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HEALTH AND ECONOMIC IMPACTS OF FLOODS IN THE MUNICIPALITY OF MALANVILLE, BENIN

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ABSTRACT

Flooding in Malanville is a structural obstacle to development that weakens the health and economic foundations of the municipality. Because of its position on the Niger River, the municipality is exposed to recurrent floods. This study analyses their health and economic impacts. The approach combined a literature review, a socio-economic survey of 383 people, data processing and analysis with SPSS 17.0 and ArcGIS 10.8. Intense rainfall (98%), climate change (33%), inadequate sanitation infrastructure (19%) and uncontrolled land occupation (14%) were cited as causes of pluvial flooding. Sixteen per cent of the territory has a high drainage density, 55% a medium and 29% a low one. The rainfall aggressiveness index ranges from 1,550.91 to 7,304.33. The main health impacts reported are a resurgence of waterborne diseases (57% of respondents), proliferation of disease vectors (23%), limited access to care (12%) and degraded sanitation (8%). Malaria cases rise from 1,289 in January to a peak of 3,289 in September and fall to 1,254 in December; diarrhoea cases rise from 109 in January to a peak of 343 in September and reach 128 in December. Both increase steadily from June, in line with the Niger flood. Agriculture is the most affected economic sector (86% of respondents). The districts of Garou and Mandécali are the most regularly and directly hit by floods.

Keywords: Malanville; Health and Economic Impacts; Climate Change; Floods; Benin

1 INTRODUCTION

Floods are undoubtedly the natural hazard that causes the most victims and damage worldwide. In coming decades, climate change, urbanisation and population growth will make coastal, fluvial and pluvial floods considerably more damaging [1]. Extreme poverty exacerbates the vulnerability of populations by limiting the capacity of households to

protect themselves and recover. Local authorities, whose financial means are limited, cannot implement effective relief measures or durable protection infrastructure [2]. Beyond the loss of life, floods destroy infrastructure at a cost of tens of billions of dollars every year and aggravate health precarity and financial instability in the affected communities [3].

In Africa, floods act as a catalyst for health crises by exacerbating the structural vulnerabilities of the poorest communities [4]. Contamination of drinking-water and sanitation systems triggers outbreaks of waterborne diseases such as cholera and typhoid, while stagnant water favours vectors and multiplies cases of malaria and other insect-borne diseases. Health systems that are already fragile are overwhelmed [5]. Stagnant water also drives dengue and other arboviruses, and damaged health infrastructure cuts people off from emergency care and halts vaccination programmes [6]. Destruction of crops and food stocks undermines household food security and entrenches child malnutrition [7]. After the disaster, damp and unhealthy housing leads to skin, respiratory and eye conditions; the loss of property and forced displacement leave lasting psychological scars; and the isolation of flooded areas causes indirect mortality, notably for pregnancies and chronic diseases [8].

Between 1999 and 2010, Benin experienced five catastrophic flood episodes, the floods of 1999, 2009 and 2010 being exceptional in scale. They originate mainly in the Niger River, whose overflows, combined with those of the Ouémé, Mono and Couffo basins, devastated riverside ecosystems, while urban drainage systems proved unable to evacuate the water [9].

In the municipality of Malanville, uncontrolled urbanisation and increasingly frequent extreme weather expose populations in low-lying and marshy areas to periodic floods whose health and economic consequences are becoming unsustainable. The lack of early-warning systems and resilient sanitation infrastructure turns every flood into a health disaster, while the diversion of scarce public resources to emergency response slows development. The objective of this study is to analyse the health and economic impacts of floods in the municipality of Malanville.

2 MATERIALS AND METHODS

2.1 Study area

Malanville lies in the extreme north of Benin, in the Alibori department, between 11°52'02" and 12°00'01" N and between 3°03'00" and 3°13'03" E (Figure 1). It borders Niger at the town of Gaya, covers 3,016 km² and comprises five districts (arrondissements) with about 168,006 inhabitants in 2013 (RGPH4). It is bounded to the north by Niger, to the south by the municipalities of Kandi and Ségbana, to the west by Karimama and to the east by Nigeria. Crossed by the Niger River, it extends over vast floodplains, and this transborder position exposes the riverside districts to seasonal floods. Malanville is also a strategic commercial and agricultural crossroads, which amplifies the effect of floods on trade, food security and health.

2.2 Data

The study used hydro-climatic, demographic, agricultural and socio-anthropological data. Demographic data were used to determine the sample size and to capture the population's perception of flood disasters and their effects on public health. Rainfall and hydrological data for 1961–2022 were obtained from Météo-Bénin and used to analyse flood indicators. Respondents had to be at least 30 years old and to have lived in the municipality for the last 20 years. The sample size was determined with the formula of Schwartz [10] at a 95% confidence level and a $\pm 5\%$ margin of error. A sample of 383 households was retained and distributed proportionally to the population of each district. Questionnaires were administered with the KoboCollect application, and the data were exported to and centralised in Excel 2010. Health data (monthly malaria and diarrhoea cases) come from the Ministry of Health.

2.3 Data processing and analysis

The data were sorted, grouped and presented as tables and figures. Statistical processing was carried out with SPSS 17.0 and STATA 16.0 to compute measures of central tendency and dispersion (arithmetic means and standard deviations) and to generate the graphs. The share of responses to each question was expressed as $P = (n / N) \times 100$, where n is the number of households giving positive answers and N the sample size at municipal level. The rainfall aggressiveness index was computed with the simplified method of Sitou and M'Bouka Milandou [11], which uses only mean annual rainfall (P). For $P > 850$ mm, as in Malanville, the formula is $R = 587.8 - 1.219 P + 0.004105 P^2$, where R is the rainfall aggressiveness index and P the annual rainfall (mm). Results were interpreted with the classification of the same authors [11]: the higher the index R , the more powerful and concentrated the runoff generated. Results are presented as tables, graphs and thematic maps.

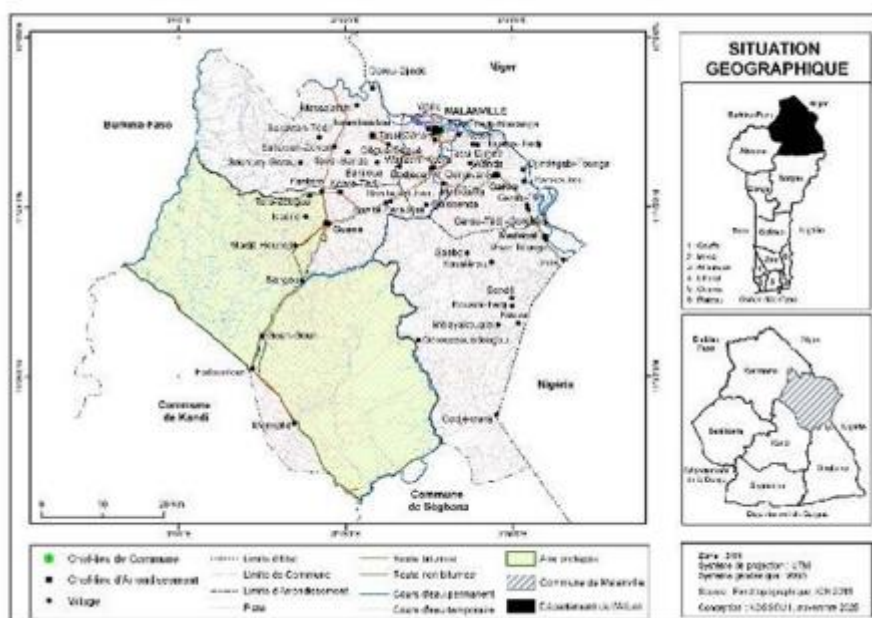


Figure 1: Geographical and administrative location of the municipality of Malanville

3 RESULTS

3.1 Typology and recurrence of floods in Malanville

Floods in Malanville are of natural origin and are either pluvial or fluvial.

3.1.1 Pluvial floods

Pluvial floods result from a complex interaction between climatic, pedological, geological and botanical factors that predispose the territory to submersion. The intensity and frequency of rainfall, exacerbated by current climate disruption, exceed the absorption capacity of ecosystems and trigger sudden flash floods, while soil properties and the underlying geology govern runoff. Figure 2 presents the causes of pluvial floods in the study area.

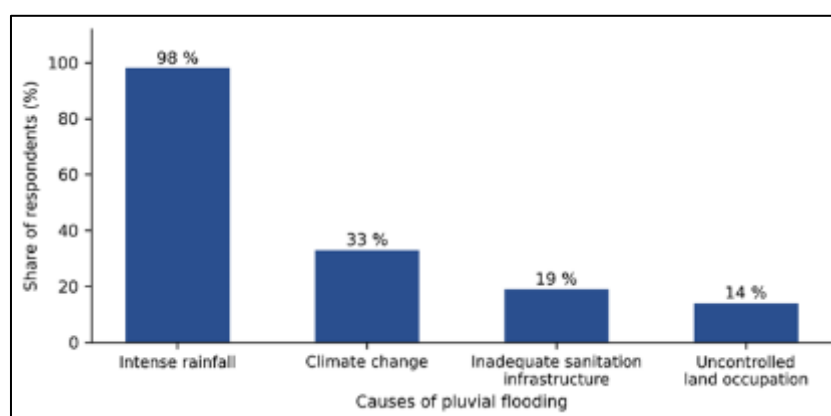


Figure 2: Causes of pluvial floods in the study area

Source: field survey, August 2025.

Figure 2 shows that intense rainfall (98%), climate change (33%), inadequate sanitation infrastructure (19%) and uncontrolled land occupation (14%) are the causes of floods. Figure 3 presents drainage density in the municipality.

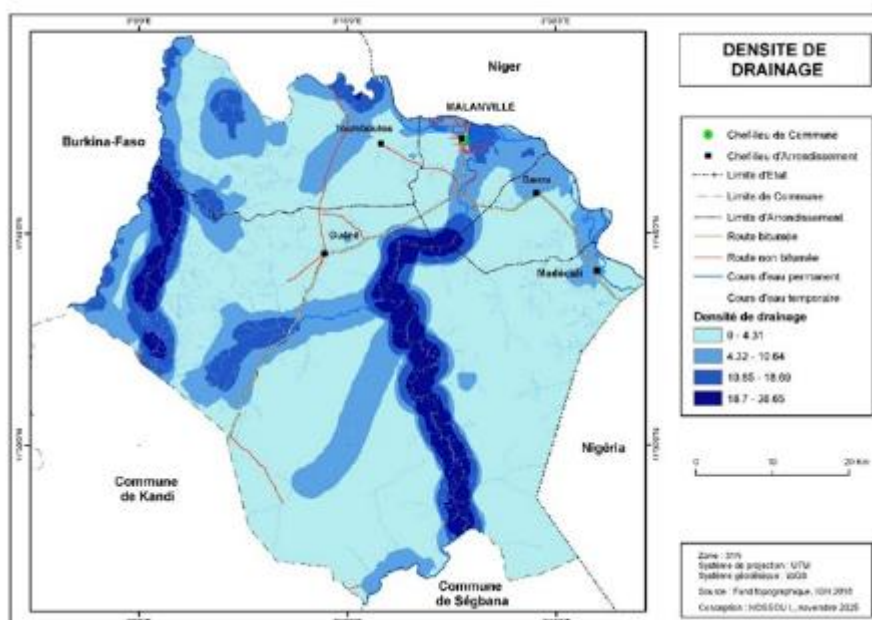


Figure 3: Drainage density in the municipality of Malanville (map labels in French)

Source: Météo-Bénin, August 2025.

Figure 3 shows that drainage density ranges from 4.31 to 36.65: 16% of the area has a high density, 55% a medium and 29% a low density. Malanville's drainage works are rudimentary and fail to protect its economic heart during hydrological peaks. Wind and torrential rain carry large quantities of sand that fill the gutters, and solid waste from commercial activity blocks drainage structures. During major floods, the Niger rises above the urban outlets, which prevents the town's water from draining and causes flooding by flow reversal. These shortcomings expose markets and farmland to Niger floods that paralyse cross-border trade and destroy stocks. Figure 4 shows the rainfall aggressiveness index.

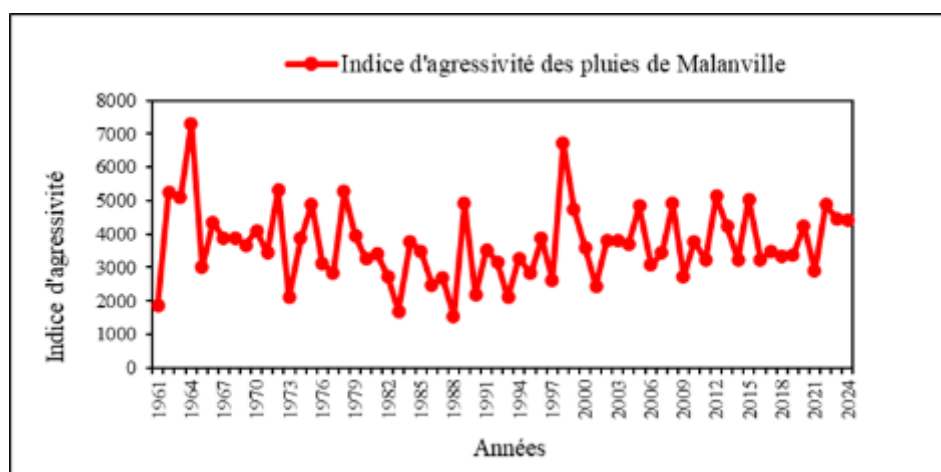


Figure 4: Evolution of the rainfall aggressiveness index in Malanville, 1961-2024 (axis labels in French)

Source: Météo-Bénin, July 2025.

Figure 4 shows that the index ranges from 1,550.91 to 7,304.33 in the municipality. It rose sharply in 2010; it is very low in 1977 and 1988 and very high in 1968, 2010 and 2012.

3.1.2 Fluvial floods

Figure 5 presents the hydrological regime of the Niger at Malanville between 1961 and 2024.

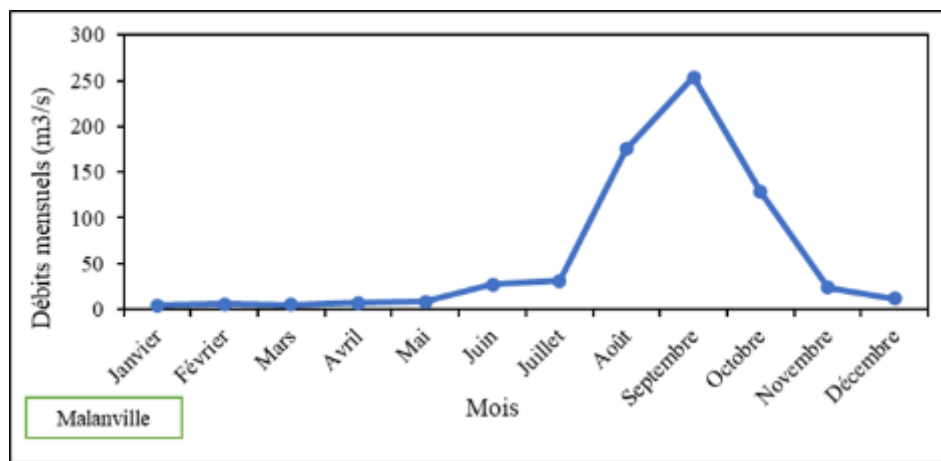


Figure 5: Hydrological regime of the study area, 1961–2024 (axis labels in French)

Source: Météo-Bénin, August 2025.

Figure 5 shows that the rise of the water begins in August and peaks in September ($253.78 \text{ m}^3/\text{s}$); the mean monthly discharge over the whole series is $56.83 \text{ m}^3/\text{s}$. September and October are the months that determine floods. Monthly discharge depends on the rainy and dry seasons: flood peaks occur from June to October, followed by lower flows in the dry season, and the highest discharges (July–October) result from heavy rainfall in the upper basin, notably in northern Benin and neighbouring countries. With regular rains in Niger and Burkina Faso, the river overflows and invades the plains even without local rainfall. The Mékrou, the Alibori and the Sota, tributaries of the Niger downstream of Niamey, also contribute to the floods that inundate the municipality.

3.2 Health impacts

3.2.1 Trends in water-related infections

In every rainy season, stagnant water and fouled basic infrastructure turn the urban landscape into a high-risk infectious focus. Proliferation of vectors and contamination of water sources upset the health balance of the municipality, and waterborne diseases cease to be occasional risks and become a constant threat. Figure 6 presents the population's perception of the health impacts of floods.

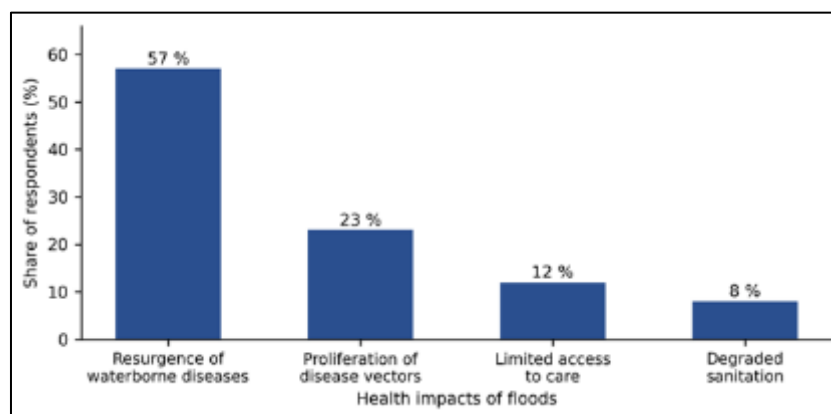


Figure 6: Population's perception of the health impacts of floods

Source: field survey, August 2025.

Figure 6 shows that the main health impacts are a resurgence of waterborne diseases (57% of respondents), proliferation of disease vectors (23%), limited access to care (12%) and degraded sanitation (8%). Overcrowding and consumption of contaminated water favour cholera, dysentery and acute diarrhoea, particularly among children. Flooded areas become ideal breeding sites for mosquitoes, with a sharp rise in malaria and, periodically, dengue. Flooded latrines and waste-disposal systems contaminate groundwater and domestic wells, and cut roads and inaccessible health centres delay the care of patients whose conditions would normally be mild. Floods thus turn environmental insalubrity into a major public-health crisis. Figure 7 shows the monthly evolution of malaria and diarrhoea cases.

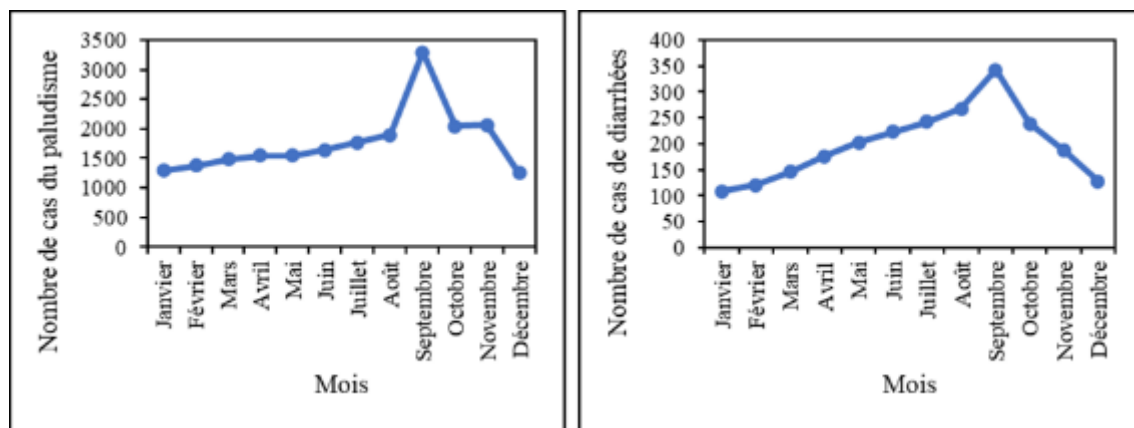


Figure 7: Mean monthly number of malaria cases (left) and diarrhoea cases (right) (axis labels in French)

Source: Ministry of Health, August 2025.

Figure 7 shows that malaria cases rise from 1,289 in January to a peak of 3,289 in September and then fall to 1,254 in December. Diarrhoea cases rise from 109 in January to a peak of 343 in September and reach 128 in December. Both increase gradually from June and peak sharply in September, exactly when the Niger floods (August–October). Flooding favours stagnant water and the multiplication of breeding sites for malaria vectors, and contamination of wells and failing sanitation drive diarrhoeal disease. Floods also promote acute respiratory infections, aggravated by persistent damp and precarious housing after the disaster.

3.2.2 Access to health services during floods

Access to care in Malanville during floods is a major challenge: floods regularly submerge infrastructure and land and hinder movement towards health centres (60% of respondents). Photo 1 shows a road degraded after flooding.



Figure 8: Partial view of a road degraded after the floods in Malanville

Photo: Kossou, October 2025.

Such roads impede mobility between places. Poor hygiene and sanitation linked to stagnant water spread disease and further overload local health services. Even outside flood periods, the health system faces insufficient vaccination coverage and late recourse to care, and users sometimes judge the reception and quality of services unsatisfactory, which discourages attendance.

3.2.3 Health and nutritional precarity in flooded areas

In Malanville, health and nutritional precarity is closely tied to the recurrent flood cycle of the Niger. Submersion of homes and farmland causes immediate loss of food stocks and income and plunges households into acute nutritional insecurity. Drinking-water sources are frequently contaminated by runoff and overflowing traditional latrines, favouring diarrhoeal diseases. The districts most vulnerable to these hydrological hazards are those of the lower valley (Table 1).

Table 1: Summary of the most vulnerable districts of Malanville

District	Vulnerability factors	Main health and nutritional risks	Vulnerability level
Garou	Direct structural exposure to Niger floods	Food insecurity from crop loss, resurgence of malaria, diarrhoeal diseases	Very high
Mandécali	Direct and frequent impact of river overflows	Disruption of drinking-water supply, child malnutrition, health isolation	Very high
Malanville (central)	High population density, low-lying areas	Rapid spread of waterborne diseases, saturated health services, overcrowding	High
Guénè	Pockets of poverty, limited resilience	Difficult access to care, increased nutritional fragility	Moderate to high

Source: field survey, October 2025.

Table 1 shows that Garou is structurally exposed, as is Mandécali, which regularly suffers the direct impact of floods; both compromise livelihoods and physical access to infrastructure. The central district of Malanville is critically vulnerable during rising waters because of its density and low-lying areas, and its infrastructure saturates quickly in crises. Guénè, although more diversified, has pockets of poverty where household resilience to the double health and nutritional threat is extremely limited.

3.3 Impacts on economic activities

Recurrent floods in the Niger valley have deep and multiple economic impacts. Agriculture is the hardest-hit sector (86% of respondents): floods submerge and destroy crops, notably rice and cotton, causing massive harvest losses, smothered seedlings and growing indebtedness of farmers (Photo 2).

**Figure 9: Partial view of a flooded rice field in Malanville**

Photo: Kossou, October 2025.

Farmers lose both production and inputs such as fertiliser, which compromises the following seasons. Prolonged floods cause the total loss of food stocks and goods, particularly for local traders and craftspeople, and reduce the income of households that depend on small income-generating activities. Damage to bridges and roads isolates entire villages, hinders the movement of goods and people, and blocks access to markets and regional trade. Faced with these risks, 74% of the farmers interviewed try adaptation strategies such as off-season farming, although it requires costly investment (motor pumps, tube wells) and remains vulnerable to climate variability. Repeated disasters often prevent the durable reconstitution of capital and assets. Table 2 summarises the vulnerability of the main economic activities.

Table 2: Vulnerability of economic activities in Malanville to floods

Economic activity	Vulnerability factors	Direct impacts	Vulnerability level
Agriculture (cereals, cotton)	Location in alluvial plains and lowlands	Total crop loss, destruction of inputs, farmer indebtedness	Very high
Trade (food, goods)	Cut roads, isolated local markets	Loss of stocks, interrupted trade, reduced income	High
Crafts	Flooded workshops, destroyed tools	Production stops, loss of productive capital	High
Livestock	Submerged pastures, loss of feed resources	Forced displacement of herds, health risks, livestock loss	Moderate to high
Fishing	Water pollution by waste and debris after floods	Health risks for products, changes in ecosystems	Moderate

Source: field survey, October 2025.

Table 2 places agriculture at the top of the scale with a very high level of vulnerability: its location in fertile alluvial plains exposes producers directly to total crop losses and to structural indebtedness that is hard to overcome. Trade and crafts are highly vulnerable, paralysed by the rupture of logistic routes, isolation of markets and destruction of productive capital in workshops. Livestock is moderately to highly vulnerable because submerged pastures force transhumance and aggravate veterinary risks. Fishing is moderately vulnerable: less exposed to immediate destruction of its working tools, it suffers medium-term constraints from changes in aquatic ecosystems and water pollution. The fragility of roads and bridges amplifies the vulnerability of trade by isolating production areas from consumption centres, and the lack of planning and uncontrolled occupation of lowlands aggravate losses in all sectors.

4 DISCUSSION

In Malanville, the rainy season turns the urban landscape into a major infectious focus because of stagnant water and degraded infrastructure. The statistics confirm a significant peak of malaria and diarrhoea in September, precisely when the Niger floods. These results corroborate those of MCVDD [12] and Abassi et al. [6], who showed that when water invades living space it becomes a devastating vector of disease. Submerged traditional latrines cause massive faecal contamination of surface water and domestic wells and trigger outbreaks of diarrhoea, dysentery, typhoid fever and cholera, while permanent stagnant water sustains malaria at endemic levels with deadly epidemic peaks. Prolonged contact with soiled water exposes children to severe skin diseases, and damp housing favours moulds and mites that worsen asthma. Forced displacement to precarious shelters induces chronic stress that further weakens people with pre-existing conditions.

Access to care is severely hindered by the submersion of roads, which isolates villages and delays emergencies; transferring a high-risk delivery or severe malaria by pirogue becomes an ordeal in which every minute lost reduces survival chances. According to Arouna et al. [13], the impact of floods goes far beyond the isolated disaster and paralyzes survival systems. When health centres are themselves submerged, the health response collapses: the cold chain is broken, vaccine stocks are lost and essential drugs are destroyed by water and damp. The sudden loss of dietary diversity also drives acute malnutrition among children under five and breastfeeding women, and the paralysis of agriculture and cross-border trade makes the national economy structurally vulnerable.

5 CONCLUSION

The cyclical repetition of Niger floods considerably aggravates the living and health conditions of the population of Malanville. Systematic pollution of drinking-water sources forces residents to use river water, causing a resurgence of waterborne, skin and respiratory diseases. Prolonged stagnant water amplifies the endemicity of malaria, and overflowing latrines and insalubrity on relocation sites become the main foci of infectious diseases. Access to care is almost systematically disrupted: degraded rural roads and the need to travel by pirogue make emergency transport perilous, and the cost of medical transport becomes prohibitive for the poorest families. Destruction of food crops causes acute malnutrition, and blocked roads stifle trade, rot products in isolated areas and raise prices on urban markets. Faced with the paralysis of local employment, most families fall into over-indebtedness or sell their assets, and many young people leave temporarily for the cities.

To address this vulnerability durably, an integrated strategy is needed that combines strengthened community alerts, modernised sanitation infrastructure and strict land-use management with targeted epidemiological surveillance, professional local risk governance and agricultural practices adapted to limit farmer indebtedness and out-migration

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Statement of informed consent

Participation in the survey was voluntary. All respondents were informed of the purpose of the study and provided their informed consent before participating in the interviews. Confidentiality was maintained, and responses were anonymised to protect participants' identities. No formal ethical approval was obtained for this study.

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