

Comparing the Effectiveness of Different Financial Mechanisms in Women's Disaster Resilience in The Coastal City of Mahajanga, Madagascar

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Abstract

Mahajanga, located in northwest Madagascar, is a coastal city where cyclones, erratic rainfall, drought, and floods are intensifying. Consequently, the population is facing risks and becoming more vulnerable. A large number of studies have claimed the unequal effect of the changing climate, with women being more vulnerable compared to men due to their crucial role within the household. Financial mechanism has been identified earlier as a pivotal means to socioeconomically build adaptation, which therefore inevitably leads to the effectiveness of these tools in responding to the real needs of the women users. The lack of data at the local level on climate change is hindering any effective plan for building resilience in the socioeconomic context. This research explores how different financial mechanisms support women to socioeconomically cope with disasters. To do so, we proceed to socioeconomic risk and vulnerability analysis of 810 women across 27 neighborhoods before comparing financial mechanism effectivity using a set of criteria.

This work was part of a [multi-country research initiative](#) led by the Global Disaster Preparedness Center of the American Red Cross.

1. Introduction

1.1 The climate change status around the world

Climate change unequally affects communities around the world depending on their geographic location and their socioeconomic status. With rising sea levels, global warming, and shifts in seasons, low-income countries often face difficulties regarding building effective adaptation strategies. The World Meteorological Organization stated that Africa experienced its warmest decade on record, with sea temperatures, droughts, and floods all rising in 2024 (World Meteorological Organization, 2025). The African continent is continuously facing an escalating risk of extreme weather; several countries face more intense and frequent floods, abnormally long periods of drought, storms, and heat waves throughout the year.

Extreme weather and natural disasters make the African continent the most vulnerable to climate change at the global scale, although it contributed to only 4% of the world's greenhouse gas emissions in 2021 (Figure 1). Not only did climate change cause detrimental health conditions such as malnutrition, trauma, and vector-borne diseases, but also it affected the livelihood of a million people who primarily rely on natural resource exploitation such as agriculture and small-scale fishing. Studies have shown a relationship between urbanization and climate change (Zeleňáková et al., 2015), where a lack of green infrastructure and the use of building materials such as concrete trap heat at the surface. In addition, researchers explained how the demands of energy and pollutants use further exacerbate the situation and contribute to phenomena such as the heat island effect (Taha, 1997; Oke, 2011; Oleson, 2012). Zeleňáková et al. (2015) research demonstrates the difference in temperature between urban and rural areas, where the first shows a higher score compared to the second.

The IPCC estimates that urban areas are responsible for 70% of the global CO₂ emissions (IPCC, 2018). First, the current migration pattern along with the rapid technological evolution has induced an even faster urbanization, which causes an increasing temperature occasioned by the urban heat island effect. Second, in several developing countries, including Madagascar, the lack of land and economical settings has pushed poor communities to settle in slums and flood-prone areas ((Ramiaramanana & Teller, 2021).

Consequently, disaster risks are disproportionately impacting different socioeconomic categories of people, with women being more vulnerable than men.

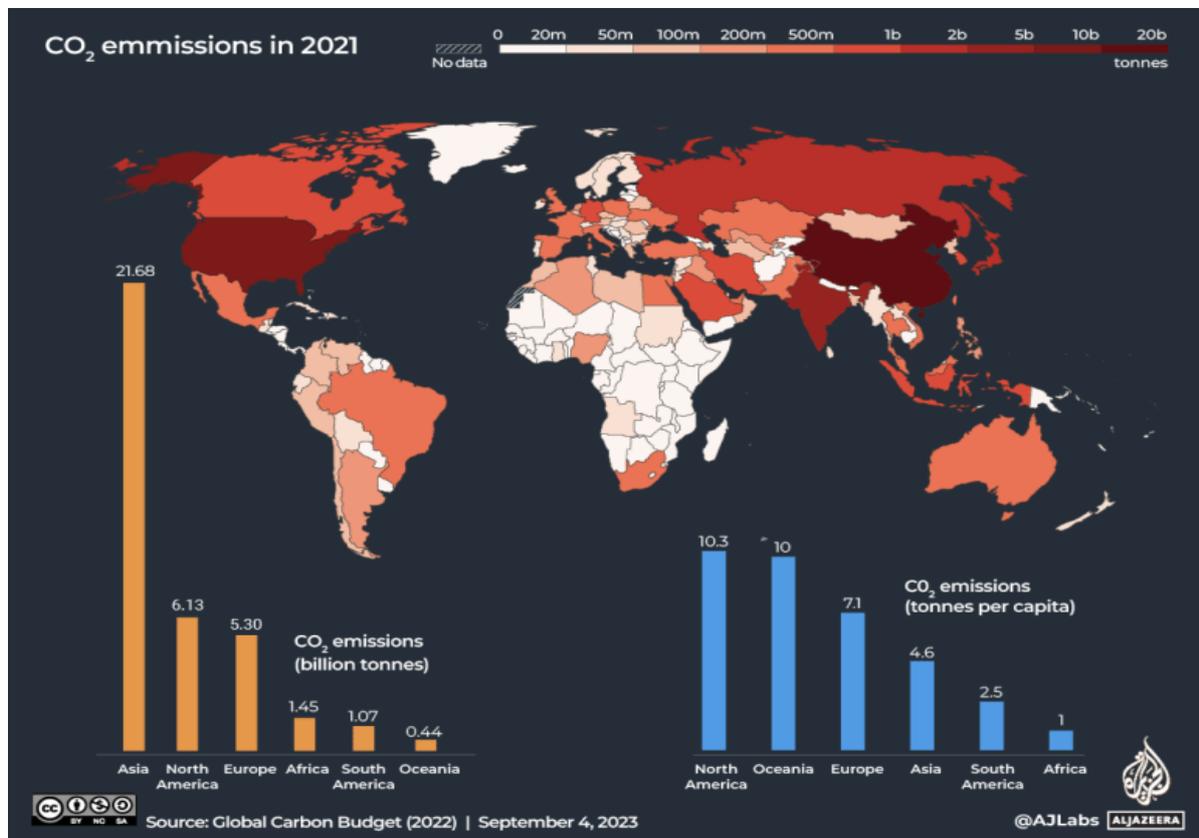


Figure 1: Africa contribution to climate change (Source: AlJazeera and Global Carbon Budget (2022))

1.2 The unequal effect of climate change on men and women

The gender dimension study of climate change has shown an unequal effect of its hazard on men and women, with the latter being mostly affected. Afridi et al. (2021) highlighted that women increased labor by 11% more than men in response to the climate hazard, which increased their exposure and vulnerability (ADB, 2022). In addition, several factors, including socioeconomic status, cultural aspects, and geographic area, further increase this gap, with women living in the low-elevation coastal zone and slums being the most vulnerable (Akinsemolu & Olukoya, 2020). The report of UN Women stated that if no actions are urgently undertaken, nearly 340 million women and girls will still live on the extreme poverty line by 2030 (United Nations Women, 2023) and may push 158 million additional ones into poverty by 2050 (Sonja & Mehrdad, 2024). Rahman's study in Bangladesh (2013) showed a significant difference in the vulnerability level between men and women given the local climatic conditions. Because of their role and responsibility in fetching water and

fuel and procuring food, often in very precarious and harsh conditions, women in poverty are more vulnerable than others.

1.3 Case of Madagascar on climate change

According to ACAPS (2024), Madagascar scores 5.7/10 in hazard vulnerability and a low coping capacity of 7.1/10, which indicates limited resources to withstand severe events, particularly given the increase in cyclone frequency since 1994. For instance, Mahajanga suffers substantial economic losses from cyclones, with residential damages constituting 75% of total losses in addition to a lack of appropriate infrastructure to cope with the disaster (Global Facility for Disaster Reduction and Recovery, 2016).

Malagasy people are on the front line of the climate crisis. While nearly the whole of Madagascar suffers from temperature increases above normal, some places like Mahajanga and Maevetanana exceptionally face extreme heat further exacerbated by the urban heat island. Several studies show an annual increase of temperature across the southern African regions since 1900 (Hulme et al., 2001; Tadross & Johnston, 2012). The water crisis and shortage are affecting nearly all the 23 regions of Madagascar, with drinking water only available for 21% of households (INSTAT, 2019).

The lack of climate baseline data in Madagascar hindered effective research on climate change. In some areas where information is available, their translation and incompleteness also do not allow proper working on them (Weiskopf et al., 2021). In addition, outdated information makes it difficult to develop effective strategies and adapted policies.

The IPCC, in its sixth assessment, stated that in rural Africa, poor and female-headed households face greater livelihood risks from climate hazards. In urban areas, growing informal settlements without basic services increase the vulnerability of large populations to climate hazards, especially women, children, and the elderly. Therefore, in both rural and urban areas women are mostly vulnerable to climate change regardless of their location, but this is especially the case in the developing countries, where the poverty level is higher compared to the other countries.

With the intensifying cyclones, the unpredictability and severity of drought leading to crop failure and food insecurity, and the erratic rainfall disrupting agricultural cycles, there is a burning need to collect extensive data in all the sectors, but especially among vulnerable communities. Without any accurate data, it is nearly impossible to make effective forecasts, early warnings, or even a simple seasonal prediction. In that way, policymakers and local governments are “blindly” managing their locality, with information gaps severely affecting planning, which hardly includes proactive disaster management or livelihood adaptation strategies. This crucial baseline affects the

whole population, but it especially hits women and girls hardest due to their pre-existing social and economic roles.

1.4 The scope of this research

Women in urban areas face vulnerability from the convergence of climate hazards, especially in the coastal part, such as Mahajanga, where fragile urban infrastructure, poor urban planning, and pre-existing gender inequalities are omnipresent. Women are therefore on the frontlines of what are called “compound risks.” In that way, there is an increasing population living in slums with numerous informal settlements and overcrowding. Those low-lying areas near clear-cut mangroves are also hazard-prone and polluted areas that further expand risks and vulnerabilities, not only in terms of the socioeconomic domain but also in terms of health and well-being.

Ensuring access to useful and affordable financial products and services becomes a critical mechanism to build resilience. Financial inclusion is a coping strategy that could shift poor households' strategy from daily struggling to enabling them to manage financial shocks more effectively. In this research context, financial inclusion not only means having a bank account; it also encompasses savings accounts, access to credits, insurances, and secure digital payment systems. The financial inclusion is not only access to the financial mechanisms after the shocks but also before and during the shocks.

While the protectiveness of financial inclusion is increasingly recognized in climate adaptation literature, there are still knowledge gaps in context-specific applications. The existing research has highlighted the disproportionate vulnerability faced by women to climate shocks and the role of financial mechanisms as critical coping strategies. Furthermore, studies about the crucial role of financial inclusion in alleviating climate shocks in Uganda (Maweje, 2019) and India (Bhatia & Singh, 2019) have begun to demonstrate the gender benefits of mechanisms like microcredit and insurance.

However, the literature is notably sparse when it comes to comparing the relative effectiveness of the currently available options—formal versus informal savings, microcredit, and insurance—specifically for enhancing disaster-related resilience among women in coastal urban areas in a developing country like Madagascar. In this research, we choose Mahajanga, a coastal city of Madagascar, as a case study regarding the dynamics of vulnerability characterized by the extent of the informal economy and the increasing settlement in slums and hazard-prone areas. These are major socio-economic factors that condition the need for and dependence on financial mechanisms and financial solutions that are effective for a given women's group but may not be optimally suited for other women.

This research seeks to fill this gap by conducting a focused comparative analysis in the urban city of Mahajanga, Madagascar. By empirically investigating the risks and vulnerability and the optimal financial mechanism according to fixed criteria for building resilience in a context-specific setting, this study will move beyond theoretical assumptions. The findings from this study will provide a foundational baseline and support for policymakers and different NGOs working in Mahajanga to develop targeted programs for climate resilience. Additionally, the local financial institutions can also use these findings to develop adapted products for women's needs regarding their socioeconomic status. As such, access and affordability can be improved. In terms of research, the adopted methodology could serve as a model for other studies in urban areas across Madagascar, where climate change causes a consequent vulnerability.

The goal of this research is to identify the most effective finance system that enables women in Mahajanga to optimally choose among various financial mechanisms, helping in building resilience to climate shocks. The study objectives are:

1. Conduct a socioeconomic risk and vulnerability analysis with gender-disaggregated data to understand specific vulnerabilities of women and provide baseline data at the local level for future use.
2. Assess and analyze financial mechanisms as resilience strategies employed by women in Mahajanga to prepare for and cope with climate-related hazards, considering both traditional and innovative strategies.
3. Evaluate and compare the financial inclusion dimension of each coping mechanism using the framework from ADB (2022) based on four dimensions—access, affordability, quality, and impact on women's livelihoods (Mohammed & Uraguchi, 2017)—through a standardized scale.

2. Methodology

2.1 Research Design and Conceptual Framework

This study uses mixed methods to comprehensively a) assess the risk and vulnerability, and b) compare the effectiveness of different financial mechanism in building disaster resilience among women in Mahajanga. The design is structured in two phases:

1. Quantitative phase, from a cross-sectional household survey to collect broad, quantifiable data on vulnerability, disaster experiences, and financial behaviors.
2. Qualitative phase, applying a direct observation and participatory assessments to provide depth, context, and explanation for the quantitative findings.

We chose this approach because of the complex nature of vulnerability and resilience cannot be fully captured by numbers alone. While the quantitative data identifies

measure use of financial mechanisms and reveals statistical patterns, we use the qualitative data to explain why certain mechanisms are more effective or accessible and how the very specific urban context in Mahajanga city shapes these outcomes.

The IPCC defines “vulnerability” as the tendency of people, ecosystems and species, economic, social and cultural assets, and services to be affected by climate hazards. Vulnerability is a product of the sensitivity, exposure, and adaptive capacity level (Mwangi et al., 2017; Pramova et al., 2013). The vulnerability assessment helps identify scenarios and their impact, leading to assessing risks' likelihood. The definition from Adger (1999), reproduced by Ahsan & Warner (2014), explains “vulnerability” as the exposure of a group or individual to stress due to social and environmental change that disrupts livelihoods. This concept motivates the study of “socioeconomic vulnerability” occasioned by climate change. The strong relationship between exposure and sensitivity helps in identifying potential impact and adaptive capacity, which then allows climate vulnerability assessment (Figure 2).

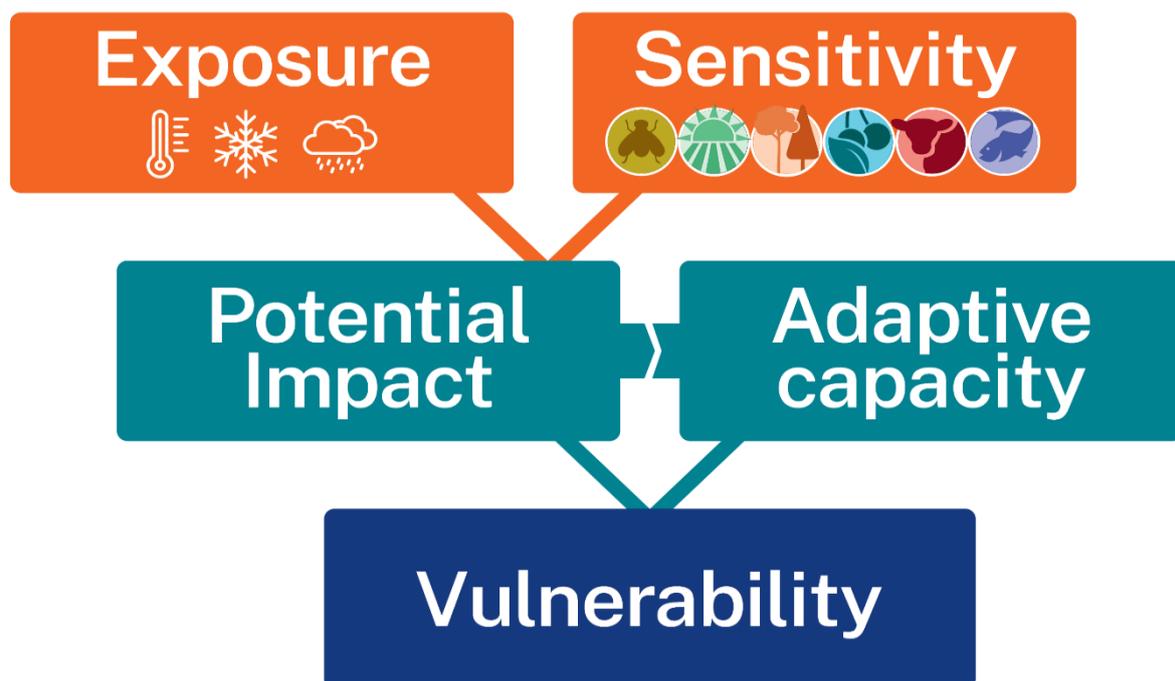


Figure 2: Relationship between exposure, adaptive capacity, and vulnerability. (Source: www.dpi.nsw.gov.au; 2023)

There is a growing body of research exploring the socioeconomic impact of climate change on indigenous communities and their well-being (Bowles, 2015; Norton-Smith, 2016; Piya et al., 2019). Climate change affects communities differently, and therefore, vulnerability level might also differ depending on age, gender, ability, and

socioeconomic status (Lynn et al., 2011). Over the years, scientists are increasingly interested in investigating the importance of vulnerability and adaptive capacity to support policy making (Juhola & Kruse, 2015; Smit & Pilifosova, 2003).

There are several vulnerability assessment indexes aiming at exploring different aspects of the climate change impact, including social vulnerability (Y.-J. Lee, 2014) and the livelihood effect index (LEI) (Urothody & Larsen, 2010). Building on the Pressure and Release Model (Blaikie et al., 1994), Ahsan and Warner's Socioeconomic Vulnerability Index (2014) developed a site-specific model that incorporates domains and dimensions following IPCC's concept and allows flexibility and adaptability depending on local context.

2.2 Study Area and Population

The case study in this research will be conducted in the urban city of Mahajanga. The city is located in the coastal northwest of Madagascar within the Boeny region and has 26 neighborhoods. The western coast is facing the Mozambique Channel, where the sea is particularly hotter and prone to cyclone genesis. Mahajanga and other localities along western Madagascar are transitions of dry forest from the central land to mangrove forest towards the littoral. Mangroves play key roles in the daily life of the community, from supporting fish offspring development to providing virtuous honey for healing. Beyond these direct and tangible functions, the mangrove ecosystem also protects cities from storms, waves, and cyclones, minimizing losses and damages. Unfortunately, numerous mangrove areas have been clear-cut due to rapid and poor urbanization planning. While richer people could benefit from technologies in filling in such areas for settling, poorer communities just build informal settlements, creating slums in a disaster-prone area, and increasing risks during the cyclonic season.

Similar to many localities in Madagascar, women slightly outnumber men in general with a younger population. The population of Mahajanga is a mix of migrants from other regions and from the neighboring islands, such as the Comoros, for the most part. The informal sector, represented by street selling, represents a large part of the poor community, while the middle to upper class is in the tertiary sector.

The city of Mahajanga comprises 26 neighborhoods, namely Ambalavola, Ambohimandamina, Ambondrona, Amborovy, Ambovoalanana, Antanimalandy, Antanimasaja, Aranta, Fiofio, Mahabibokely, Mahajanga-ville, Mahatsinjo, Mahavoky Atsimo, Mahavoky Avaratra, Manga, Mangarivotra, Manajrisoa, Marovato Abattoir, Morafeno, Tanambao Ambalavato, Tanambao Sotema, Tsaramandroso Ambany, Tsaramandroso Ambony, Tsararano Ambony, Tsararano Ambany, Tsararano Nosikely. The outskirts near the city is Belobaka. We conducted our research in all of the green areas (Figure 3).



Figure 3: Map of the city of Mahajanga and its outskirts

2.3 Sampling strategy and participant recruitment

This research used a multi-stage random sampling approach to ensure a representative and unbiased selection of participants from the neighborhoods of Mahajanga. The strategy was elaborated to capture a wide spectrum of experiences related to disaster vulnerability and financial coping mechanisms among economically active women in the city and its outskirts.

The fieldwork was conducted between March and May 2025. This period coincides with the tail end of the cyclonic season in Madagascar. Data collection during this time allowed capturing real-time and/or recent recollections of climate shocks and the immediate financial coping mechanics used by the participants. By adopting this approach, we ensure the validity of data related to disaster response.

We chose all of the 26 neighborhoods (also called fokontany) within the urban area of Mahajanga and one of its populous outskirts, Belobaka, to conduct the survey to ensure an exhaustive assessment of the city. The individual sampling unit consists of an economically active woman (aged 18 and above), whether engaged in informal or formal income-generating activities (e.g., street sellers, artisans, domestic workers, small business owners...).

The study followed five stages before conducting the survey:

- First stage: inclusion of all neighborhoods. All 27 neighborhoods were included in the study to account for the varying levels of exposure to coastal hazards (e.g., flooding, storm surges) and different socio-economic conditions across the city.
- Second stage: random selection within neighborhoods. Within each of the 27 neighborhoods, a predetermined sample of 30 economically active women was selected using a random sampling method. The target sample size was 810 women (27 neighborhoods × 30 women/neighborhood). This sample size ensures representativity of the broader population of economically active women in Mahajanga and gives significant statistical power for robust quantitative analysis.
- Third stage: all along the survey, but especially during the sampling frame, we collaborated with the chief of the fokontany using available household lists and their knowledge to identify the ideal neighborhood sector for the survey. Next, using a random sampling technique, we identified potential households.
- Fourth stage: We proceed to the screening of households for eligibility; precisely, we identify the presence of an economically active woman. If a household had more than one eligible woman, the provider or the head of the house is selected for the study.
- Fifth stage: Once a household is selected, research assistants are trained to familiarize themselves with and pre-test the survey to make sure data collection accuracy. Before each survey, research assistants were taught to explain the study's purpose, confidentiality protocols, and the voluntary nature of participation. Each woman provided their informed consent before administering the survey and conducting the observational component. Two midterm assessments will occur between survey periods to track progress and resolve any challenges that may happen.

2.4 Data Collection Methods

Data collection for this study included both quantitative and qualitative techniques through three techniques: a semi-structured household survey, direct observation, and participatory assessments. This combination of techniques ensured a

comprehensive understanding of both measurable facts and the underlying contextual realities faced by women in Mahajanga.

Household survey: A semi-structured questionnaire was used for the survey as a primary quantitative instrument for data collection. Research assistants conducted face-to-face surveys using the Malagasy language. The questionnaire captures data across four key domains: a) socioeconomic and demographic profile (age, household size, literacy level, and income); b) disaster exposure, climate knowledge, and impacts; c) financial mechanism assessment (uses, access, availability, variety, formal/informal); d) financial needs and perspective as a coping strategy.

Direct observation: The observational study helped in reinforcing data collection on risk and vulnerability analysis, including the status of the house and access to basic services (health, water), and to ground-truth the survey responses.

Participatory Risk and Vulnerability Assessment (RVA): To complement the survey and get accurate information, participatory tools were used. Chiefs of Fokontany of the neighborhoods collaborated during this phase, describing the hazard that mainly hit their locality, the pressing challenge, and the hazard-prone areas for each neighborhood. This provided a spatial understanding of risk. In addition, we organized a focus group discussion with Fokontany representatives to validate the relevant indicators used in the Risk and Vulnerability Assessment and to provide weight for each of the validated indicators using a Likert scale of 1 (least important) to 5 (most important); the process followed the one used by Ahsan & Warner (2014).

2.5 Data Analysis

2.5.1 Mapping

We used the Digital Earth Africa services to map settlement evolution with the available time data from 2015 and 2019. The World Settlement Footprint spatial data has been used and treated under QGIS 3.40. The World Settlement Footprint WSF 2015 and 2019 are each a 10m resolution binary mask outlining the extent of human settlements globally for the year 2015 and 2019 which use Landsat-8 and Sentinel-1 imagery (of which ~217K and ~107K scenes have been processed, respectively) (Marconcini et al., 2021).

2.5.2 Risk and Vulnerability Analysis:

where:

x_i = original value of indicator for the household;

x_{max} = the highest value of indicator for the household;

x_{min} = the lowest value of indicator for the household.

To conduct risk and vulnerability analysis, this research uses a methodological framework developed by Ahsan & Warner (2014) to obtain a socioeconomic vulnerability index (SEVI). This index encompasses three dimensions—adaptive capacity, sensitivity, and exposure—divided into five domains: demographic, social, economic, physical, and exposure to natural hazards, and 20 standardized indicators validated by researchers (table 1), which are adaptable to any study case. The difference of scale measurement related to indicators is standardized as an index value by using the following formula (equation 1):

$$\text{Indicator index score}_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (1)$$

The indicator value ranges between zero and one, which is adjusted to avoid values exceeding one or zero. Next, indicators are multiplied by pre-defined relative weight as per the equation 2:

$$\text{Weighted indicator score (WIS)}_k = \text{Indicator index score}_k \times \text{Average weight}_k \quad (2)$$

The next step is to determine Domain vulnerability, noted DO, score by computing the average weighted scores of all indicators within the same domain as indicated in the equation 3:

$$DO_i = \frac{\sum_{k=1}^n (WIS)_k}{\sum_{k=1}^n (\text{Average weight})_k} \quad (3)$$

Here, DO_i indicates vulnerability index for a given neighborhood i ,

Each indicator will be weighted using Likert scales and will be averaged to provide a domain-specific vulnerability score. The three dimensions will be scored by averaging the relevant domain scores. The final index will combine the three dimensions to provide a score for each individual. Further, calculating the index upwards to the above-mentioned three dimensions, noted DM, the equations (equations 4– 6) indicated by the SEVI methodology (Ahsan & Warner, 2014) are the following:

$$DM_{\text{adaptive capacity}_i} = \frac{\sum_{j=1}^2 DO_j}{2} \quad (4)$$

$$DM_{\text{sensitivity}_i} = \frac{\sum_{l=1}^2 DO_l}{2} \quad (5)$$

$$DM_{\text{exposure}_i} = \sum_{m=1} DO_m \quad (6)$$

Where j, l, m indicates number of domains under each of the three dimensions and i denotes the neighborhood. To obtain the Socioeconomic Vulnerability Index (SEVI) of a given neighborhood i , we use the equation 7:

$$SEVI_i = \frac{DM_{adaptive\ capacity}_i + DM_{sensitivity}_i + DM_{exposure}_i}{3} \quad (7)$$

2.5.3 Financial mechanism and financial inclusion assessment:

This component of the analysis aims to categorize the financial mechanisms used by women and quantitatively assess their perceived level of financial inclusion across key criteria. The objective is to generate comparable metrics that can be linked to the RVA scores. Financial mechanisms are classified as informal, formal, innovative/digital, and family/relatives borrowing, and respondents are also classified according to the usage of these financial mechanisms.

Informal: informal saving and credit groups, informal pawnbroking;

Formal: microfinance institutions, insurances, and banks;

Innovative/Digital: use of digital platforms, mainly mobile money services for savings, transfers, or credit.

Family and relatives' borrowing is separated from the informal financial mechanism because it operates on a distinct logic of a non-market reciprocity and social relationships, rather than contractual financial agreements compared to the above options. This separation is critical to isolate the role of formal and semi-formal markets from that of personal social safety nets, allowing for a clearer analysis of the financial ecosystem versus the social support system.

To measure the financial inclusion criteria, we assess the following key indicators, developed by (Asian Development Bank, 2022):

Accessibility: the ease of reaching and utilizing the service;

Affordability: the cost associated with the use of any given service (fees, interest rates);

Usability: the degree to which the product's design, terms, and support meet user needs, leading to sustained and effective usage.;

Impact: the capacity of the financial mechanism in improving livelihoods of users.

Respondents were asked to rate their perspective for each of the above-mentioned dimensions based on their preferred financial mechanism using a Likert scale (Bhatia & Singh, 2019). The average scores for each dimension will be measured to see how each financial mechanism performs across access, affordability, usability, and livelihood improvement and how effective they are in building resilience.

2.6 Ethical Considerations

Three key points were considered to ensure our research follows ethics:

1. Informed consent: we needed to make sure all participants understand the purpose and procedures of the study. Participants were asked to give their consent prior to the survey.
2. Privacy and confidentiality: personal data collected are anonymized to protect all participants. Data is stored with limited access to research team members only.
3. Cultural dimension: with Mahajanga being a city where migrants come from different places, participant's cultures and beliefs

Table 1: Dimension, domain, and variables adopted for the Risk and Vulnerability Analysis

IPCC dimension	Domain	Variable/indicator
Adaptive capacity	Demographic	People per km ²
		Male-female ratio in sample
		Population growth rate
	Social	Percentage of migrated households in last 5 years in sample
		Percentage of illiterate households in sample
		Percentage of households not having brick-built house
Sensitivity	Economic	Percentage of households participated in the last local election
		Percentage of households depending on natural resource for their income (to the primary sector)
		Percentage of unemployed households
	Physical	Percentage of households below poverty line (\$3/pers./day)
		Percentage of households suffered the damage or lost their capital goods due to disasters
		Percentage of households not getting electricity
Exposure	Exposure to natural hazards	Percentage of households not having sanitary latrine
		Percentage of households using pond, river and well water for drinking and
		Percentage of households not willing to go to cyclone shelter
		Percentage of households not having shelter or with neighbors
		Percentage of households not understanding the warning systems implemented by BNGRC
		Provision of local early warning system
Number of cyclones in last five years		
Number of floods in last five years		

Source: adapted from Ahsan et al., 2014

3. Results

3.1 Sociodemographic evolution of the urban city of Mahajanga and its outskirts

The figure below shows settlement evolution using data from the World Settlement Footprint WSF 2015 version 2 (wsf2019 v2 and wsf2015 v2). The city is concentrated around the southwest side and along the seaside, especially in Amborovy (number 18 in Figure 4), whereas the outskirts have less settlement. However, between 2015 and 2019, the city of Mahajanga extended eastwards according to Figure 4. Low-lying areas are located near the mangrove zone, specifically in the southern part of Antanimalandy (16), Tanambao-Sotema (15), Mahatsinjo (12), and Antanimasaja (13). Besides, the mangrove zone crosses the city through the Metzinger valley, such as Fiofio (8), Tsararano Nosikely (9), Tsararano Ambony (10), Tsararano Ambany (11), and the western part of Ambondrona (17).

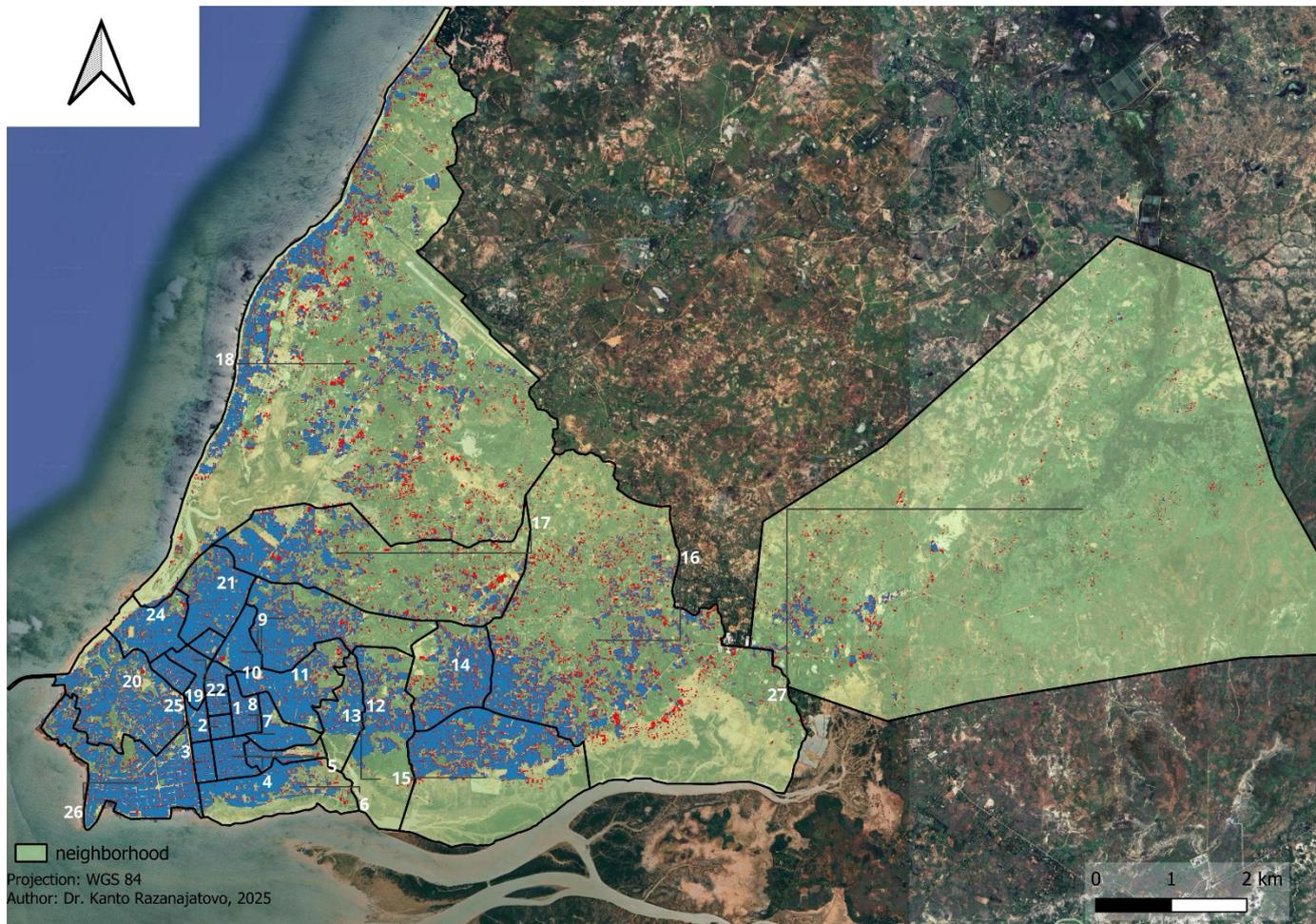


Figure 4: Evolution of Mahajanga city and its outskirts between 2015 and 2019

In blue, 2015 evolution of the city, In red, 2019 evolution. 1.Mahabibokely, 2.Morafeno, 3. Ambovoalanana, 4. Marovato Abattoir, 5.Manjarisoa, 6.Aranta, 7.Ambalavola, 8.Fiofio, 9.Tsararano Nosikely, 10.Tsararano Ambony, 11.Tsararano Ambany, 12. Mahatsinjo, 13.Antanimasaja, 14.Ambohimandamina, 15.Tanambao-Sotema, 16.Antanimalandy, 17.Ambondrona, 18.Amborovy, 19.Tanambao Ambalavato, 20.Mangarivotra, 21.Mahavoky Avaratra, 22.Tsaramandroso Ambany, 23.Tsaramandroso Ambony, 24.Mahavoky Atsimo, 25.Manga, 26.Mahajanga-ville,27.Belobaka

The population density aligns with the above figure indicating high concentration in Tsaramandroso Ambany (22), followed by Marovato Abattoir (4), as indicated by Figure 5. The lowest density is recorded in Belobaka (27), on the outskirts.

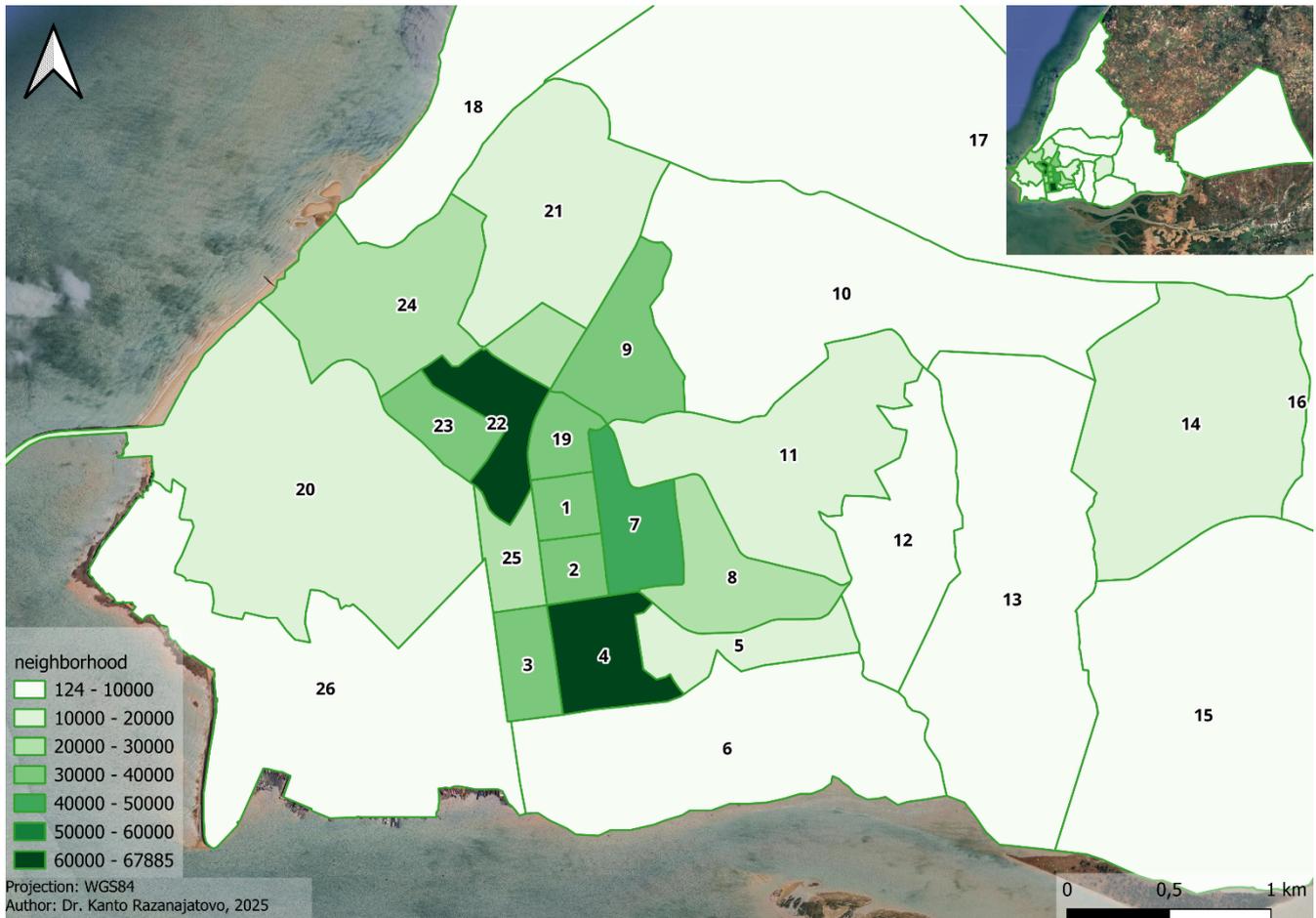


Figure 4: Population density in Mahajanga and its outskirts

3.2 Risk and vulnerability in Mahajanga

3.2.1 Demographic domain

Tsaramandroso Ambany is the most vulnerable neighborhood in Mahajanga city, with the weighted average score being 0.69, followed by Tsararano Ambony with an average score of 0.68, whereas Manjarisoa (0.18) and Belobaka (0.22) are the least vulnerable. Actually, Belobaka, which is one of the most important outskirts of Mahajanga, only has a 124.11 population density per km², while Tsaramandroso Ambany is a populous neighborhood representing 67,884.96 people/km². The male-female ratio and population growth do not vary highly between neighborhoods, 30%-50% and 14.25%-14.26%, respectively.

3.2.2 Social domain

The neighborhood of Ambondrona is the most vulnerable socially, with a weighted average score of 0.80, whereas Manjarisoa is the least vulnerable, showing a weighted average score of 0. Actually, nearly all of the respondents affirmed receiving at least the minimum basics of literacy except in Ambondrona, where 11 people were illiterate. In addition, the proportion of houses not being brick-built is higher in Tsararano Nosikely (0.72) and Aranta (0.71), whereas it is the lowest in Mahajanga-ville (0.15) and Manjarisoa (0.2). The participation in the last

election showed more voters in Antanimalandy, with the indicator index score being 1.0, whereas the lowest voters were observed in Morafeno, with an indicator index score being 0.

3.2.3 Economic domain

The neighborhoods of Marovato Abattoir and Ambalavola are the least economically vulnerable, both showing a weighted average score of 0.40, whereas Antanimasaja is the most vulnerable, with a weighted average score of 0.87. Natural resource dependence when it comes to income-generating revenue activities is higher in the neighborhoods of Aranta, Belobaka, and Antanimasaja, with indicator scores being 0.99, 0.99, and 0.95, respectively. The unemployment rate of people is higher in Mahajanga-ville (0.36) and lower in Tsararano Ambony (0.08). The proportion of households living below the poverty line does not show larger variation since it is within all of the 27 neighborhoods, ranging between 0.8 and 1. In addition, the proportion of households suffering damages from natural hazards was higher in Mahavoky Avaratra, Mahavoky Atsimo, Tsararano Ambony, Tsararano Nosikely, Mahabibokely, and Antanimalandy, which are all 0.9. The neighborhood reported the least damage frequency was in Marovato Abattoir (0.4).

3.2.4 Physical domain

In terms of physical domain, the neighborhood of Belobaka is the most vulnerable, showing a weighted average score of 0.83, whereas Mahajanga-ville is the least vulnerable, with a weighted average score of 0. First, the proportion of the population not benefiting from electricity is higher in Aranta and Tsararano Ambony, which are both 0.9. Access to electricity could be one or more of the following challenges: not benefiting from the service 24/7, not being a subscriber, being out of reach of the current electricity line, and not having even a basic solar panel. Second, the use of appropriate latrines is challenging in the neighborhoods of Antanimasaja, Belobaka, and Aranta mostly, which was observed in 0.6, 0.4, and 0.35, respectively. On the contrary, in Mahajanga-ville the proportion of people not using latrines is only 0.1. Finally, the access to safe water for everyday use is also challenging among 0.9 of the community in Belobaka and 0.8 in Aranta, whereas it is only 0.2 in Mahajanga-ville.

3.2.5 Exposure domain

All of the people in Mahajanga-ville are not willing to leave their home for shelters during natural hazards, followed by those in Tsararano Nosikely (0.75), whereas in Mahabibokely this proportion is relatively lower (0.1). However, besides the willingness to move to a shelter during a critical period, the existence of nearby shelters itself could also be an issue. In this study, shelters represent any safe place from flooding and other damage where people could settle for a given period. For instance, shelters can be a family/relative's home, designated community shelters, and others. The proportion of respondents reporting not having shelters is higher in Antanimasaja and Tsaramandroso Ambony, both having a value of 1, followed by those in Tsararano Ambony and Antanimalandy, represented by 0.98. The lowest score is observed in Mahajanga-ville. Regarding the implemented national warning system, a higher proportion of respondents in Tsararano Nosikely (1) and Tsararano Ambony (0.86) declared not understanding the indications. Neighborhoods such as Antanimasaja, Aranta, Fiofio,

Mahavoky Atsimo, Mahavoky Avaratra, Morafeno, Tanambao Ambalavato, Tsaramandroso Ambany, Tsararano Ambany, Tsararano Ambony, and Tsararano Nosikely were subject to at least six flooding episodes over the last five years.

3.3 Vulnerability by criteria and overall score

A summary of the dimension-wise vulnerability is indicated in Figure 6. Overall, the sensitivity dimension dominated among the three studied domains. Higher sensitivity was observed in Aranta (0.78), Belobaka (0.77), and Antanimasaja (0.74), whereas the lower score was observed in Mahajanga-ville (0.31).

Comparing The Effectiveness Of Different Financial Mechanisms In Women's Disaster Resilience In The Coastal City Of Mahajanga, Madagascar

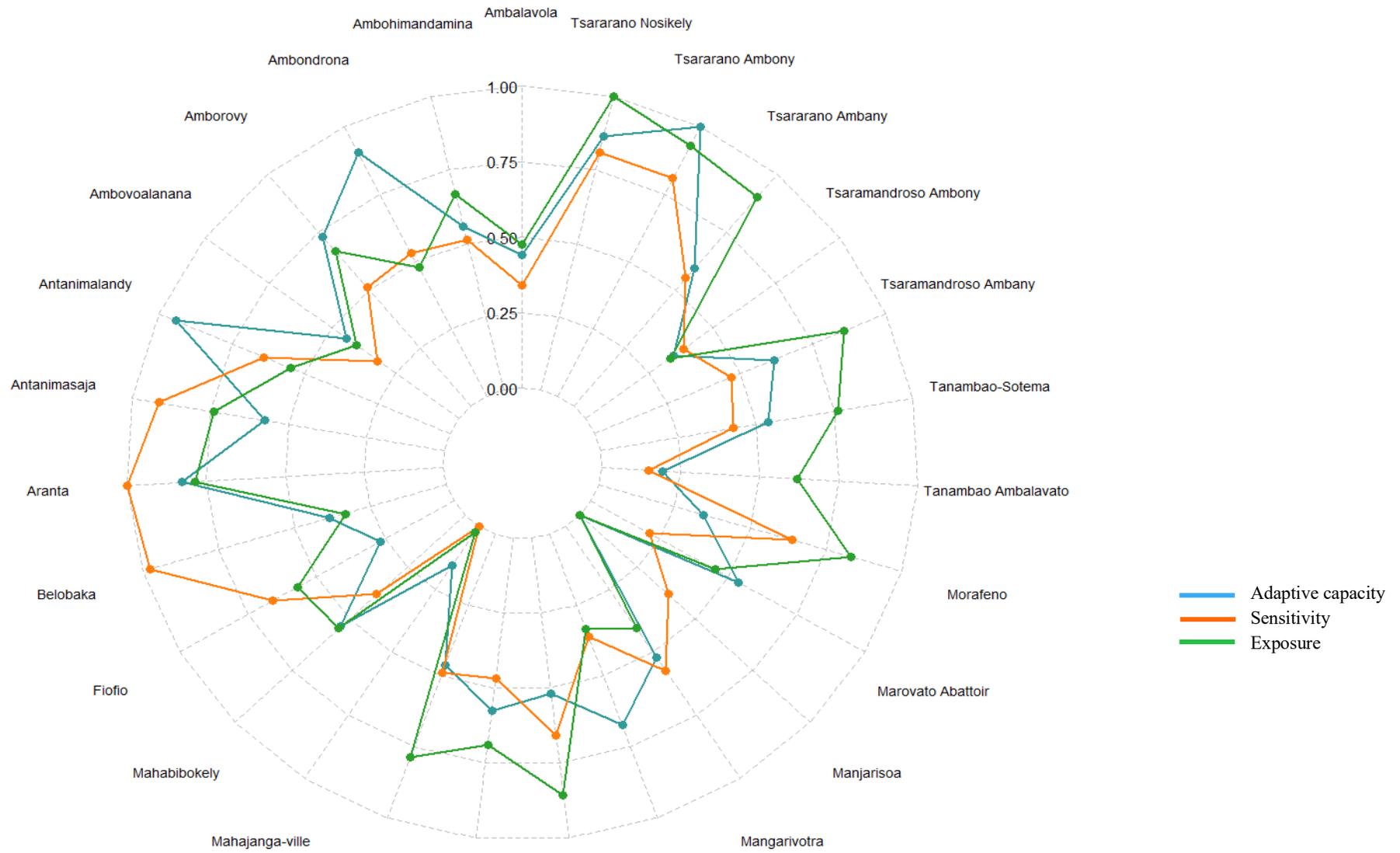


Figure 5: Adaptive capacity, sensitivity, and exposure score by neighborhood

Concerning the exposure to risks, the neighborhoods of Tsararano Nosikely (0.61), Tsararano Ambony (0.54), and Tsararano Ambony (0.53) are the most vulnerable. whereas Manjarisoa (0.09) and Mahajanga-ville (0.23) are the least vulnerable. However, the latter also showed the lowest adaptive capacity score. With Manjarisoa being 0.12 and Mahajanga-ville 0.20, whereas the highest adaptive score is recorded in Tsararano Ambony (0.64) and Antanimalandy (0.61).

All things considered, the SEVI score for all 27 neighborhoods is indicated in the figure below (Figure 7). Tsararano Nosikely and Tsararano Ambony are the most socioeconomically vulnerable neighborhoods in the urban area of Mahajanga. both indicating a SEVI score of 0.62. followed by Aranta with a score of 0.62. The least vulnerable are Manjarisoa and Mahajanga-ville, with scores of 0.23 and 0.25, respectively.

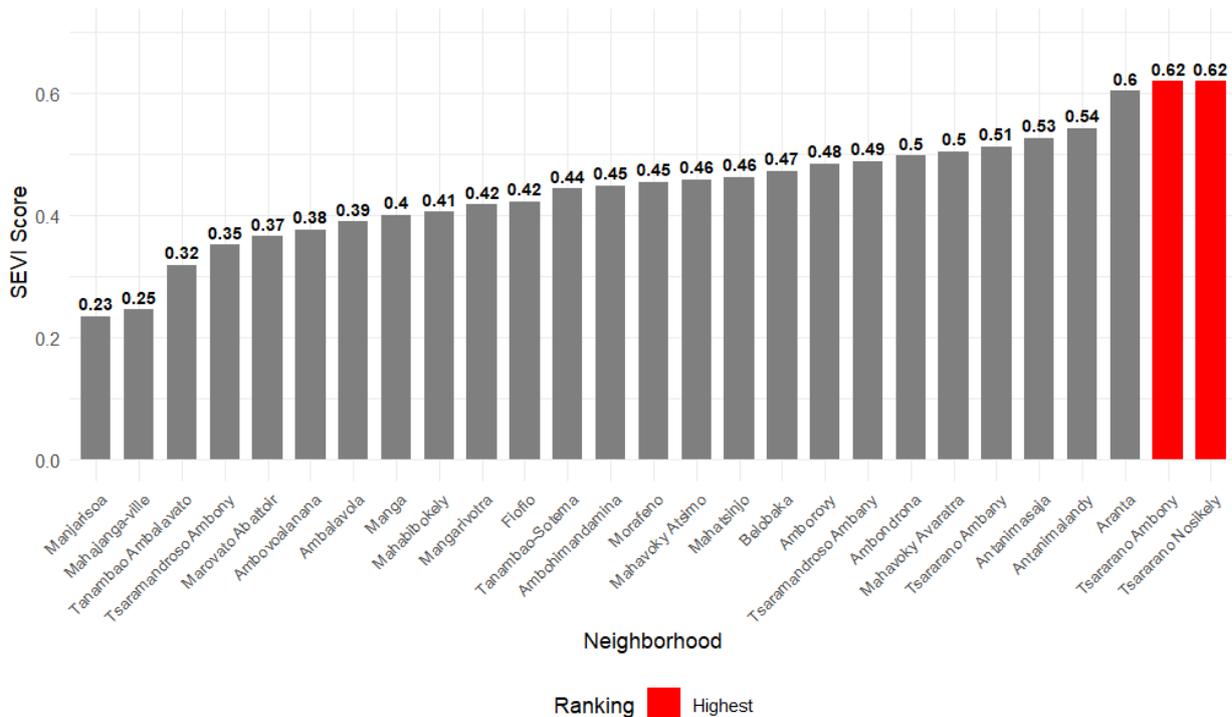


Figure 6: Overall Socioeconomic Vulnerability Index per neighborhood

3.4 Financial access and financial inclusion

3.4.1 Labor Force Composition and Occupational Distribution

As indicated in Figure 8, the predominance of self-employed women all over the 27 neighborhoods provides an insight into the occupational activities in Mahajanga. Neighborhoods such as Tsararano Ambony and Antanimasaja are counting only self-employed women, whereas those from Mahajanga-ville indicate a relatively large subset of salaried workers compared to others. In total, 742 out of 810 women are self-employed. whereas only 68 are salaried workers. From the self-employed subset

of the sample, 62% are engaged in farming activities, including rice, vegetables, and greens cultivation. The other part, 26%, is farming and selling their own products, while only 12% are engaged in selling-only activities.

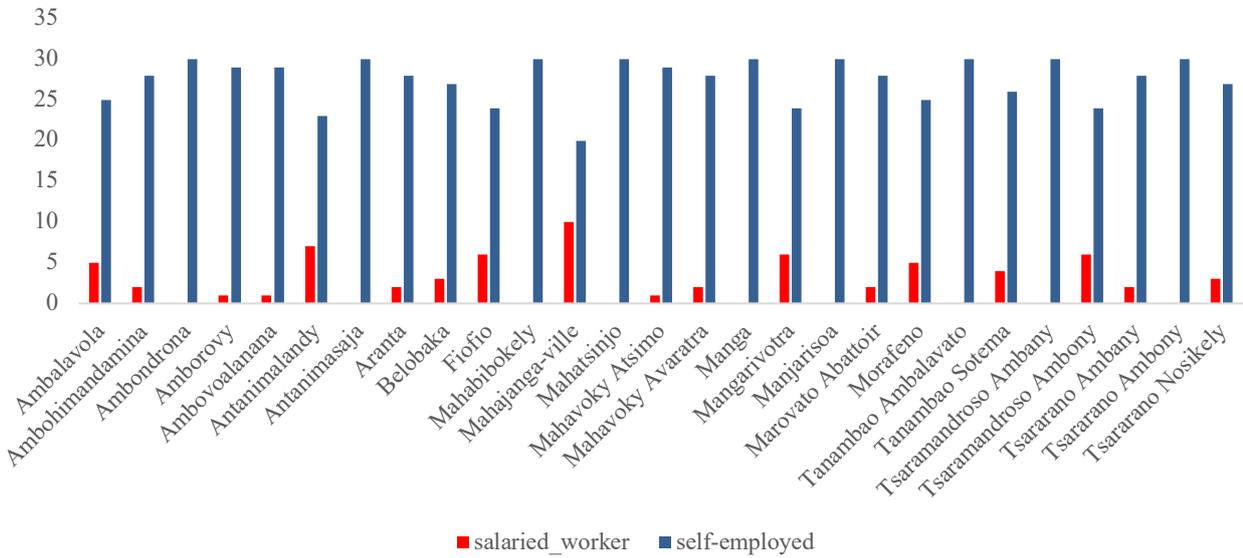


Figure 7: Job situation per neighborhood

3.4.2 Climate change literacy and financial impacts

Among the 810 survey respondents, only 12% affirmed not knowing fully or partially the term “climate change.” While the remaining were able to describe from their own knowledge what climate change is. Hence, a large proportion of the respondents identified food insecurity, yield diminution, drought, and flooding as the impact of climate change. Only a few (0.1) described species’ decline and insecurity as a consequence of the changing climate.

Financial Mechanisms n Women's Disaster Resilience in the Coastal City of Mahajanga, Madagascar

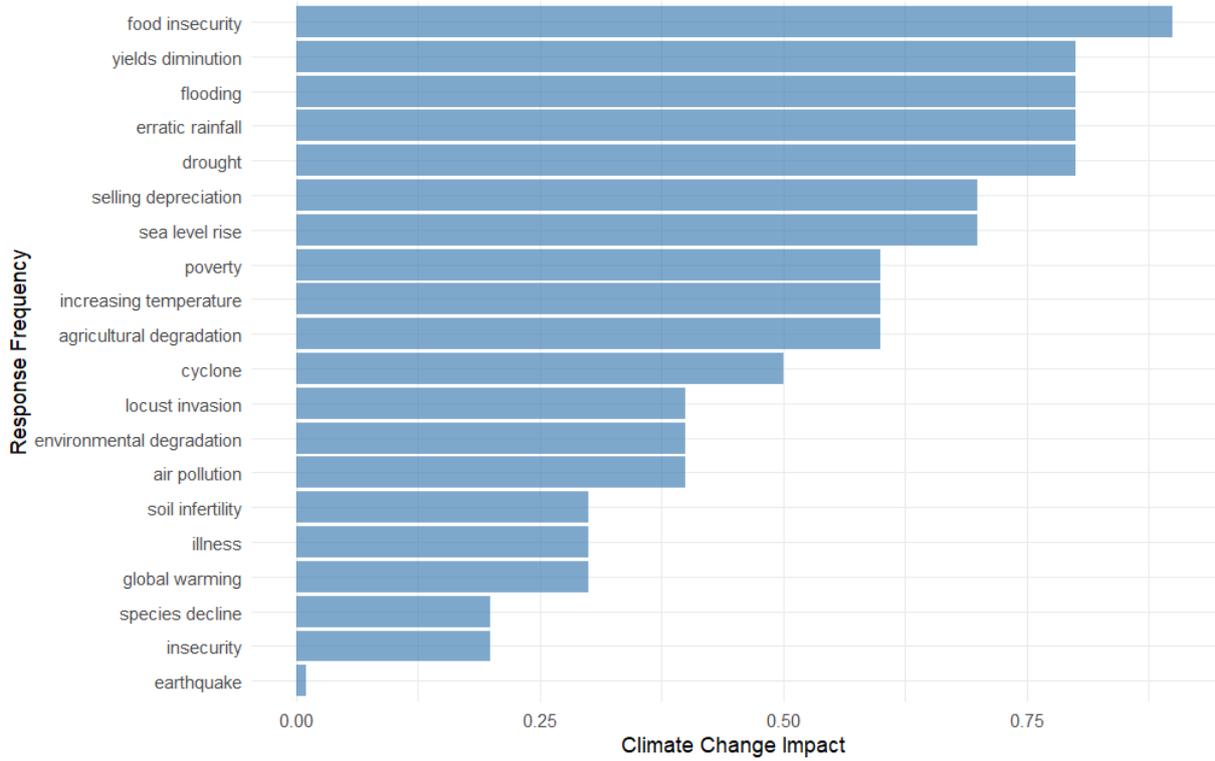


Figure 8: Climate change impact according to respondents

All of the women reported undergoing the negative impact of intense cyclone and drought each year, with 85% (n=742) of the self-employed affirming their income-generating revenue has decreased during the cyclonic season, between January and late April. After the cyclone, 65% (n=742) declared their revenue still remained lower compared to the average revenue before the cyclone. To cope with the situation. 685 women from the sample are engaged in different types of saving (40%), borrowing (25%), or the combination of the first two (35%). In other words, to cope with disaster and building resilience, 274 women rely on saving-only, 171 are borrowing money

from different sources, and 240 are both relying on their saving and/or are borrowing money.

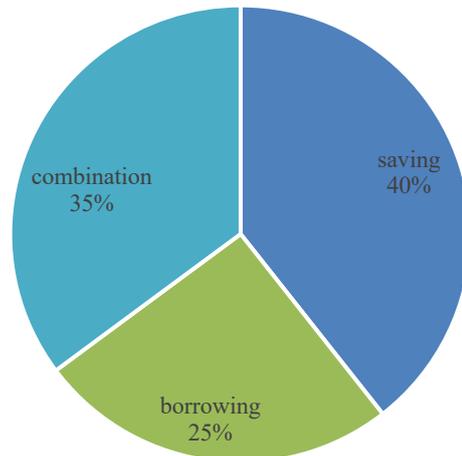


Figure 9: Proportion of financial product use

3.4.3 Types of financial product used by women

First, among the 198 of 411 women who relied on borrowing or a combination of borrowing-saving, the preferred source was family. This represents a mean of 7.33 (SD = 5.68) women per neighborhood. Second, 102 women expressed interest in formal borrowing from banks and microfinance institutions, with a mean of 3.78 (SD = 2.82) per neighborhood. Third, 77 women were interested in using mobile money services to meet their financial needs, with a mean of 2.85 (SD = 2.61) per neighborhood. Finally, only 34 women reported engagement in informal borrowing, which included the pawning of rice products and participation in community-based savings and credit groups (e.g. VOAMAMY. SICO). A Kruskal-Wallis test indicated that the distributions of these preferences were not the same across the four financial mechanisms (family. formal. mobile money. informal). $H(3) = 28.97, N = 108, *p^* < .05$.

Regarding saving schemes, among the 511 women who used savings or a combination of strategies, several were more interested in informal savings (n = 202). with a mean of 7.48 (SD = 5.79) women per neighborhood. Saving at home was the second most preferred method (n = 152). with a mean of 5.63 (SD = 4.08) women per neighborhood. Traditional savings with banks and microfinance institutions ranked third (n = 88). with a mean of 3.26 (SD = 3.27) women per neighborhood using this option. Finally, only 72 women used mobile money for savings, with a mean of 2.67 (SD = 1.82) women per neighborhood. A Kruskal-Wallis test indicated that the

number of women using these saving methods differed significantly across the four categories, $H(3) = 13.62$, $N = 108$, $p = .003$.

3.4.4 Effectivity of different financial product

Overall, respondents affirmed that digital services (e.g., mobile money) were more accessible ($M = 7.48$, $SD = 2.15$) than other mechanisms, whereas formal financial mechanisms were the least accessible ($M = 5.74$, $SD = 1.53$). In terms of affordability, informal options were perceived as more affordable ($M = 8.24$, $SD = 0.78$). While formal options were perceived as the most expensive ($M = 3.00$, $SD = 1.12$).

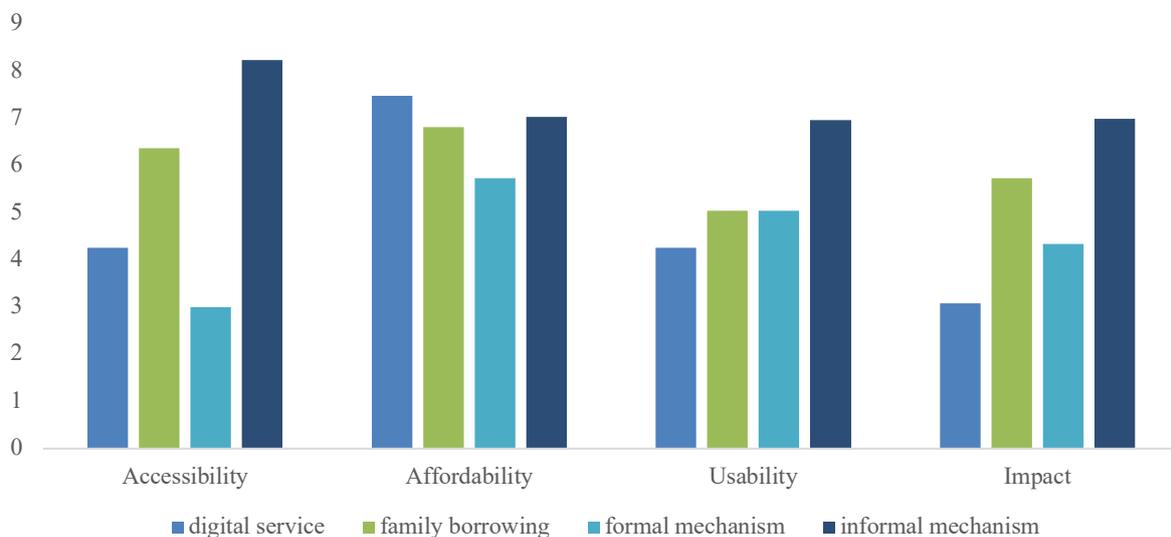


Figure 10: Financial mechanism comparison

The informal financial mechanism was rated as most likely to satisfy user needs ($M = 6.96$, $SD = 1.34$), whereas digital services via mobile money were the least preferred option ($M = 4.26$, $SD = 1.40$). Regarding the perceived impact on improving livelihoods, informal services were seen as more impactful ($M = 7.00$, $SD = 1.39$), while digital services were seen as unlikely to improve livelihoods ($M = 3.07$, $SD = 1.44$). In summary, the informal financial mechanism ($M = 7.31$, $SD = 0.61$) best meets the overall financial inclusion needs of women compared to the other options, whereas the formal/traditional financial mechanism ($M = 4.53$, $SD = 0.83$) meets these criteria the least (see Table 2).

Table 2: Overall score of each financial mechanism

Criteria	Digital service	Family borrowing	Formal mechanism	Informal mechanism
Accessibility	4.26	6.37	3.00	8.24
Affordability	7.48	6.81	5.74	7.04
Usability	4.26	5.04	5.04	6.96
Impact	3.07	5.74	4.33	7.00

Overall mean	4.77±0.84	5.99±0.98	4.53±0.83	7.31±0.61
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A Kruskal-Wallis test was conducted to compare the overall mean scores across neighborhoods for the four financial mechanisms. The results indicated a statistically significant difference in the distributions of scores. $H(3) = 64.19$, $N = 113$, $*p* < .001$.

4. Discussion

The methodology for risk and vulnerability analysis adopted in this research is based on the framework developed by Ahsan et al. Certain limitations must be acknowledged regarding its application. Particularly concerning the quality and accuracy of responses to ensure they accurately reflect reality. In other words, a margin of error must be considered, as responses may not fully capture the lived experiences of women for various reasons. Conversely, the flexibility of this risk and vulnerability analysis methodology, developed by Ahsan et al., allows for significant adaptability to the study context and encompasses essential elements in line with IPCC standards. In this regard, adopting such a methodology enabled the tailoring of survey variables to local realities rather than constraining them within rigid norms.

Since data were collected during the cyclonic and/or rainy season in Madagascar, the aforementioned risks of error are minimized, and the responses are more likely to reflect the actual experiences of women in terms of resilience. During the study, the lack of freely accessible data and statistical data in general posed a significant challenge for analyzing the local and even regional context.

Regarding risk and vulnerability analysis, certain neighborhoods are considerably more exposed to risks than others, owing to the geographical position of the city of Mahajanga. As a coastal city, some neighborhoods facing the sea are at elevation level zero and are more exposed to sea-level rise, particularly Mahavoky Avaratra, Aranta, Mahajanga-ville, and Antanimasaja. Additionally, the presence of the Metzinger valley, a canal traversing the city and its neighborhoods on both sides, contributes to this exposure. Neighborhoods along the canal, such as Fiofio, Tsararano Ambany, Tsararano Ambony, and Tsararano Nosikely, are all vulnerable to sea-level rise as well as severe flooding. The Metzinger valley is not merely a water channel; it also features mangroves along its course until it discharges into the sea in the Amborovy neighborhood.

However, this expanse of mangroves forms a natural barrier against extreme weather events (cyclones and large waves). has been gradually converted into informal settlements by affluent individuals with socio-political influence or migrants living in informal settlements. Awareness-raising regarding the crucial role of mangroves in

climate change adaptation in urban settings is virtually nonexistent. Rapid population growth and urbanization have attracted numerous migrants to the city of Mahajanga and its peripheries, leading to increased population density in neighborhoods such as Tsaramandroso Ambony. This rapid urbanization has rendered communal development plans and urban planning schemes obsolete, as updates are rarely implemented. Consequently, rising temperatures due to the heat island effect accelerate vulnerability, particularly among the very young and the elderly. This phenomenon is common among the developing world (Benna & Garba, 2016).

In the physical domain of risk and vulnerability analysis, the prevalence of precarious housing and the lack of access to potable water and electricity in daily life hinder socioeconomic resilience and financial prosperity for women, who are often engaged in informal micro-entrepreneurship (Pendall et al., 2012; Saad, 2021). With rising temperatures, high evapotranspiration and severe droughts have become common in Mahajanga and the region at large. The absence of potable water and adequate technologies to address this issue makes resilience even more challenging, both in urban and rural areas. The precariousness and lack of sanitation facilities such as latrines in certain locations further exacerbate the spread of infectious diseases (Rahelinirina et al., 2024; Razafiarimanga et al., 2022).

Financially, this study revealed that loans are primarily obtained from family and acquaintances. Several researches also have demonstrated the importance of this option (Barr, 2004; Turvey et al., 2010; Turvey & Kong, 2010; S. Lee & Persson, 2016). The second preferred option is traditional lending. However, for the latter, respondents indicated that even within this option, their choices do not lean toward banking institutions but rather toward microfinance organizations such as "MAMPITA" whose systems are more favorable to women's contexts. Indeed, according to respondents, banking institutions remain inaccessible due to high fees and interest rates and do not meet their urgent needs. The statistically significant difference across the four loan categories may be largely driven by this argument. At the same time, some respondents avoid borrowing altogether for security reasons.

Regarding savings, the surveys revealed a strong preference for informal sectors such as VOAMAMY and SICO, which operate based on social contracts without formal documentation within groups, particularly among women. This community-based saving system was deemed invaluable by financially struggling mothers (Landman & Mthombeni, 2021; Lukwa et al., 2022). Savings kept within households ranked second. Indeed, many respondents expressed a lack of trust in the traditional banking system due to complicated procedures and fees.

The financial inclusion findings explicitly confirm the difficulty for users to use formal financial mechanisms, especially in terms of affordability where fees and interests are

far more expensive compared to the overall purchasing power of the community. The result also confirms how informal and socially implemented mechanisms are more powerful in responding to user needs especially in building resilience.

5. Conclusion

This study aimed to assess the efficacy of existing financial mechanisms in building climate change resilience for women in the urban area of Mahajanga. First, it sought to address the data gap on climate impacts by providing localized statistics on risk and vulnerability for the city's 26 neighborhoods and one of its outskirts. Second, it analyzed how different financial mechanisms align with the principles of financial inclusion for building effective resilience, using a framework adapted from the Asian Development Bank.

The analysis revealed two central themes. First, neighborhoods within the city exhibit higher socioeconomic vulnerability, particularly those traversed by the Metzinger valley. Second, while most women rely on saving, borrowing, or a combination of both, a greater propensity for saving over borrowing was observed. However, saving methods vary, with informal community savings groups emerging as the most preferred option. This finding reinforces the financial inclusion of results, which shows a strong overall preference for informal financial mechanisms. On average, these informal options better fulfill the criteria of accessibility, affordability, usability, and improvement of livelihood.

These findings suggest that women depend more on socially embedded financial mechanisms than on formal ones. Interviews with neighborhood chiefs provided further insight into how successfully implementing these informal mechanisms can improve women's daily lives and build effective resilience. Although informal financial mechanisms appear to be the most suitable option for women in urban Mahajanga. They also carry a higher risk of loss. Instances of breached trust within community savings groups are not uncommon. Consequently, it is recommended that policymakers recognize the existence of these socially built systems and support them by developing contextualized regulations to ensure their security and sustainability.

While this research provides a robust overview, it is limited by its reliance on qualitative data, which inherently reflects the diverse perspectives of the participants. Future research should, therefore, focus on integrating these findings with biogeographical and climate change modeling to produce more robust and precise results.

In conclusion, the path to socioeconomic resilience through financial inclusion lies in further empowering women to co-design financial mechanisms that respond directly

to their specific needs. Several best practices from such projects exist and can serve as a valuable blueprint, despite their projects having concluded.

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Annex

Photos of Mahajanga during the rainy season, 2025. Neighborhoods of Mahavoky Atsimo, Fiofio, and Tsararano Ambany





