Long title : Maternal and neonatal vulnerability in a flood-prone area: a mixed-methods study in Agbétiko canton, Togo

Short title : Flood-related maternal and neonatal vulnerability, Togo

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Abstract

Flooding is increasingly recognised as a determinant of maternal and neonatal health in low-resource settings, yet the mechanisms by which it disrupts access to obstetric care remain poorly documented in West Africa. This mixed-methods study examined whether the flood season constitutes a period of heightened vulnerability for obstetric care access in the rural canton of Agbétiko, Togo. A retrospective analysis of 547 obstetric records from three peripheral health units (2020- 2024) was combined with a parallel ethnographic survey in the same localities. Exposure was defined by season (flood season, July-October, versus the rest of the year) and by an exploratory inter-annual classification of flood intensity. The main indicator of restricted access was delivery outside a health facility. Overall obstetric activity remained stable during the flood season (rate ratio 0.91, 95% confidence interval (CI) 0.76–1.09). Out-of-facility deliveries did not differ significantly by season (4.2% versus 5.4%; OR 0.78, 95% CI 0.27–2.23) or by inter-annual flood intensity. However, 17 of 18 out-of-facility deliveries occurred in the catchment area of one health unit (Agbétiko) despite both highly flood-exposed units serving comparable populations, pointing to marked village-level heterogeneity. Low birthweight was slightly, though not significantly, more frequent during the flood season (12.7% versus 10.7%; OR 1.21, 95% CI 0.69–2.14). Interviews

highlighted mobility constraints, limited household financial reserves, and gendered decision-making delays as plausible contributors to this heterogeneity. In Agbétiko, flooding was not associated with a uniform disruption of obstetric care at facility level; vulnerability instead appears concentrated at village level, shaped by proximity, mobility and household economic resources rather than by service availability alone. Interventions calibrated to village-level access barriers may be more effective than broader supply-side responses.

Keywords: flooding; climate change; maternal health; obstetric care access; mixed methods; sub-Saharan Africa; Togo

Introduction

Climate change is no longer simply an environmental backdrop; it has become one of the major determinants of global health, to the point of being described as a genuine ”threat multiplier”, capable of amplifying health vulnerabilities that existed well before the climate began to shift [1]. Flooding is one of its most concrete expressions. According to the 2024 Lancet Countdown report, 61% of the world’s land area recorded an increase in the number of days of extreme rainfall between 2014 and 2023, compared with the 1961–1990 baseline, a trend that mechanically raises the risk of flooding, infectious disease spread and water contamination [2]. In sub-Saharan Africa, where health systems remain structurally fragile, this climatic shift compounds long-standing difficulties, particularly in access to health services and, more broadly, in the functioning of health systems [3].

This holds true for Togo, and specifically for the canton of Agbétiko, which is flooded almost every year between July and October by the rising waters of the Mono River and by the accumulation of rainwater. These floods cause major disruption to daily life and to how communities interact with health facilities. While this general picture is well documented [4,5,3], far less is known about the health effects of these floods, particularly on maternal and neonatal health, in this part of Togo.

Maternal and neonatal health is among the areas of health most heavily affected by extreme environmental events, particularly flooding, as numerous studies attest. A study covering 34 countries, for example, established a link between severe drought exposure and excess infant and neonatal mortality [6], while an analysis of 36 countries and nearly 290,000 births showed that prenatal flood exposure significantly increased the risk of low birthweight, with a more pronounced effect for more severe flooding [7]. In Mozambique, several years of routine data revealed a 6% drop in facility-based deliveries during the rainy season, with a stark estimated toll of 74 additional maternal deaths and 726 additional neonatal deaths each year attributable to this seasonality alone [8]. In Tanzania, following Cyclone Hidaya, community interviews documented home births for lack of any alternative, as health centres themselves became flooded [9]. Similarly, in India, a spatial analysis of 707 districts found that postnatal care coverage fell significantly in flood-prone areas, and even further where multiple climate hazards overlapped [10]; at a larger scale, an analysis of 640 Indian districts linked flood exposure to a 7% rise in abandonment of the recommended minimum antenatal care schedule [11]. Pregnant women in Indonesia have described postponing antenatal visits or wading through flooded areas on foot, in a state of constant anxiety [12]. Work conducted in Pakistan similarly reports disruption to the access and use of maternal health services in flood contexts [13,14,15]. Beyond physical access to health centres, other, more indirect but equally decisive, mechanisms must be considered. The deterioration of women's nutritional status linked to food insecurity [16,17], together with gender-based violence often associated with flooding [18,19,20], can affect maternal and neonatal health, including by contributing to antenatal depression [21]. These various challenges can accumulate into a cascading vulnerability, at the intersection of physical access to facilities, availability of care, nutritional conditions and mental health.

Set against this background in Agbétiko, Togo, this observation raises the question of whether the flood season constitutes a period of particular vulnerability for access to obstetric care in the rural communities of Agbétiko. In other words, to what extent does the flood season represent a period of heightened

vulnerability for access to obstetric care in rural Agbétiko, and what environmental, social, economic and organisational mechanisms explain its existence?

These questions, which lie at the heart of this article, help to fill, in part, the gap in scientific work that goes beyond the well-established link between flooding and health, or, more specifically, child health, to try to pin down the precise configuration of these links. They lead to the hypothesis that the flood season may constitute a period of heightened vulnerability for access to obstetric care in Agbétiko, driven by the combined effect of environmental, socio-economic and organisational constraints.

To test this hypothesis, the study combines a quantitative analysis of obstetric registers from three peripheral health units with a qualitative field survey, in order to capture both the statistical scale of the phenomenon and the concrete mechanisms, often invisible in routine data alone, through which it plays out in the lived experience of the populations concerned.

Methods

The study used a convergent mixed-methods design, combining a retrospective analysis of routine obstetric data from three Peripheral Health Units (PHUs) in the canton of Agbétiko (Agbétiko, Agomé-Séva and Batonou) with an ethnographic survey conducted in parallel in the same localities. The two strands were analysed separately and then integrated at the interpretation stage, in order to relate the variations observed in routine data to the social, economic, environmental and organisational mechanisms documented in the field.

The quantitative analysis covered 547 obstetric records registered between January 2020 and December 2024. Duplicate entries, records that did not correspond to an obstetric event, and records for which the date or nature of the event could not be established, were excluded. Extracted data included the PHU, delivery date, maternal and obstetric characteristics, mode of admission, place of delivery, birthweight, and selected maternal and neonatal indicators. Missing data did not lead to exclusion of a record; each analysis was carried out on the observations available for the variable concerned.

Exposure was defined along two dimensions: period, distinguishing the flood season (July–October) from the rest of the year, and territorial exposure level, with Agbétiko and Agomé-Séva classified as highly exposed and Batonou as less exposed. A complementary exploratory analysis distinguished 2020–2021, locally characterised as years of more severe flooding, 2022–2023, characterised as more moderate, and 2024, a year with no reported flood episode. This inter-annual classification is a contextual measure of exposure rather than an individual hydrological measure. These two classifications served distinct analytical purposes: the first aimed to compare periods within the year, while the second allowed exploration of inter-annual variability in exposure.

The main indirect indicator of restricted access to obstetric care was the occurrence of a delivery at home or en route to a facility. The proportion of out-of-facility deliveries was compared between periods and between PHUs using contingency tables, crude odds ratios (OR) and their 95% confidence intervals. Fisher's exact test was used where numbers were small. Data from Batonou, for which only 3 records indicated the place of delivery, were presented descriptively and excluded from inferential comparisons. Differences in obstetric activity volume between periods were expressed as rate ratios with 95% confidence intervals. Inter-annual comparisons were similarly conducted using Fisher's exact test and crude ORs. A Haldane–Anscombe correction was planned for any table containing a zero cell; none of the inferential comparisons retained in the results required this correction, as zero counts were confined to the Batonou data, which were treated descriptively. The significance threshold was set at 5%.

Data were collected in the field using KoboCollect v2023.2.4, for both the quantitative extraction from obstetric registers and the structured components of the ethnographic survey. Quantitative data were cleaned, coded and analysed using Microsoft Excel (Microsoft 365). Qualitative data (interview transcripts and field notes) were coded and analysed thematically using QDA Miner Lite 3.0

The ethnographic component documented care-seeking trajectories and the mechanisms likely to affect access to care during flooding, including mobility constraints, economic resources, gender relations,

emergency decision-making processes, and organisational responses. Qualitative data were analysed thematically and used to interpret convergences and divergences with the quantitative findings.

The completeness of the main variables was assessed. Given the substantial proportion of missing data for the main indicator (34.4%), the findings on out-of-facility deliveries are interpreted as relating to the records with available data, rather than as an estimate of their frequency across the whole population.

This study did not require review by a formal institutional ethics committee, in accordance with current national regulations in Togo, under which studies of this nature (retrospective analysis of routine health facility records combined with a qualitative field survey) are authorised directly by the Ministry of Public Health rather than by an institutional ethics review board. Authorisation to conduct the study, including access to obstetric records from the Agbétiko, Agomé-Séva and Batonou peripheral health units and to carry out interviews in the field, was granted by the Secretary General of the Ministry of Public Health and Hygiene of Togo, under reference N° 1242/2025/MSHP/SG/DGEPIS/DEPP, dated 24 April 2025. All data were extracted, handled and analysed confidentially and anonymously, in accordance with the terms of this authorisation. Verbal informed consent was obtained from all interview participants prior to data collection.

During the preparation of this work the author used ChatGPT to support the literature review process as a complementary tool alongside academic databases. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

Results

Rather than being presented separately, qualitative material is woven throughout the quantitative results it helps to illuminate. Each subsection thus combines what routine registers can quantify with what interviews reveal about the lived experience of access to care.

General characteristics of the population and health units studied

The annual distribution of cases (547 records) was relatively stable from year to year (110 records in 2020, 119 in 2021, 107 in 2022, 108 in 2023 and 103 in 2024). Among the three PHUs studied, Agbétiko accounted for the majority of records (n = 312; 57.0%), followed by Agomé-Séva (n = 172; 31.4%) and Batonou (n = 61; 11.2%); PHU information was missing for two records (0.4%) (Table 1). This variation in record numbers across PHUs reflects differences in the populations they serve. At the time of the survey, Agbétiko, the canton's main town (around 3,000 inhabitants), was considerably more populous than Agomé-Séva (around 1,661 inhabitants), which was in turn more populous than Batonou (around 1,043 inhabitants).

Table 1. Distribution of obstetric records by PHU and level of flood exposure

PHU	Level of flood exposure	n	%
Agbétiko	High	312	57.0
Agomé-Séva	High	172	31.4
Batonou	Lower	61	11.2
Not recorded	–	2	0.4
Total	–	547	100.0

The territorial exposure level is a qualitative classification based on local hydrological knowledge; it is not an individual variable measured in the health database. In line with the territorial classification described in the Methods section, 484 records (88.5%) came from the two PHUs located in the highly flood-exposed zone (Agbétiko and Agomé-Séva), against 61 (11.2%) for Batonou, in the less-exposed zone. This uneven distribution of records across exposure zones, particularly the very small number available for Batonou on the study's central variable, led to the Batonou data being treated descriptively rather than being included in the formal statistical comparisons presented in the following sections.

Overall stable obstetric activity, but perceived accessibility remains fragile

The 547 deliveries were spread across all twelve months of the year, with monthly totals ranging from 34 in December (6.2%) to 57 in June (10.4%). According to the hydrological calendar adopted for the study (flood season from July to October, peaking in August), 171 deliveries (31.3%) occurred during the flood season and 376 (68.7%) during the remaining 8 months. Relative to the number of month-years available for each period (40 month-years outside the flood season, 20 during it), the mean number of monthly deliveries was 9.40 outside the flood season versus 8.55 during it, a rate ratio of 0.91 (95% CI 0.76–1.09; p = 0.304), as shown in Table 2.

Table 2. Recorded obstetric activity by flood season

Indicator	Outside flood season	Flood season
Deliveries, n	376	171
Month-years, n	40	20
Mean monthly deliveries	9.40	8.55
Rate ratio (95% CI)	1 (ref.)	0.91 (0.76–1.09)
p	-	0.304

Analysis by phase of the flood season showed a progressive decline in the number of deliveries from the start to the end of the season: 48 in July (onset of flooding), 46 in August (peak intensity), 39 in September (progressive recession of floodwaters) and 38 in October (end of the period). The month corresponding to peak reported flood intensity (August) did not stand out with a marked drop in obstetric activity relative to the other months of the season.

This apparent stability in activity volume from month to month contrasts with how field actors describe the situation. An early-warning system (alert chain, emergency management committees) set up by the Red Cross was mentioned in an interview by a community leader, who also reported low attendance at designated evacuation sites. This suggests that the existence of an organisational mechanism does not guarantee its uptake by the population, and that the statistical stability of activity recorded by the PHUs may mask care-seeking strategies that escape aggregate indicators, a point the data on out-of-facility deliveries help to clarify below.

Out-of-facility deliveries: the concrete test of physical access

Delivery at home or en route, used as an indirect indicator of restricted physical access to obstetric care, was recorded in 359 of the 547 records (65.6%; 188 missing, 34.4%). Among records with data, 18 deliveries occurred outside a facility (5.0%; 17 at home and 1 en route). The proportion of out-of-facility deliveries did not differ significantly between the flood season (5/118 records with data; 4.2%) and the rest of the year (13/241; 5.4%) (crude odds ratio [OR] = 0.78; 95% CI 0.27–2.23; p = 0.799).

The distribution of these events by PHU revealed a marked contrast between Agbétiko and Agomé-Séva: 17 of the 18 recorded out-of-facility deliveries (94.4%) came from the Agbétiko PHU (17/271; 6.3%), against a single case in Agomé-Séva (1/83; 1.2%) (Table 3). Compared with Agomé-Séva, Agbétiko showed an increased, though non-significant, risk of out-of-facility delivery (OR = 5.69; 95% CI 0.75–43.39; p = 0.086). No out-of-facility delivery was recorded at Batonou (0/3). This finding is reported here purely descriptively and is not included in any comparative calculation or significance test.

Table 3. Deliveries at home or en route by PHU and level of flood exposure

PHU	Exposure level	Out-of-facility deliveries / recorded	%
Agbétiko	High	17 / 271	6.3
Agomé-Séva	High	1 / 83	1.2

PHU	Exposure level	Out-of-facility deliveries / recorded	%
Batonou*	Lower	0 / 3	0.0
Total (Agbétiko + Agomé-Séva)	–	18 / 354	5.1

Grouped by territorial exposure level, the highly exposed zones (Agbétiko and Agomé-Séva) accounted for all 18 out-of-facility deliveries identified among the 354 records with data on this variable. The less-exposed zone, represented by Batonou, is not included in this comparative calculation, for the statistical power reasons already outlined; the three records with data for this PHU are mentioned only for context. This statistical differential finds a direct echo in the interviews.

The midwife at the Batonou PHU described the travel conditions faced by some patients as follows:

> *"Access is not easy for people living in the countryside. They have to put the canoe on the water before they can even come." (Health worker, Batonou PHU, interview, 28 May 2025)*

This account, collected precisely at the PHU where no out-of-facility delivery was recorded over the study period, illustrates the travel difficulties reported in the field, without it being possible, given the very small number of records with data, to draw a numerical comparison with Agbétiko or Agomé-Séva. The value of this account is here qualitative. It gives concrete substance to a plausible mechanism, independently of its contribution to the statistical results. Several interviews also described 'indigenous' building techniques adapted to the recurrent flooding of the Mono River, together with a technical hydrological monitoring system (water-level markers, an alert chain running the length of the Mono River) designed to reduce the time between hazard detection and getting people to safety. The persistence of a marked differential between Agbétiko and Agomé-Séva, despite these environmental measures, suggests that they operate at a scale that does not offset the proximity-related obstacles specific to each village.

Inter-annual flood intensity and household economic resilience

According to contextual information gathered in the field, 2024 experienced no flood episode, making it a flood-free reference year within the study period. Flooding in 2022 and 2023 was, moreover, judged less severe than in 2020 and 2021. The study period therefore comprises three distinct inter-annual configurations: severe flood years (2020, 2021), moderate flood years (2022, 2023), and a flood-free year (2024), which offers a natural point of comparison absent from the initial classification.

Comparing the flood-free reference year (2024) with the severe flood years (2020–2021) showed no statistically significant difference (3/64, 4.7% vs 11/149, 7.4%; OR = 1.62; 95% CI 0.44–6.02; p = 0.561, Fisher's exact test). The comparison between the reference year and the moderate flood years (2022–2023) was likewise non-significant (3/64, 4.7% vs 4/146, 2.7%; OR = 0.57; 95% CI 0.12–2.64; p = 0.438). Pooling all flood years (2020–2023, regardless of intensity) and comparing them with the flood-free reference year, the proportion of out-of-facility deliveries also remained comparable (15/295, 5.1% vs 3/64, 4.7%; OR = 1.09; 95% CI 0.31–3.88; p = 1.000).

Table 4. Deliveries at home or en route by inter-annual flood intensity

Inter-annual intensity	Records with data	Events	%
Severe (2020–2021)	149	11	7.4
Moderate (2022–2023)	146	4	2.7
Reference, flood-free (2024)	64	3	4.7
Total	359	18	5.0

Contrary to the hypothesis of a regular dose–response gradient between flood intensity and the frequency of out-of-facility deliveries, the disaggregated data show no monotonic progression. The proportion was highest in severe years (7.4%), intermediate in the flood-free reference year (4.7%), and lowest in moderate years (2.7%), this last figure even falling below that of the year with no climate hazard at all. This absence of a clear gradient, combined with the small annual numbers available (64 to 149 records with data

depending on the group), calls for caution. The routine data cannot distinguish here between a genuine absence of a dose–response effect and a simple lack of statistical power to detect one.

Despite this absence of a clear quantitative gradient, the way several interviewees spontaneously linked obstetric vulnerability to households' economic capacity to mobilise resources in an emergency retains its heuristic value: it gives concrete substance to a plausible mechanism that is not, however, confirmed by the routine data given the numbers available. Introducing a completely flood-free year (2024) into the study period nonetheless offers a point of comparison that a simple contrast between 'severe' and 'moderate' years would lack, even though, in our data, the reference year falls between the two groups rather than below them, as a strict dose–response effect would predict. One interviewee put this hypothesis as follows:

> *"Their ability to generate income is a key factor in their resilience, their capacity to prepare, protect themselves, and adapt to illness and to all the other risks linked to flooding." (Key informant, interview, 11 April 2025)*

Conversely, the absence of any formal financial solidarity scheme in the event of disaster was reported in a group interview in Agbétiko: *"When there is a flood, there are no savings groups or other mechanisms to help people out…"*. This account gives concrete substance to the hypothesis of a link between household economic capacity and vulnerability in access to obstetric care, but, as Table 4 shows, the disaggregated quantitative data do not, given current numbers, allow a strict dose–response relationship between inter-annual rainfall intensity and out-of-facility delivery to be confirmed. This absence of an economic safety net nonetheless remains a plausible mechanism to explain part of the year-to-year variability observed, one that only a larger study, with greater annual numbers, could test statistically.

Low birthweight and the social dimensions of care-seeking

Birthweight was available for 532 of the 547 records (97.3%). Low birthweight (< 2,500 g) was observed in 60 newborns (11.3%). Its frequency was slightly higher during the flood season (21/166; 12.7%) than outside it (39/366; 10.7%), though this difference did not reach statistical significance (OR = 1.21; 95% CI

0.69–2.14; p = 0.554) (Table 5). This analysis, built on the flood season/non-flood season contrast within each year, is unaffected by the inter-annual reclassification of 2024, which concerns only the year-to-year comparisons presented above.

Table 5. Low birthweight by flood season

Birthweight	Outside flood season	Flood season	Total
< 2,500 g, n (%)	39 (10.7)	21 (12.7)	60 (11.3)
≥ 2,500 g, n (%)	327 (89.3)	145 (87.3)	472 (88.7)
Total with data	366	166	532

This slight over-representation, though non-significant, sits alongside the social mechanisms described in the interviews. Community solidarity schemes (health funds, committees, mothers' clubs) were cited as mobilisable resources, but their uneven distribution was questioned by several participants. The gendered division of roles in obstetric emergency decision-making was also documented, notably through an individual account of a complicated delivery during the flood season, in which arranging transport depended on people outside the household. Such a decision-making delay, contingent on people being away from home at the time of the emergency, constitutes a plausible mechanism, albeit not directly measurable in obstetric records, to explain why the same environmental exposure translates, depending on the household, into different care-seeking trajectories and neonatal outcomes.

Data completeness

Completeness varied considerably across variables (Table 6). Year, month and PHU were almost fully recorded (≥ 99.6%), as was birthweight (97.3%). By contrast, the variables most directly related to access to care showed substantial missing data: 34.4% for delivery at home or en route, 28.7% for mode of admission, 25.0% for gestational age, and even more for Apgar score (67.5%) and management of retained placental tissue within 72 hours post-partum (69.8%).

Table 6. Completeness of the main variables in the obstetric register

Variable	Recorded, n (%)	Missing, n (%)
Year	547 (100.0)	0 (0.0)
Month	547 (100.0)	0 (0.0)
PHU	545 (99.6)	2 (0.4)
Maternal age	481 (87.9)	66 (12.1)
Gravidity	475 (86.8)	72 (13.2)
Parity	473 (86.5)	74 (13.5)
Gestational age	410 (75.0)	137 (25.0)
Mode of admission	390 (71.3)	157 (28.7)
Delivery at home / en route	359 (65.6)	188 (34.4)
Birthweight	532 (97.3)	15 (2.7)
Newborn condition at birth	456 (83.4)	91 (16.6)
Maternal condition at discharge	442 (80.8)	105 (19.2)
Infant condition at discharge	429 (78.4)	118 (21.6)
Apgar score	178 (32.5)	369 (67.5)

Variable	Recorded, n (%)	Missing, n (%)
Retained placental tissue within 72h	165 (30.2)	382 (69.8)

Discussion

Stable care supply, differentiated access

This study set out to determine whether the flood season compromises access to obstetric care in the rural communities of Agbétiko canton. The first finding was that overall obstetric activity across the three PHUs remained stable during the flood season (rate ratio = 0.91; 95% CI 0.76 to 1.09), contrary to what other African settings have documented. In Mozambique, a 6% drop in facility-assisted deliveries during the rainy season was associated with substantial excess maternal and neonatal mortality [8]. This result does not mean that flooding has no effect in Agbétiko. Rather, it shows that vulnerability operates at a finer scale than that of the PHU. Deliveries at home or en route, a direct indicator of restricted physical access, were concentrated 17 out of 18 in the Agbétiko PHU catchment area, against a single case in Agomé-Séva (Batonou's situation is now reported separately, descriptively, rather than integrated into this numerical contrast). Flooding therefore does not close facilities. For some women, it complicates the journey to reach them. This pattern corresponds to the second of the three classically described delays in access to obstetric care in sub-Saharan Africa, the delay in reaching a facility rather than in deciding to seek care or in receiving treatment once there [22]. A study in the Barotse floodplain, Zambia, showed through fine-grained modelling that access to maternity services varies dynamically in space and time, with marked drops at flood peak, even within a single zone classified as exposed [23]. This helps explain why Agbétiko and Agomé-Séva, classified in the same territorial exposure category, show such different profiles. Proximity factors, the state of tracks, the distance between village and PHU, and the availability of a canoe or other means of transport, make the difference at this fine-grained scale. The Batonou midwife's account of patients having to put a canoe on the water before travelling illustrates this mechanism, but should be read

as a qualitative illustration of local context rather than as evidence strengthening or weakening a numerical comparison. The number of records with data for this PHU, only 3, allows no statistical conclusion on this point.

The overall stability observed is also explained by the nature of the event studied. In Hyderabad, Pakistan, a flood caused antenatal consultations to fall by 60% and the availability of caesarean sections to drop from 90% to 35%, with neonatal mortality almost tripling [24]. Following the 2022 floods, several displacement camps in Pakistan were left with no reproductive health services at all [18]. These studies concern sudden disasters that destroy health infrastructure itself. The floods of the Mono River, by contrast, are recurrent and have been anticipated for generations, owing to local building techniques and an early-warning system; the PHUs are neither destroyed nor closed. This is why vulnerability in Agbétiko plays out less through the availability of care than through the margins of demand.

Economic resources, gender and decision-making delay

The year-by-year disaggregated analysis (Section ‘Inter-annual flood intensity and household economic resilience’, Table 4) shows no clear dose–response gradient between inter-annual flood intensity and the frequency of out-of-facility deliveries. This frequency was highest in severe years (7.4%), lowest in moderate years (2.7%), and intermediate in the flood-free reference year (4.7%), with none of these differences reaching significance (Fisher’s exact test, $p > 0.4$ for each pairwise comparison, and $p = 1.000$ when comparing all flood years combined with the reference year). This result contrasts with a larger-scale Indian analysis, in which classifying districts as at-risk zones remained associated with under-coverage of postnatal care, even within a more developed health system than Togo’s [10]. The discrepancy is plausibly explained, at least in part, by the small annual numbers available here (64 to 149 records with data depending on the year), which strongly limits the statistical power of a five-year disaggregated comparison. Introducing a completely flood-free year (2024) into the study period remains a useful point of comparison, but it calls, given the current data, for caution against over-interpreting the contrast between severe and moderate years as proof of a linear relationship between rainfall intensity and obstetric vulnerability.

The interviews nonetheless offer a complementary perspective on this uncertain quantitative result. Several interviewees linked obstetric vulnerability to household economic capacity, itself dependent on the palm-oil sector, whose deferred income is difficult to mobilise in an emergency. The reported absence of savings groups or other financial solidarity mechanisms in the event of disaster suggests that a severe flood year translates not only into more water in villages and on roads, but potentially also into a narrower economic safety net precisely when it would be most needed, a plausible mechanism that the routine data, at the annual scale and with the numbers available here, cannot, however, confirm statistically.

The decision-making delay observed in our interviews, through the account of a complicated delivery whose transport depended on people absent from the household, falls within the same register. In South Africa, a qualitative study conducted after the April 2022 floods showed that such events redistribute domestic responsibilities and tensions between women and men within poor households, to the point that the authors call for a rethink of general models of the effects of disasters on violence against women [25]. The delay observed in Agbétiko is therefore not simply a logistical matter. It relates to who, within the household, holds the authority to trigger an emergency journey, an authority that may itself be displaced during a crisis. The community solidarity mechanisms cited in interviews, health funds, local committees, mothers' clubs, could offset this delay, but their uneven distribution limits their reach.

Low birthweight: a coherent but underpowered signal

The slight over-representation of low birthweight during the flood season, 12.7% versus 10.7% (OR = 1.21; 95% CI 0.69 to 2.14; p = 0.554), points in the same direction as recent literature without reaching statistical significance. A study of 290,008 births across 36 African countries found a significant association between prenatal flood exposure and low birthweight (OR = 1.076; 95% CI 1.028 to 1.128), with a dose–response gradient by severity [7]. A Chinese cohort of over 4.4 million births reported an association of almost identical magnitude, concentrated in the three months before conception and the first trimester [26]. A meta-analysis of 25 studies across 13 countries confirms the direction of the effect globally, albeit more modestly (RR = 1.03; 95% CI 1.00 to 1.05) [27].

These three studies, covering numbers ranging from hundreds of thousands to several million births, detect only modest associations. Applied to our 532 births with recorded weight, an effect of this magnitude would, by construction, remain below the significance threshold even if it were real. Our non-significant result therefore most likely reflects a lack of statistical power rather than an absence of effect. The classification used here, the whole season, also does not allow us to target the preconception period and first trimester identified as the highest-risk window; an individualised exposure measure based on conception date could reveal a more pronounced association. This plausible link finally fits within a broader set of mechanisms (food insecurity, disruption of family planning, psychological distress) that our interviews partly echo through accounts of economic strain and decision-making delays already discussed [18,19,20].

Limitations and implications

Several limitations should be noted. A first set of limitations concerns the analytical strategy itself: the study draws on around ten distinct statistical comparisons (by season, PHU, inter-annual intensity, birthweight) without correction for multiple comparisons, consistent with the exploratory aim of the analysis, but calling for each significance threshold to be interpreted cautiously in isolation rather than as part of a series of independent confirmatory tests. The study's central variable, delivery at home or en route, was recorded in only 65.6% of records, which may have introduced bias. The Batonou data, treated descriptively rather than comparatively, remain limited to 3 records with data on this variable; their value is illustrative and should not be over-interpreted. This nonetheless speaks to the wider issue of medical record completeness within African health systems, widely discussed in the literature [28]. Data on Apgar score and management of retained placental tissue, recorded in fewer than a third of records, could not be used, depriving the study of direct indicators of severe neonatal morbidity. The retrospective nature of the register also limits precise matching between each birth and its individual exposure, a limitation that future work could address by combining fine-grained hydrological modelling, as in the Zambian approach [23], with cohort follow-up. In addition, comparisons of monthly or annual rates treat each month-year or year

as an independent observation, whereas the same PHUs and the same seasonal dynamics recur from one year to the next; this panel structure, not modelled here, may somewhat underestimate the true variability of the estimates.

From an operational standpoint, these findings support interventions calibrated to village level rather than to the health-facility catchment area, prioritising localities where distance and poor road conditions coincide, strengthening the network of midwives or community relays in Agbétiko's more isolated areas, and better linking existing early-warning systems with economic solidarity mechanisms in the event of disaster, which our interviewees described as almost entirely absent today.

Conclusion

This study shows that, in Agbétiko, flooding is not associated with a uniform disruption of obstetric activity at health facilities. Routine data show no statistically significant increase in out-of-facility deliveries or in low birthweight during the flood season. They nonetheless suggest a more localised vulnerability in care-seeking trajectories, particularly through the mobility difficulties and economic and social constraints reported by the population. The organisational dimension of vulnerability, in particular the regularity of service and supply availability during the flood season, remains, by contrast, poorly documented by this study and represents an avenue for further work. The stability of aggregate indicators may therefore mask substantial inequalities at village level.

These findings suggest that adaptation to flooding should be considered beyond service availability alone, with particular attention to the concrete conditions of accessibility. Interventions targeting obstetric transport, community relays, early-warning systems, and crisis-support mechanisms may be relevant in the most isolated localities. Studies combining individualised hydrological data, more complete health registers, and follow-up of care-seeking trajectories are needed to clarify these mechanisms further.

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Supporting information

S1 Checklist. STROBE checklist for the quantitative/observational component of the study.