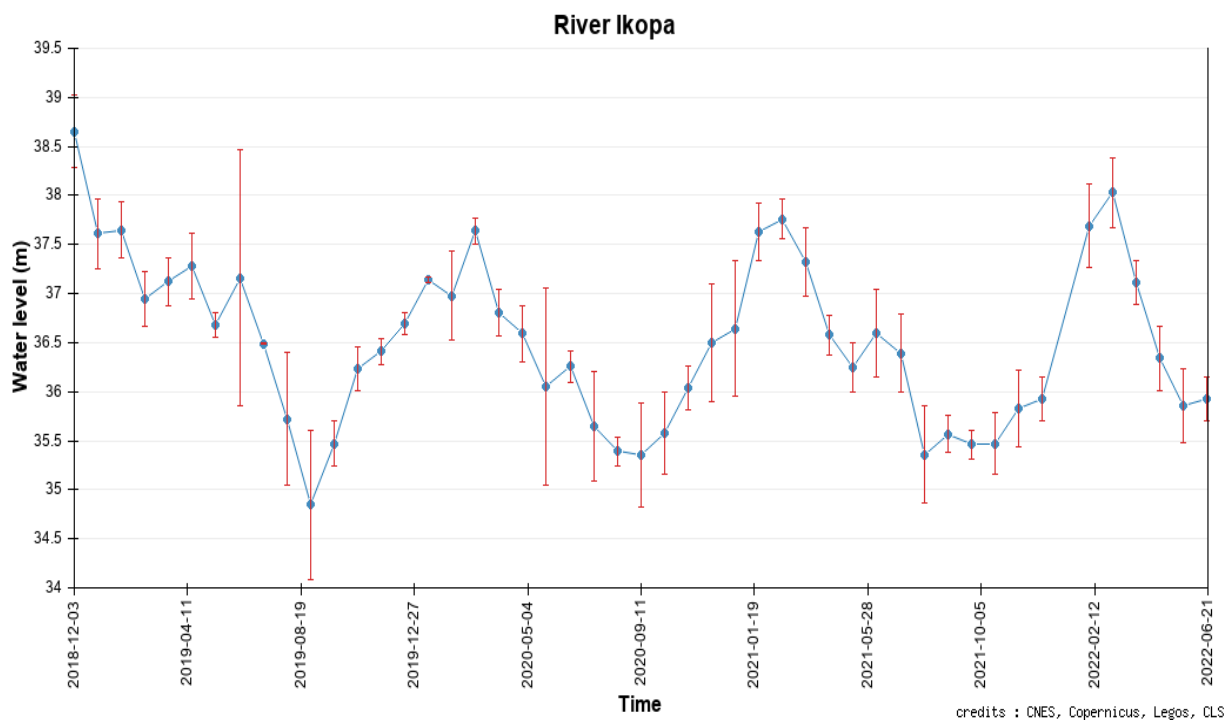


Figure 3: Water level of River Ikopa from December 2018 to June 2022

Source: Timeseries specified by LEGOS and computed by CLS on behalf of CNES and Copernicus Global Land

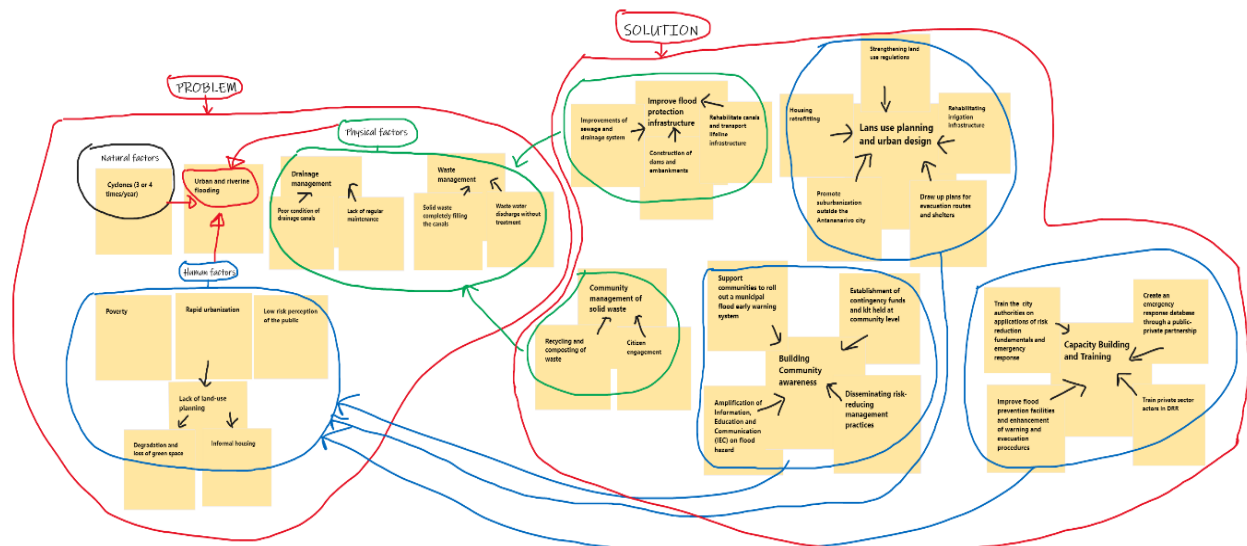


Figure 4: KJ analysis for flood disaster in Antananarivo city, Madagascar (Source: Authors)

Economic vulnerability: It was found that low-income households and households with children with disabilities were not prioritized for assistance and were rarely identified by the humanitarian responses. Previous studies highlight that Government and citizen capacity rank low due to extreme poverty which is also exacerbated by the impact of COVID-19. Citizens are ill-equipped and cannot participate actively in responding to unexpected shocks or disasters due to the high levels of poverty (poor outcomes, education and health). As shown in figure 6, rescue boats are not enough that is why makeshift boats and the army force intervened.

Rescue crews are still battling to access regions where roads and bridges have been swept away after the storm cut off tens of thousands and left without power. Traveling on makeshift boats, small groups row through water and a common floating plant called tsifakona is normally given to pigs as food. Some refused to spend the 300 Malagasy ariary (\$0.08) for transport and are forced to carry their children where the water level remains high.

Physical vulnerability: Due to the lack of means, the poor population often builds their homes with the local materials that they find at their disposal. The constructions do not comply with the climatic conditions and the known natural risks. The population growth and the lack of an urban plan led to the settlement of low-income families in areas exposed to floods or other hazards. Moreover, informal housing due to corruption leads people to build their houses in a swamp or a field (Figure 7). Indeed, weak infrastructure is one of the major vulnerability factors for certain types of hazards such as cyclones, floods and earthquakes. For lack of means, the poor population often builds its dwellings with the local materials that it finds at its disposal.

As shown in figure 8, heavy rain caused a landslide and physical damage to the buildings (collapse of the structure, dilapidation of the walls, partial detachment of the roof) leading to loss of life. The main problem is the inadequacy

of equipment (firefighters used small shovels) and the lack of specialists (people just look and do not help the rescuers). Therefore, people should be given training so they can help and not always play the victims. Most of the vulnerable houses in Antananarivo city are those with old, unmaintained roofs that let water through. The same applies to houses with earth walls, unstabilized earth bricks, or even houses built with materials that are not resistant to humidity. The resilience of buildings is linked to the solidity of the walls and the sealing of the roof. It has also been observed that the majority of the houses in Antananarivo city are either made of cement or clay (the least expensive and requires minimum maintenance).

The literature review indicates that flood risks often occur in the city, but public perception of the risk remains low. The issues of urbanization and the perception of risk were reported as a big challenge in managing the flood risk in Antananarivo city. Urban and riverine flooding is mainly caused by the passage of cyclones and heavy rainfall. This finding further supports the argument that 32% of the population lived in flood-prone zones in 2018 and one out of every four buildings was in flood-prone zones.¹⁶

The demand for housing exceeds the supply that the city can offer⁹. The city's resilience is constrained by the low-risk perception of the population and the weakness of the public infrastructure and services. These results match those mentioned in the KJ method. Taken together, this study suggests the following strategies to solve those problems:

- Improving flood protection infrastructure: strengthening the water retention capacity, improving sewage and drainage system, rehabilitating canals, embankments and roads.
- Community management of solid waste: recycling and composting of waste, citizen engagement for effective solid waste management and improved sanitation.



Figure 5: Photo of people affected by the tropical storm ANA and staying at shelters in Akorondrano and Mahamasina (Source: © UNICEF/UN0582228/Ramasomanana)



Figure 6: Photo of rescue types during the flood in Antananarivo city (Source: BNGRC, 2022 and © 2022 AFP)



Figure 7: Photo of rising waters after Cyclone ANA in January 2022 (Source: BNGRC, 2022)



Figure 8: Photo of the parking lot and the house in the capital before and after the landslide (Source: BNGRC, 2022)

- Urban planning and design considering disasters: promoting suburbanization outside Antananarivo city, drawing up plans for evacuation routes, shelters and first response centers.
- Strengthening land use regulations: reinforcement of the law and policy, housing retrofitting.
- Land use planning: preserving rice fields in flood-prone areas by rehabilitating irrigation infrastructure for agricultural land.
- Capacity building and training: supporting local communities and authorities to roll out a municipal flood early warning system, establishing contingency funds and kits held at the community level and creating an emergency response database through a public-private partnership.
- Improvement of flood prevention facilities (availability of information, climate database), enhancement of warning and evacuation procedures.

Conclusion

Among the natural risks likely to affect the Malagasy territory, flooding represents more than half of the cost of damage attributable to natural disasters. Being the capital of Madagascar, the city of Antananarivo is particularly vulnerable to the risk of flooding. The various social, political and economic problems that affect the population make them especially vulnerable to the risk of flooding. In other words, poverty, damaged protection infrastructures and the irresponsibility of inhabitants and authorities are major indicators of the population's vulnerability to the risks of natural hazards, which highlight the existence of a close relationship between vulnerability and socio-economic development. In addition, the evolution of people's perceptions and behaviors about risk is still not very tangible. Spatial planning, therefore, contributes to the resilience of the city by recommending the management of space that takes into account potential risks, but the city as a whole is not resilient.

To manage the risk of floods, the most important step is to minimize the impacts of the hazard by increasing the resilience capacity of the community. Establishing a real culture of risk in areas exposed to flooding is an absolute necessity. Nothing will be possible or effective if the populations do not perceive the reality of the risk to which they are subjected. That is why many efforts will have to be made to raise the awareness of the inhabitants of flood-prone areas. Local authorities will be the main spearheads. They will have to innovate and invent new ways to communicate about the flood risk. The population by adopting behaviors compatible with the prevention and risk reduction measures put in place by the authorities, contributes to reducing the vulnerability of urbanized flood zones and allows greater efficiency. The need for an efficient working method on the part of government officials is strongly recommended while coordinating their activities with the population. Strategies to reduce vulnerability and build community resilience must therefore be everyone's priority in Madagascar, to minimize

the impact of disasters on the Malagasy population and the country's economy. To enhance the resilience of Antananarivo city, we suggest the prioritization of flood disasters by allocating funds, decentralizing the activities at the hamlet level, organizing focus group discussions between the authorities and the communities and providing training to the vulnerable community.

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