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Flood exposure and intimate partner violence in low- and middle-income countries

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Intimate partner violence (IPV) is a global public health challenge, causing physical and psychological harm to victims. Although studies have explored the impacts of various extreme weather events on IPV, there is still inadequate evidence on the association between flood exposure and IPV on a multi-country or global scale. Therefore, we utilized the Demographic and Health Surveys database to examine this association on a multi-country scale and further explored modification effects of inequality outside and within the household. This study included 340,955 ever-partnered women from 31 low- and middle-income countries across Asia, Africa and Latin America. The results showed that flood exposure was associated with increased prevalence of total IPV (percentage difference 10.78%, 95% confidence interval 8.24–13.38%), physical violence (4.94%, 2.31–7.64%), sexual violence (13.03%, 8.61–17.62%) and emotional violence (17.62%, 14.28–21.06%). We found stronger flood–IPV associations among household with greater inequality. Our findings indicate additional harm associated with flood exposure for women in low- and middle-income countries, emphasizing the role of gender inequality under climate change.

Intimate partner violence (IPV) is defined as physical, sexual or psychological harm committed by partners, encompassing physical assault, sexual coercion and psychological abuse[1]. The World Health Organization identifies IPV as the most prevalent form of violence against women worldwide, affecting 27% of women in their lifetime[2]. The prevalence of IPV varies by region, with the highest prevalence reported in low- and middle-income countries (LMICs), such as North Africa and the Middle East (31%) and South Asia (35%)[2]. IPV can result in immediate physical, reproductive and mental health issues for women, such as injuries, chronic pain, sexually transmitted infections, unwanted pregnancies, post-traumatic stress disorder and suicide[3–7]. In addition, IPV has indirect and long-term health impacts on women and their children, including increased risk of acquired immune deficiency syndrome, low birth weight, child maltreatment, anxiety, depression and the intergenerational transmission of violence[3,4,8].

Previous research has linked extreme weather events (EWEs) such as droughts[9,10], extreme heat[11–14] and earthquakes[15–17] to increased violent behaviours[18], including IPV[19,20]. Studies have also examined associations of flooding caused by cyclones[21–24], tsunamis[25] and excessive rainfall[9,26,27] with IPV or gender-based violence[9,19,28–30]. However, previous studies have not always reached consistent conclusions. Some studies[21,23,31,32] reported that exposure to floods or hurricanes was associated with increased IPV or gender-based violence, while others[33,34] observed a non-significant association. This discrepancy may be due to various reasons. First, some earlier studies focused only on changes in IPV before and after a single event of extreme weather, such as Hurricane Katrina[21–23,34], attenuating the data representativeness

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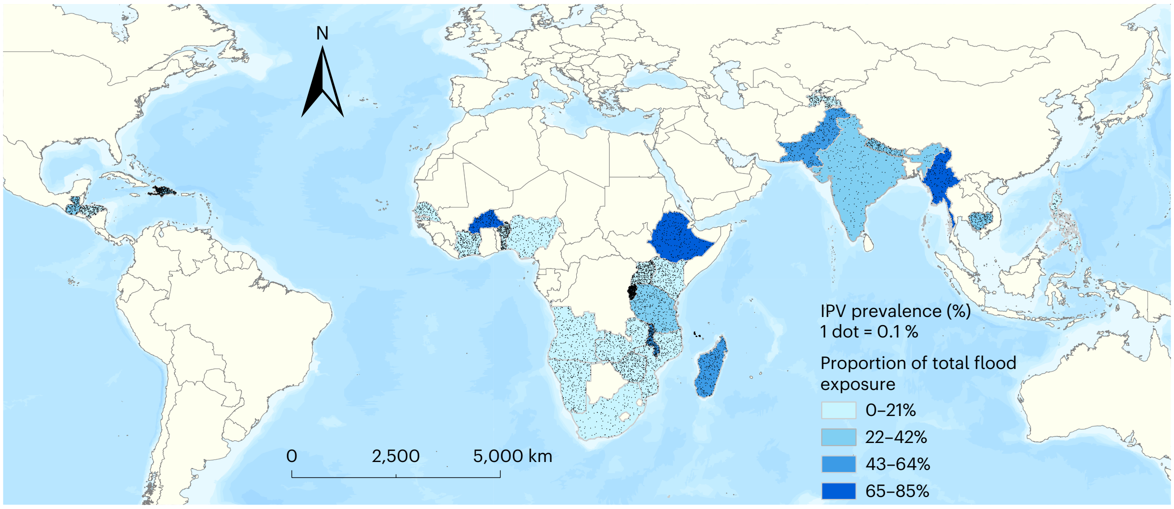

Fig. 1 | The IPV prevalence and proportion of flood exposure in 31 LMICs. One dot represents 0.1% of the IPV prevalence in the study population. This map was reproduced from https://www.naturalearthdata.com/.

and introducing confounding factors that are difficult to control for. Second, findings may vary by region, with studies in the Asia-Pacific region[35,36] supporting a generally positive association between flood exposure and IPV, whereas parts of North America failed to reach uniform conclusions[21,23,31–34]. Third, smaller sample sizes in previous studies may introduce larger estimation errors and make the results less stable.

Generally, EWEs could increase both male aggression and the vulnerabilities of women to violence. Natural disasters such as floods are strongly associated with psychological disorders[8,37–39] and substance abuse[20,40], increasing the likelihood of aggression[20,40,41]. The disruption of traditional domestic roles of women[19,29,30], such as the inability to collect sufficient food and water, can amplify household stress and increase violence against women. The increasing evident impact of climate change in developing countries could further exacerbate the situation, given the limited resources, inadequate infrastructure and higher socio-economic vulnerabilities. As a result, women living in LMICs may be at additional risk of flood-related IPV.

Under the context of climate change, floods have become one of the most prevalent types of natural disaster[42]. Considering the direct damage of flood to communities[37,43,44] and its lasting adverse health consequences both physically[45–47] and mentally[8,37–39], it is crucial to further investigate the impact of flood exposure on the prevalence of IPV. To bridge this gap, we utilized the Demographic and Health Surveys (DHS) data collected in global LMICs to examine the associations between qualitative and quantitative indicators of flood exposure and various forms of IPV. We also explored the modifying role of inequality at both societal and household levels.

Results

Descriptive statistics

This study included 31 LMICs across Africa, Asia, Latin America and the Caribbean from 2008 to 2021 (Fig. 1). After excluding data without key information, a total of 340,955 ever-partnered women aged 15–49 years were finally included (Supplementary Fig. 1). No significant differences were observed in the distribution of demographic and socio-economic variables between the final data included in the analysis and the original data (Supplementary Table 1). The percentage of survey respondents with flood exposure in the past 12 months and the IPV prevalence in each country during the survey period are presented in Table 1. On average, 31.17% of women interviewed in DHS surveys experienced flood exposure in our dataset (Table 1). Specifically, 88,460 women reported the experience of at least one IPV in the past year, with physical violence being the most prevalent (19.44%), followed by emotional violence (16.03%) and sexual violence (6.18%) (Supplementary Table 2). Generally, the prevalence of physical and emotional violence was consistently higher than that of sexual violence in each country. The highest IPV prevalence was observed in Comoros (45.57%), while the lowest prevalence was recorded in Rwanda (10.44%) (Supplementary Table 2). We also observed significant differences in residence type, age, education and household wealth levels as well as a within-household difference between women who experienced IPV in the past year and those who did not (Supplementary Table 3).

Association between flood exposure and IPV

Figure 2a shows that flood exposure significantly increased the prevalence of total IPV and its three categories globally. Globally, women who were exposed to floods in the past year were at a higher risk of experiencing all forms of IPV by 10.78% (odds ratio (OR) 1.108, 95% confidence interval (95%CI) 1.082–1.134) compared with those who were not exposed to floods (Table 2 and Supplementary Table 4). Emotional violence showed the largest percentage increase (17.62%, OR 1.176, 95%CI 1.143–1.211) associated with flood exposure, followed by sexual violence (13.03%, OR 1.130, 95%CI 1.086–1.176) and physical violence (4.94%, OR 1.049, 95%CI 1.023–1.076) (Table 2 and Supplementary Table 4). Regionally, the associations between flood and IPV were stronger in Africa (OR 1.214, 95%CI 1.163–1.267) and weaker in Asia (OR 1.046, 95%CI 1.015–1.077), while no evidence for associations between flood exposure and all types of IPV was found in Latin America and the Caribbean (OR 0.963, 95%CI 0.885–1.048) (Fig. 2). Table 2 and Supplementary Table 4 present the effect estimates of the other two quantitative indicators of flood exposure measurements (that is, number of flood events and days of flood exposure) at the global and regional levels. Overall, IPV prevalence would increase by 3.88% (95%CI 2.07–5.73%) per additional flood event and by 0.23% (95%CI 0.13–0.32%) per additional day of flood exposure.

Figure 3 and Supplementary Table 5 illustrate that the associations between all three indicators of flood exposure and IPV prevalence were stronger for younger respondents (<33 years old) than older respondents. In addition, women living in rural areas, with lower household wealth level and with higher-educated partners were more vulnerable to IPV in relation to the number of flood exposure days. Considering intra-household inequalities, the 'younger than partner' group exhibited stronger flood–IPV associations compared with the 'not younger than partner' group. However, the age gaps between women and their

Table 1 | Summary statistics for flood exposure and IPV cases during the study period in 31 LMICs

Region	Country	Sample size	Number of total IPV cases	Number of physical violence cases	Number of sexual violence cases	Number of emotional violence cases	Proportion of total flood exposure	Average number of flood events	Average number of flood exposure days
Africa		150,846	44,161	31,246	7,681	30,927	20.02%	0.24	4.71
	Angola	7,358	2,306	1,778	609	1,532	12.54%	0.13	1.73
	Benin	4,253	1,344	547	146	1,213	0.26%	0.003	0.05
	Burkina Faso	9,340	1,289	950	20	772	74.59%	1.07	14.76
	Burundi	7,060	2,280	1,972	498	1,227	1.91%	0.02	0.10
	Comoros	3,656	1,666	1,209	0	1,239	3.31%	0.04	1.51
	Cote d'Ivoire	4,658	1,349	1,070	60	781	2.49%	0.02	0.15
	Ethiopia	4,249	1,027	685	202	801	84.37%	0.87	46.14
	Kenya	4,320	1,413	1,073	379	1,032	1.06%	0.01	0.02
	Madagascar	5,579	1,455	845	162	1,216	48.88%	0.55	2.09
	Malawi	5,127	1,672	1,197	343	1,189	49.13%	0.49	16.63
	Mozambique	7,339	2,509	1,709	476	1,878	13.39%	0.13	5.22
	Namibia	1,349	409	298	139	310	11.27%	0.11	1.80
	Nigeria	28,709	6,940	3,657	886	5,856	18.54%	0.19	4.41
	Rwanda	6,960	2,591	2,351	283	801	46.45%	0.75	3.18
	Senegal	5,084	710	506	147	444	3.86%	0.04	0.33
	South Africa	3,399	506	291	35	393	0.53%	0.01	0.04
	Tanzania	7,107	2,440	1,910	426	1,803	27.34%	0.31	4.34
	Uganda	8,732	3,660	2,726	885	2,742	2.13%	0.02	0.31
	Zambia	16,139	5,251	4,211	1,234	3,322	1.21%	0.01	0.17
	Zimbabwe	10,428	3,344	2,261	751	2,376	7.86%	0.08	3.07
Asia		157,000	37,039	31,194	11,909	17,367	31.68%	0.38	5.29
	Cambodia	3,216	587	324	130	518	27.18%	0.27	4.35
	India	119,270	30,548	26,755	10,536	12,924	34.09%	0.42	5.76
	Myanmar	3,094	529	369	95	370	64.61%	0.65	22.61
	Nepal	6,639	1,102	905	382	639	35.35%	0.35	4.69
	Pakistan	3,642	1,078	619	252	906	55.60%	0.56	4.44
	Philippines	12,261	1,280	765	190	954	13.14%	0.19	0.97
	Tajikistan	8,878	1,915	1,457	324	1,056	2.56%	0.03	0.10
Latin America and the Caribbean		33,109	7,260	3,849	1,481	6,365	25.14%	0.32	2.98
	Dominican Republic	5,265	1,445	749	388	1,296	25.28%	0.25	1.26
	Guatemala	6,120	1,058	518	0	947	29.38%	0.29	3.23
	Haiti	10,171	2,204	1,362	516	1,775	49.91%	0.74	7.08
	Honduras	11,553	2,553	1,220	577	2,347	1.03%	0.01	0.03
Global		340,955	88,460	66,289	21,071	54,659	25.89%	0.31	4.81

partners did not significantly affect the flood–IPV association. Similar patterns were observed in stratified analyses for different types of IPV (Fig. 4 and Supplementary Table 6). All three types of IPV showed stronger associations with flood exposure in younger women. We also found a stronger association between flood exposure and emotional violence among women with lower household wealth level, lower education and older partners.

In sensitivity analyses, the associations between flood exposure and total IPV remained robust after reintegrating data of countries with no flood exposure, excluding annual precipitation, annual temperature and household wealth from the main model and excluding data of each country individually from the main analyses. Detailed results of the sensitivity analyses are presented in Supplementary Tables 7 and 8.

Discussion

Over recent decades, human-induced climate change has increased the frequency and intensity of flood events globally[42]. This study offers convincing and concrete insights into the association between flood exposure and various categories of IPV in LMICs from a global multi-country perspective. Emotional violence showed the largest increase associated with flood exposure, followed by sexual violence and physical violence. Our findings also underscore the significance of intra-household inequality for IPV associated with EWEs in the context of climate change, a topic that has been largely overlooked.

Multiple studies have linked EWEs such as droughts[9,10], cyclones[21–23], extreme heat[11–14], abnormal rainfall[9,10,26,27] and floods[21–25,28,29] to increased IPV[19,20]. As suggested by the general aggression model, adverse

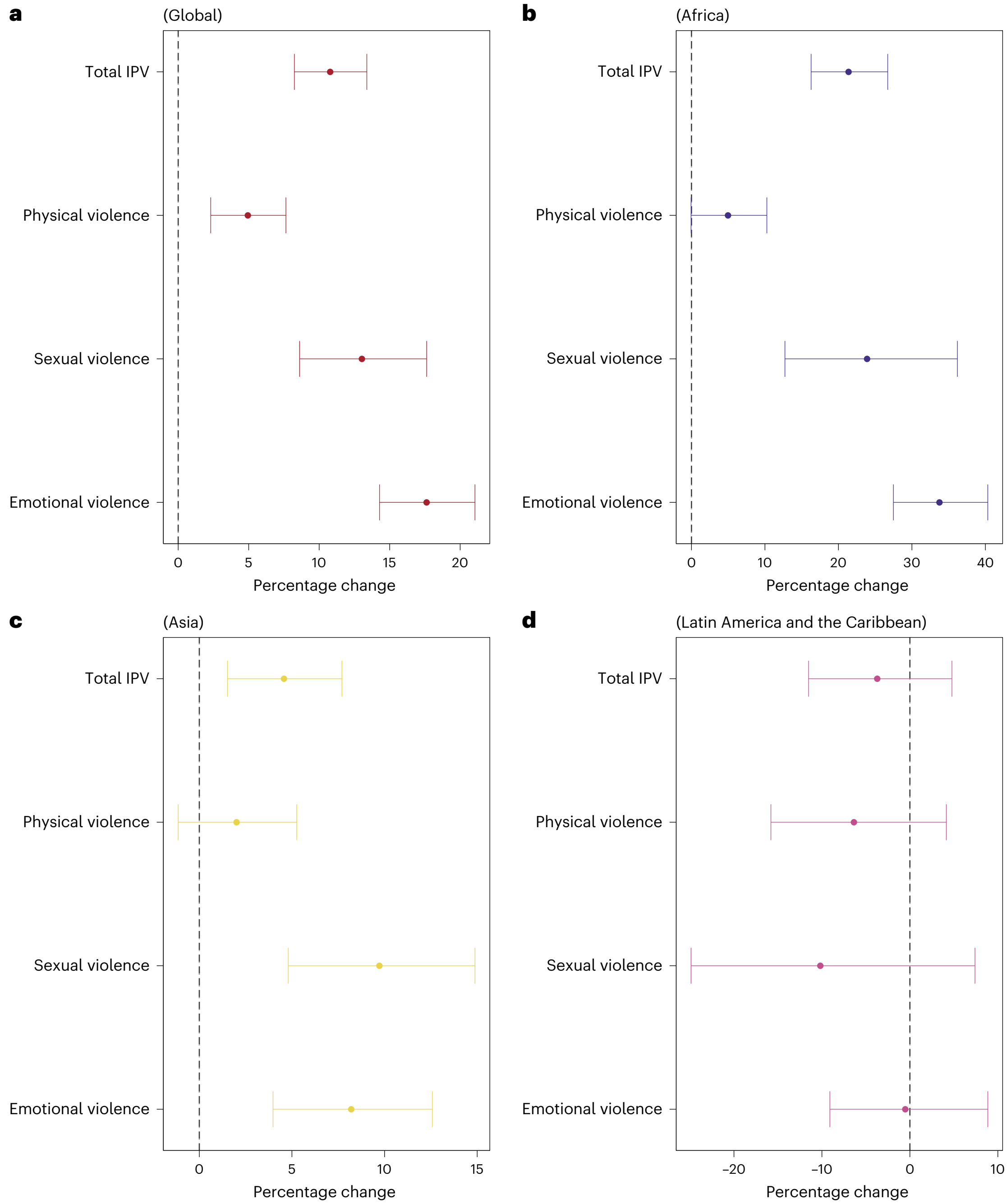

Fig. 2 | Percentage difference (and 95%CI) of IPV prevalence associated with flood exposure globally and regionally. a–d, The dots are the mean estimates, and the lines are their 95%CIs (global (**a**), Africa (**b**), Asia (**c**) and Latin America and the Caribbean (**d**)). Exact sample sizes for each group are presented in Table 1.

environmental factors may increase body arousal and impair cognitive functioning[48–50], thereby increasing aggression and violence[50–52]. Flood experiences can also be traumatic[35], causing long-term mental health issues[20,35,38,53] such as anxiety, depression and post-traumatic stress disorder, potentially triggering substance abuse[20,40] and domestic violence. The routine activity theory further explains that EWEs may raise the number of potential perpetrators with increased aggression and force vulnerable groups into more dangerous environments owing to displacement and shortages of necessities[52]. EWEs can also disrupt local social support systems and social order[17,34], allowing violence that might otherwise be prevented to occur uncontrollably[52].

Recent research indicates that developing countries, particularly LMICs in sub-Saharan Africa, South Asia and parts of Latin America, face greater risks and impacts from climate change[47,48,54,55]. In these regions, limited resources, inadequate infrastructure and poor governance would amplify the impacts of extreme weather, leading to more severe economic losses and social disruptions compared with developed regions[42,56], leaving communities more vulnerable to disasters. Floods can cause shortages of necessities in both agricultural areas[42,57] and densely populated urban regions, heightening stress and economic hardship, which are known risk factors for IPV[23,29,56]. The rural population of these countries living in extreme poverty could face even higher risks[42]. Flooding also disrupts public services[41], cutting off access to help for victims and hindering law intervention[49,58,59]. Isolation from friends outside family during floods could result in victims spending long periods with their partners, increasing the possibility of violence[20].

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Table 2 | Percentage difference (95%CI) of IPV prevalence associated with flood exposure or a unit increase in flood exposure globally and regionally

Area	Exposure	Total IPV	Physical violence	Sexual violence	Emotional violence
Global	Total flood exposure	10.78 (8.24, 13.38)	4.94 (2.31, 7.64)	13.03 (8.61, 17.62)	17.62 (14.28, 21.05)
	Number of flood events	3.88 (2.07, 5.73)	0.46 (−1.45, 2.42)	10.02 (6.73, 13.42)	10.3 (7.90, 12.75)
	Number of flood exposure days	0.23 (0.13, 0.32)	−0.06 (−0.16, 0.05)	0.35 (0.19, 0.51)	0.53 (0.41, 0.64)
Asia	Total flood exposure	4.57 (1.52, 7.70)	2.01 (−1.14, 5.26)	9.72 (4.80, 14.88)	8.20 (3.98, 12.58)
	Number of flood events	−0.10 (−0.22, 0.02)	−0.17 (−0.30, -0.04)	0.24 (0.05, 0.42)	−0.02 (−0.19, 0.15)
	Number of flood exposure days	2.09 (−0.23, 4.46)	1.21 (−1.23, 3.72)	7.99 (4.20, 11.91)	2.41 (−0.73, 5.64)
Africa	Total flood exposure	21.38 (16.28, 26.71)	4.97 (−0.06, 10.26)	23.9 (12.72, 36.19)	33.75 (27.48, 40.33)
	Number of flood events	6.85 (3.38, 10.43)	−3.59 (−7.11, 0.07)	19.44 (11.02, 28.50)	24.27 (19.68, 29.03)
	Number of flood exposure days	0.84 (0.68, 1.00)	0.16 (−0.02, 0.35)	0.83 (0.48, 1.19)	1.17 (1.00, 1.35)
Latin America and the Caribbean	Total flood exposure	−3.71 (−11.52, 4.78)	−6.36 (−15.8, 4.14)	−10.18 (−24.88, 7.40)	−0.52 (−9.10, 8.86)
	Number of flood events	−0.83 (−6.40, 5.06)	−2.60 (−9.30, 4.60)	−2.61 (−13.26, 9.35)	1.90 (−4.20, 8.38)
	Number of flood exposure days	0.13 (−0.46, 0.72)	−0.04 (−0.76, 0.69)	0.08 (−1.11, 1.30)	0.39 (−0.25, 1.03)

A similar phenomenon has been observed with lockdown policies during epidemics[60,61]. Besides, in less-developed areas, traditional societal norms that condone gender-based violence can hinder women's ability to seek help and protection[49,58,59,62].

Furthermore, women are found to be more vulnerable to EWEs than men[20,29,30,63,64]. This heightened vulnerability could be explained by biological differences[20], differentiated family roles[19,29,30] and structural gender inequalities[19,20,29,30,41]. The burden of caregiving and household responsibilities disproportionately fall on women[20], who may be blamed for not fulfilling their obligations to obtain enough food or water for their families[9,21,27,65], while husbands may be upset by job losses and the difficulty of providing for their family due to floods[66], exacerbating tensions within the family. This friction could escalate into violent conflict. In addition, women with limited education often rely entirely on their partners for economic support. Exposure to EWEs can intensify this dependency, further exacerbating the unequal power dynamics within the household[20]. These inequalities could place women at a disadvantage in society and in the family, thereby increasing their risk of suffering violence.

We observed varied impacts of flood exposure on different types of IPV, with the largest increase in emotional violence, followed by sexual violence and physical violence. We hypothesize that this difference may be attributable to the severity and developmental trajectories of different IPV forms. Previous studies have suggested that emotional violence, hard to define and often overlooked, could act as a precursor and a cause to sexual violence and physical violence[2,67]. Therefore, flood exposure may have the strongest effects on emotional violence, potentially triggering the other two types of violence. However, studies[9,10] by Allen et al. and Epstein et al. found no association between EWEs and emotional violence, and observed that exposure to flood or drought events was associated only with increases in physical violence and sexual violence. This difference may be due to the varied mechanisms of different EWEs as well as specific cultural and socio-economic factors in different study regions. Further studies are needed to confirm the association between EWEs and emotional violence, as well as other less visible IPV, such as economic violence.

Our study also observed that the number and duration of flood exposures was associated with a higher prevalence of IPV. Our findings are more comprehensive and representative than previous studies[21–23,39], which mostly focused solely on a single event of extreme weather (for example, Hurricane Katrina). Our results suggest that the effects of flood exposure could be cumulative and a binary variable of exposure may not fully capture the differences in levels of flood exposure. We also found that the associations in Asia and Africa were consistent with the global trends while no evidence for associations was found in Latin America and the Caribbean. This finding also aligns with some previous findings[33,34], suggesting that the unique geographic and social-economic features in a region may lead to distinct responses to EWEs.

Our stratified analyses reveal that certain women could be more susceptible to flood-related IPV. This vulnerability may partly stem from societal disadvantages faced by women[2]. Our findings suggest that women living in rural areas, those with lower household wealth, and younger and less educated women could be at higher risks of flood-related IPV. A secondary analysis of surveys in 28 European Union countries reached similar conclusion, suggesting that lower levels of women's empowerment at both the national and individual levels were associated with higher prevalence of IPV[68]. Another study using multi-country data from Africa also found that, in countries where women's literacy rate was generally lower than men's, women were more likely to justify violence against women, making it easier for perpetrators to continue their violence and more difficult for women to disclose domestic violence[62]. Conversely, this phenomenon was not observed in countries where women's literacy rates were comparable to those of men[62].

Our study also reveals that intra-household inequality significantly affects flood-related IPV. Women who are younger or less educated than their partners face higher risks of flood-related IPV. Age differences often indicate unequal relationships in terms of social experience, economic income and family status. In some Asian and African countries, early marriage (under 18 years old) was reported to be an important risk factor for IPV[69]. Moreover, early marriage is associated with low education for women[70], as it may deprive them of the opportunity to continue their education, widening the gap between partners. A greater education gap between partners can suggest higher differences in personal income and authority within the family[71], exacerbating household inequality. Evidence has shown that unemployed women were more vulnerable to EWEs and could suffer more violence than employed women[10].

This study has several limitations. To begin with, flood exposure matching was conducted at the cluster level, which may lead to some degree of exposure misclassification and introduce uncertainty to our results. Besides, as this study is inherently a cross-sectional survey, we cannot draw definitive causal conclusions. In addition, because the data were obtained through survey interviews, our results could be subject to recall and self-reporting bias. Furthermore, although this study has demonstrated the overall impact of flood exposure on IPV prevalence at the global and region scales, the lack of detailed data on local socio-economic factors and lifestyles has deterred us

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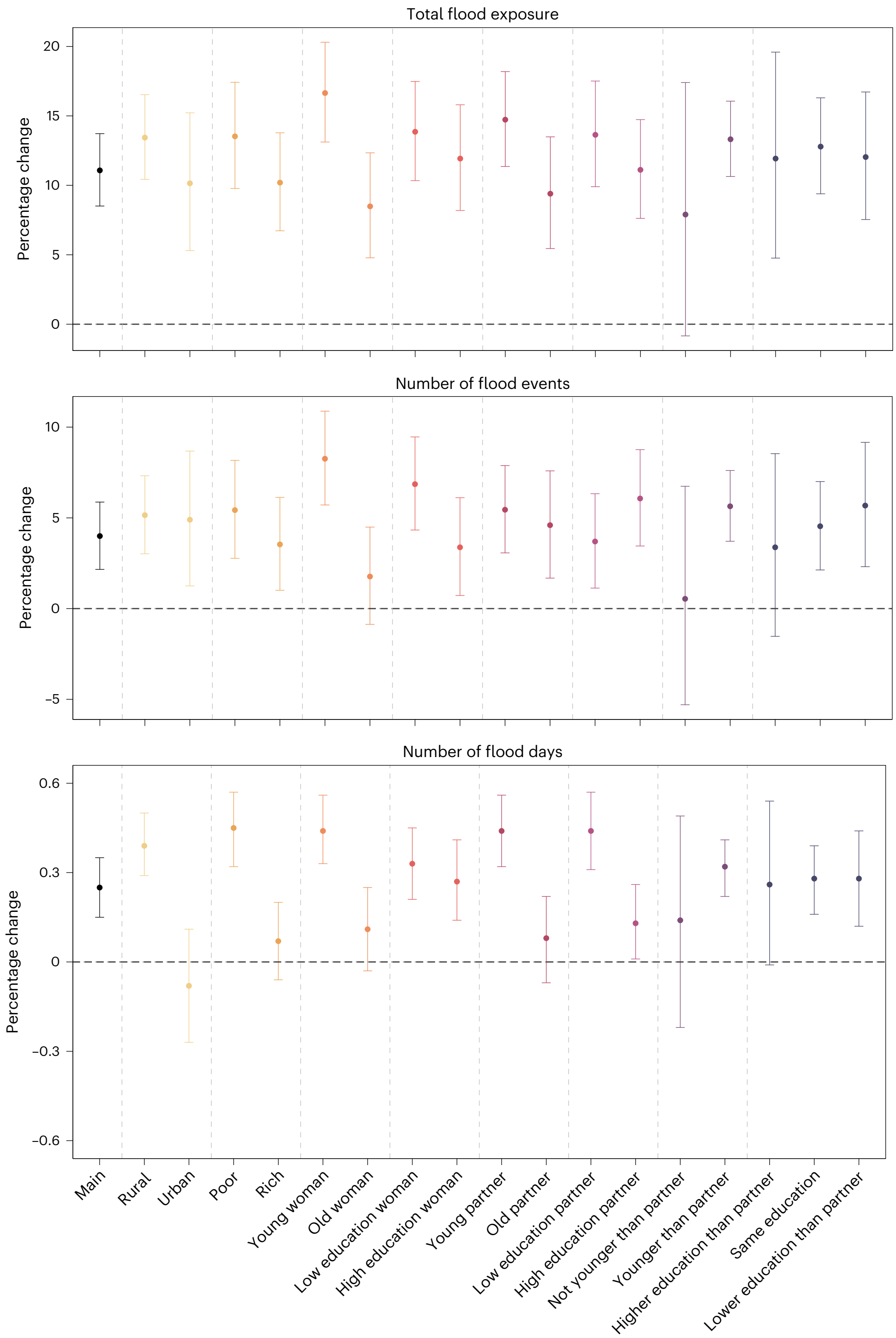

Fig. 3 | Percentage difference (and 95%CI) of total IPV prevalence associated with flood exposure in various subgroups. 'Main' represents the percentage difference in overall population; 'rural' and 'urban' represent the residence type; 'poor' represents that wealth level is below the medium level; 'young woman' and 'young partner' represent that the individual's age is below the average age (woman ≤39.1 years old, man ≤38.3 years old); 'low education' represents that the educational level is primary education or lower; 'not younger than partner' represents that the woman is older than her partner or of the same age; 'higher education than partner' represents that the woman has a higher educational level than her partner. The exact sample sizes for each group are presented in Supplementary Table 1. The dots are percentage differences of IPV prevalence associated with flood exposure, and the lines are their 95%CIs.

to thoroughly explore the possible effect modifiers and identify the specific underlying mechanisms. Finally, because IPV was defined as violence by male partners against women in the DHS, we are unable to estimate the impact of EWEs on domestic violence perpetrated by women against men or in the wider population.

Conclusion

This multi-country study reveals significant associations between flood exposure and increased prevalence of various types of IPV in global LMICs. Our findings emphasize the critical role of intra-household and societal inequalities in exacerbating flood-related IPV, particularly

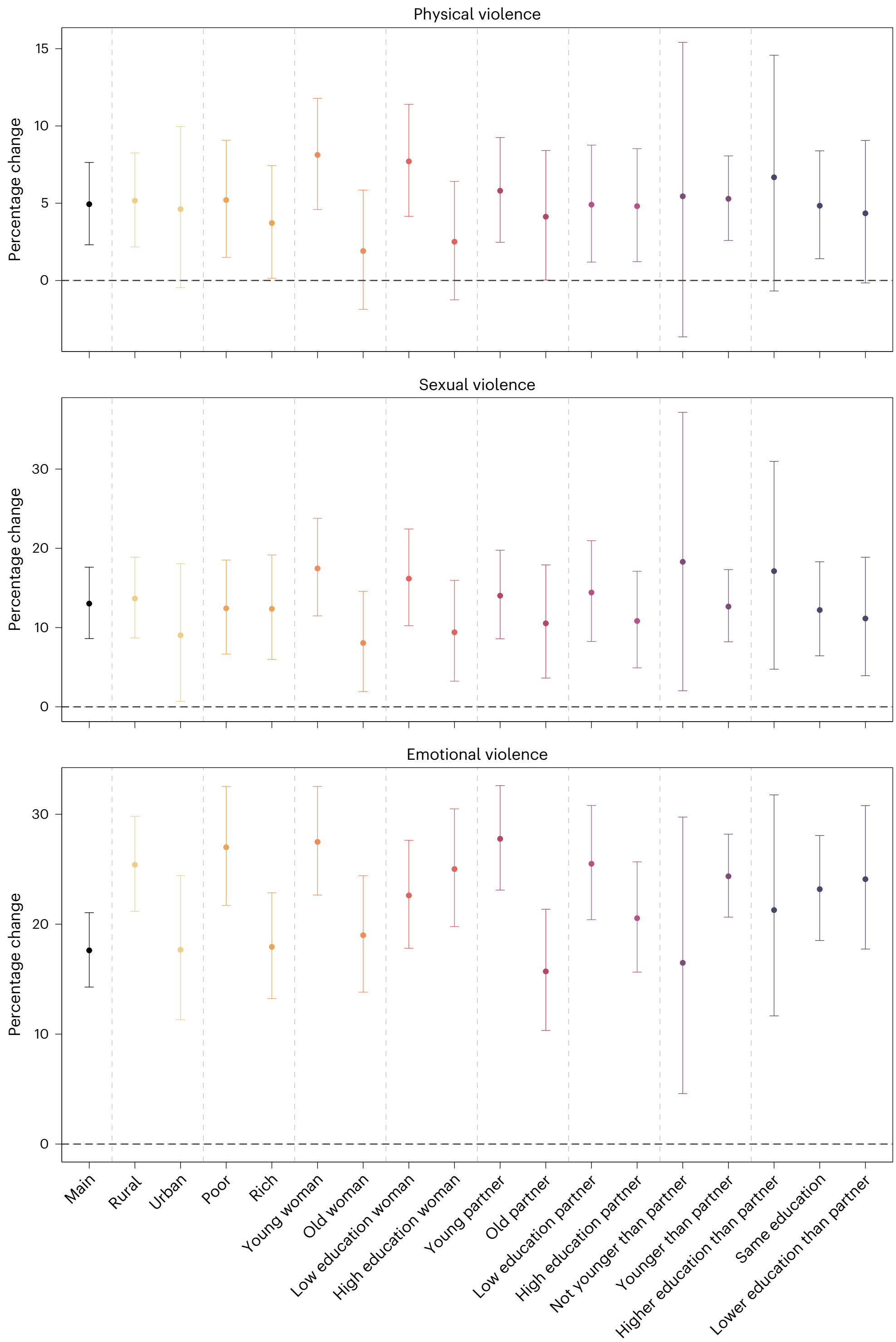

Fig. 4 | Percentage difference (and 95%CI) of IPV prevalence associated with flood exposure, classified by violence subtypes and possible modifiers. 'Main' represents the percentage difference in overall population; 'rural' and 'urban' represent the residence type; 'poor' represents that wealth level is below the medium level; 'young woman' and 'young partner' represent that the individual's age is below the average age (woman ≤39.1 years old, man ≤38.3 years old); 'low education' represents that the educational level is primary education or lower; 'not younger than partner' represents that the woman is older than her partner or of the same age; 'higher education than partner' represents that the woman has a higher educational level than her partner. The exact sample sizes for each group are presented in Supplementary Table 1. The dots are percentage differences of IPV prevalence associated with flood exposure, and the lines are their 95%CIs.

among women in rural areas, those with lower household wealth and those with younger age or lower education compared with their partners. Our study provides robust global epidemiological evidence on the heightened vulnerability of women in LMICs to IPV when facing natural disasters such as floods. Additional efforts ensuring climate justice should be made in LMICs with higher rates of poverty and unemployment and structural gender inequality, considering their lower capacity to cope with EWEs and higher prevalence of IPV.

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Methods

IPV data

The DHS Program is a comprehensive global survey conducted every 3–5 years in over 90 developing countries[72]. The survey uses a two-stage cluster sampling strategy[73]. First, urban and rural areas were stratified for each country included in the survey. Within each stratum, clusters were selected independently with probability proportional to their sizes. Then, a complete list of households was created for each selected cluster, and households were chosen using equal probability sampling. In each selected household, trained fieldwork staff administered questionnaires to identify women aged 15–49 years and conduct further interviews.

Data on IPV in the survey were collected by trained interviewers without the presence of other household members. IPV and its three types—physical, sexual and emotional violence—were recorded as a dichotomous variable, indicating whether the woman interviewed had experienced violence-related behaviours from her husband or partner in the past year. Countries with available data on domestic violence were selected for this study. Women aged between 15 and 49 years, who were or have been married to a partner and who provided information on IPV were included in the analysis. We also extracted socio-economic variables and living conditions for each household, such as the age and education level of both partners and household wealth level.

The publicly available population data used in this study have been reviewed and approved by the institutional review board of ICF Incorporated.

Exposure data

We utilized the Dartmouth Flood Observatory database to assess exposures to individual flood events, a resource widely used in previous research[47,74]. The Dartmouth Flood Observatory database is a comprehensive archive of all confirmed flood events worldwide since 1985 (http://floodlist.com/). The database recorded the dates, duration and impacted regions of global flood events from various verified sources including local news report, satellite imagery and governmental records.

To match the flood database with the spatial information of each cluster, we used statistical and spatial analytic tools from the geopandas (version 0.11.0) and pandas (version 1.4.1) packages on the Python platform (version 3.8.10). We matched three exposure variables based on flood data: 'total flood exposure' (binary variable) indicating whether the respondent experienced a flood in 12 months before the interview; 'number of experienced flood events' (continuous variable) refers to the cumulative number of flood exposures in the past year; and 'number of flood exposure days' (continuous variable) denotes the cumulative number of days when respondents were exposed to flooding in the past year.

Temperature and precipitation were obtained from ERA5 dataset, the fifth-generation atmospheric reanalysis of global climate produced by the Copernicus Climate Change Service at European Centre for Medium Range Weather Forecasts[75]. These data provide hourly estimates of numerous climate variables. We calculated the averages of daily mean temperature and daily cumulative precipitation for the entire study period and matched annual average temperature and cumulative precipitation for the past 12 months based on the geocoded addresses of clusters where the interviewed women's households were located.

Statistical analyses

After excluding records with missing key individual information and geographic data, we matched individual flood exposure based on the interview dates and household coordinates with flooding periods and areas. We then excluded countries without any flood exposure records in the year preceding the survey period (Supplementary Fig. 1).

We used a generalized linear mixed-effects model to examine the association of flood exposure with the prevalence of IPV and its three categories over the past 12 months[12]. For total flood exposure, we estimated the percentage difference in IPV prevalence, along with its 95%CI, among women who experienced flood exposure in the past 12 months compared with those without flood exposure in the same period. For the number of flood events and the number of flood days, the associations were estimated as the percentage differences and 95%CI in IPV prevalence corresponding to each unit increase of exposure (per event or per day). Meteorological factors (annual average temperature and cumulative precipitation over the past 12 months), socio-demographic factors (age, education and marital status) and household socio-economic factors (household income, residential area and housing materials) were incorporated into the model as covariates. These covariates were empirically identified on the basis of previous researches[12,20,40,62]. We further included the country as a random-effect variable, as respondents within the same country may share similar geographic and socio-economic characteristics. The effect of flood exposure was estimated as follows[76]:

$$\text{Percentage difference} = (e^{\beta} - 1) \times 100\% \quad (1)$$

$$\text{Lower 95\%CI of percentage difference} = (e^{\beta - 1.96 \times \text{SE}} - 1) \times 100\% \quad (2)$$

$$\text{Higher 95\%CI of percentage difference} = (e^{\beta + 1.96 \times \text{SE}} - 1) \times 100\% \quad (3)$$

$$\text{OR} = e^{\beta} \quad (4)$$

$$\text{Lower 95\%CI of OR} = e^{\beta - 1.96 \times \text{SE}} \quad (5)$$

$$\text{Higher 95\%CI of OR} = e^{\beta + 1.96 \times \text{SE}}, \quad (6)$$

where β is the regression coefficient from the linear mixed-effects model and SE is the standard error of β.

We also conducted stratification analyses based on household-level and intra-household variables to examine their potential modifications on the flood–IPV association. We evaluated variables such as the residential region, household's wealth level and the age and educational level of both partners on the basis of previous studies[12,20,40,62]. These indicators could reflect the social position of the respondent or her partner, suggesting societal inequality[62]. We categorized the residential location as 'urban' or 'rural' area. A household was designated as 'rich' if its wealth level was at or above the medium level, and as 'poor' if below. Individuals older than the average of all respondents of the same gender were classified as 'old' and those with higher education levels as 'high'. To explore the modification effects of intra-household inequality, we included age and education differences between the respondent and her partners as key moderating factors. If the woman was younger than her partner, the variable was labelled 'younger than partner'; otherwise, it was labelled 'not younger than partner'. Similarly, education differences were labelled as 'higher education than partner', 'lower education than partner' or 'same education' according to the difference of education between partners. We further examined the difference in effect estimates between subgroups and its 95%CI as[76]

$$(P_1 - P_2) \pm 1.96\sqrt{\text{SE}_1^2 - \text{SE}_2^2}, \quad (7)$$

where P_1 and P_2 are the percentage difference estimates of flood-related IPV in two subgroups, and SE_1 and SE_2 are their standard errors, respectively.

To further test the robustness of our estimations, we conducted several sensitivity analyses. First, we reintroduced countries with no flood exposure in the past year in the DHS database into the analysis.

Second, we excluded annual cumulative precipitation and annual mean temperature from the main model. Third, we removed household wealth level from the main model. In addition, we also adopted a leave-one-out cross-validation approach[77–79] to identify potential influential data and to examine the robustness of the model. In this method, data from each country were excluded from the dataset one at a time, and the model was reevaluated to assess the impact of excluded data on the overall estimations.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Data on IPV are publicly available from The DHS Program (https://www.dhsprogram.com/). Flood data are publicly available from The Flood Observatory (https://floodobservatory.colorado.edu/). Temperature and precipitation data are obtained from ERA5 (https://cds.climate.copernicus.eu/).

Code availability

Custom code that supports the findings of this study is available from the corresponding author upon request.

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Author contributions

R.C. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: R.C. Acquisition, analysis or interpretation of data: Y.G. and Y.Z. Drafting of the manuscript: Y.G., Y.Z. and Z.F. Critical revision of the paper for important intellectual content: Y.G., Y.Z., Z.F. and R.C. Statistical analysis: Y.G., Y.Z., H.K., C.H., L.Z. and J.B. Obtained funding: R.C. and H.K. Administrative, technical or material support: R.C. Supervision: R.C.

Competing interests

The authors declare no competing interests.

Additional information

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Software and code

Policy information about availability of computer code

Data collection	Data on intimate partner violence is publicly available for The Demographic and Health Surveys Program (https://www.dhsprogram.com/). Flood data is also publicly available from The Flood Observatory (https://floodobservatory.colorado.edu/). Temperature and precipitation data are obtained from ERA5 (https://cds.climate.copernicus.eu/). No specific software is needed.
Data analysis	Custom code were used to match the flood database with the spatial information of each individual's living cluster by adopting spatial analysis tools and statistical tools from the geopandas (version 0.11.0) and pandas (version 1.4.1) packages from the Python platform (version 3.8.10). Statistical analysis was also conducted via custom code in the R platform (version 4.0.3). All tests were two-sided with an alpha error level at 0.05.

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Research involving human participants, their data, or biological material

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Reporting on sex and gender	Demographic and violence data were collected from the DHS program. This study focused on intimate partner violence, which is a significant part of violence against women. Our findings apply primarily to individuals with partners and whose biological sex is female.
Reporting on race, ethnicity, or other socially relevant groupings	Socio-demographic factors (age, education), and household socio-economic factors (household income, type of area) were incorporated into our model as covariates. These factors were extracted from the DHS dataset. Studies have shown a possible link between the above factors and intimate partner violence.
Population characteristics	The average age of the 340,955 respondents included in the final analysis was 32.9 years old, and the average age of their partners was 38.3 years old. 80.21% of the respondents were younger than their partners and 87.75% had no higher education than their partners. 25.94% of the respondents had experienced at least one instance of any form of intimate partner violence in the past year.
Recruitment	The Demographic and Health Survey adopted a two-stage cluster sampling strategy. Firstly, urban and rural areas are stratified for each country included in the survey. Within each stratum, a cluster is selected independently with probability proportional to its size. Secondly, a complete list of households is created for each selected cluster, using equal probability sampling to select a certain number of households to be surveyed. In each selected household, a questionnaire to identify women aged 15–49 years and further interviews are completed by trained fieldwork staff.
Ethics oversight	This study compiled with ethical standards, with publicly available demographic data reviewed and approved by the ICF Institutional Review Board.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

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Study description	We designed a cross-sectional study using generalized linear mixed effect model based on the Demographic and Health Surveys database to examine the association between flood exposure and intimate partner violence and further explore potential effect modification of socioeconomic factors.
Research sample	This study included 340,955 ever-partnered women aged 15-49 from 31 low- and middle-income countries from the Demographic and Health Surveys database.
Sampling strategy	We originally collected 413164 women from 62 DHS surveys from 2008 to 2021 globally. After excluding women without key information and flood exposure in the past year, a total of 340955 ever-partnered women aged 15–49 years were finally included in this study.
Data collection	Data on intimate partner violence is publicly available for The Demographic and Health Surveys Program (https://www.dhsprogram.com/). Flood data is also publicly available from The Flood Observatory (https://floodobservatory.colorado.edu/). Temperature and precipitation data are obtained from ERA5 (https://cds.climate.copernicus.eu/).

Timing and spatial scale	The data include the time period from 2008 to 2021 in 31 low- and middle-income countries from the Demographic and Health Surveys database.
Data exclusions	We first excluded women without key personal information like age or education as well as location for exposure matching. Then we excluded women in countries without flood exposure in the past year,
Reproducibility	The results of this study were verified by sensitivity analysis.
Randomization	We conducted stratified analysis based on the socio-economic characteristics of the respondents. Confounders are controlled as covariates in generalized linear mixed effects models.
Blinding	This study did not involve blinding. This study was observational in nature, and all exposure and outcome variables were matched according to latitude and longitude information without subjective bias. For the different subgroups, we also used the same model setup for the analysis to ensure the objectivity and fairness of the results.

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Seed stocks	*Report on the source of all seed stocks or other plant material used. If applicable, state the seed stock centre and catalogue number. If plant specimens were collected from the field, describe the collection location, date and sampling procedures.*
Novel plant genotypes	*Describe the methods by which all novel plant genotypes were produced. This includes those generated by transgenic approaches, gene editing, chemical/radiation-based mutagenesis and hybridization. For transgenic lines, describe the transformation method, the number of independent lines analyzed and the generation upon which experiments were performed. For gene-edited lines, describe the editor used, the endogenous sequence targeted for editing, the targeting guide RNA sequence (if applicable) and how the editor was applied.*
Authentication	*Describe any authentication procedures for each seed stock used or novel genotype generated. Describe any experiments used to assess the effect of a mutation and, where applicable, how potential secondary effects (e.g. second site T-DNA insertions, mosiacism, off-target gene editing) were examined.*