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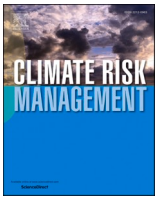

The role of gender in firm-level climate change adaptation behaviour: Insights from small businesses in Senegal and Kenya

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ABSTRACT

Literature on gender and climate change adaptation tends to propose that women are both especially vulnerable to climate change and especially valuable to climate change adaptation, but these ideas have been little considered in the context of adaptation within small businesses and have rarely been tested through quantitative empirical analysis. This paper responds to this gap within existing literature and explores how female representation in the ownership or management structures of micro and small businesses shapes firm-level adaptive capacity, as implied through adaptation behaviour. Using firm-level survey data from semi-arid regions of Senegal and Kenya, we employ a Poisson regression model to empirically investigate how female representation in ownership and management of micro and small businesses affects adoption of firm-level sustainable and unsustainable adaptation strategies, with increasing exposure to extreme weather events. Our results show that businesses with female leadership that faced a larger number of extreme events adopt more sustainable and fewer unsustainable strategies than those with only male leadership. We interpret this result recognising that unsustainable adaptation strategies, such as selling business assets, require a business to have access to business assets and resources and thus are an outcome of a business' coping capacity. Consistent with literature, we then identify that adaptation assistance can mitigate some of the harmful effects of climate shocks and additionally support micro and small businesses with female leadership to adopt more adaptation strategies (both sustainable and unsustainable) – and to a greater extent than businesses with only male leadership. Results evidence the value and efficiency of developing an inclusive business enabling environment for adaptation that targets women entrepreneurs, not just for delivering on equitable climate justice agendas, but also for strategic upscaling of resilience.

1. Introduction

Micro, small and medium enterprises (SMEs) are crucial for livelihoods and employment opportunities and play a key role in the African business landscape and in inclusive growth (Abisuga-Oyekunle et al., 2020; Crick et al., 2018b; Endris and Kassegn, 2022).

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They contribute to local economic development, including through economic growth and poverty reduction. They are also often the most realistic livelihood opportunity for a wide range of disadvantaged groups, including women and youth, who face additional barriers to accessing other forms of employment (Chrysostome et al., 2024; Gannon et al., 2022). SMEs also dominate the business landscape. In Senegal, for example, they represent 90 % of all enterprises (USAID, 2017).

Yet SMEs in Sub-Saharan Africa, hereafter called 'Africa', are highly exposed to climate risk, and often experience climate extremes causing wide-ranging impacts on their business activities (Crick et al., 2018a). SMEs in Africa, particularly in rural areas, are often concentrated in agricultural sectors, and the impacts of extreme climate events interact and propagate along agricultural value chains, including through effects on supply and demand (Carabine and Simonet, 2017). However, research has shown that even fairly moderate climate events can produce wide-ranging but under-recognised impacts on businesses across a range of rural and urban sectors through events such as flooding, water supply disruption and hydroelectric load shedding (Gannon et al., 2018; Siderius et al., 2018). The importance of business-level adaptation is therefore increasingly recognised in policymaking and academia, including in the context of climate justice agendas.

Literature highlights that businesses in Africa are generally highly aware of the climate risks that they face and tend to take action to try to manage climate risk within their operations. In some businesses, this includes taking steps to try to prepare for future climate change (Crick et al., 2018a). However, business level adaptive capacity is often very constrained by wide ranging deficits in African business enabling environments (Crick et al., 2018b). Additionally, the effectiveness of adaptation actions in establishing resilience to climate risks varies.

Various distinctions are made between different types of adaptation in existing literature, including reactive vs. proactive, autonomous vs. planned, and incremental vs transformative adaptation (Ara Begum et al., 2022). At the business level, Crick et al. (2018a) made a distinction between sustainable and unsustainable adaptation behaviours – depending on whether an action seeks to maintain business operations at existing levels (and thus implies no reduction in future capacity to adapt to weather shocks), or if it results in a temporary (or sometimes permanent) reduction in business activity. Unsustainable adaptation behaviour, as outlined in Crick et al. (2018a), constitutes coping behaviour, because it helps businesses to address immediate needs and withstand and minimise the negative impacts of shocks and stressors in the short term (c.f. IPCC, 2018). However, coping behaviour can prevent businesses from engaging in long-term adaptation and, crucially, since unsustainable adaptation as defined in Crick et al. (2018a) results in a contraction in business activity, it may harm a business' ability to absorb future shocks. Comparatively, sustainable adaptation behaviour is an indicator of adaptive capacity and longer-term resilience.

This paper adopts Crick et al.'s (2018a) definition of sustainable and unsustainable business level adaptation behaviours, to consider how female gender representation in the management and ownership of a business impacts adaptation and resilience outcomes. We do this since the literature emphasizes that climate change has very disparate impacts on different social groups who, in turn, have different adaptive capacities and preferences. Different dimensions of social identity, such as gender, age, ethnicity, socioeconomic status, social roles, marital status, livelihood, caste and geographical location, shape exposure to climate shocks and condition access to the resources that shape adaptive capacity and vulnerability (Nyukuri, 2016; Omolo, 2010; Rao et al., 2019a).

These dimensions of identity and social difference interact and can produce concurrent – and compounding – forms of inequality, as reflected in the feminist concept of intersectionality (Crenshaw, 1989; Kaijser and Kronsell, 2014). The way in which gender shapes differences in vulnerability and adaptive capacity to climate risks therefore cannot be understood in isolation from it's interactions with multiple other dimensions of identity and social difference. Yet quantitative analyses of adaptation behaviours often struggle to account for the complexity of intersecting social differences due to limitations in data disaggregation and the methodological challenges of isolating their effects in econometric models.

Given these constraints, this study focuses specifically on the role of gender within business leadership in adaptation decision making. Gender has been widely recognised as a critical factor shaping adaptation outcomes, particularly in entrepreneurial contexts, where gendered barriers and enablers to private sector adaptation shape access to resources, decision making power and business opportunities. Literatures have shown that cultural norms and established gender roles influence the types of business activities that women are likely to be concentrated in and constrain female entrepreneurs' ability to access key resources for adaptation and to participate in adaptation and business decision-making processes (Awiti, 2022; Gannon et al., 2022; Ndlovu and Mjimba, 2021; Rao et al., 2019b).

Literature in different contexts and geographical regions has also found that there are often differences in adaptation behaviour between men and women (Codjoe et al., 2012; Djoudi and Brockhaus, 2011; Jost et al., 2016; Swai et al., 2012; Van Aelst and Holvoet, 2016) and that gender often shapes different climate risk perceptions and preferences (Sanaul Haque et al., 2023). Yet there has been limited empirical research that has explored gender dimensions of adaptation behaviour at the business level, with most focused at the household level, and very little robust quantitative analysis. This is particularly problematic in Africa, where women are thought to have the highest rate of entrepreneurial activity globally (Chrysostome et al., 2024).

This paper contributes to this gap in the literature by exploring how female gender representation at the business level impacts the propensity of a business to undertake (un)sustainable adaptation behaviour. Crick et al. (2018a) found that repeated exposure to extreme events among SMEs in Kenya and Senegal is associated with a higher likelihood of a business engaging in more adaptation action. However, they also found that the otherwise almost linear link between climate stress and businesses undertaking *sustainable* adaptation behaviours levels off among firms that have faced three extreme events or more, suggesting an erosion of adaptive capacity. Given this effect of exposure on adaptation behaviour, we also consider how gendered propensity to (un)sustainable adaptation varies in the context of increasing exposure to extreme weather events.

To do this we employ a Poisson regression model to examine a sample of survey data from 325 SMEs in semi-arid regions of Senegal and Kenya. Our results suggest that firms with female representation in their leadership (women-led and mixed-gender-leadership

businesses) are less likely than businesses with male-only leadership to employ unsustainable adaptation behaviours, and more likely to employ sustainable adaptation behaviours, in the context of increasing exposure to extreme events. Since access to factors enabling adaptation can also be gendered-differentiated, we also investigate how access to adaptation assistance and training influences adaptation behaviour between businesses with, and without, female leaders.

The structure of the paper is as follows. Section 2 provides the analytical and literature context to the role of gender in private sector adaptation in Africa and introduces our approach. The subsequent sections discuss our empirical strategy (section 3) and the results (section 4). Section 5 discusses the findings, and finally, section 6 concludes.

2. Gendered dimensions of adaptation at the business level

2.1. Women entrepreneurs face a 'triple differential vulnerability' to climate change

Women entrepreneurs in Africa are generally considered to be particularly at risk from the impacts of climate change. Recognising that climate risk results from the interaction of vulnerability, exposure and the occurance (or likelihood) of climate-related hazards (IPCC, 2018), this differential risk profile occurs at the level of exposure and vulnerability. Traditional gender roles and responsibilities, coupled with additional barriers to entrepreneurship, mean women entrepreneurs are often involved in small-scale livelihood activities and sectors, such as agriculture, small-scale agricultural processing, informal trade, and hospitality; sectors that are highly vulnerable to climate disruption (Awiti, 2022; UN Women, 2018). Some literature also suggests that women are more likely to be confined to more marginal, degraded or flood-prone land that is less resilient to climate shocks (e.g. Davies, 2017; Djoudi and Brockhaus, 2011). Additionally, women entrepreneurs are also often responsible for tasks at the household level, such as water fetching, food preparation and childcare, that are susceptible to disruption through climate variability and extreme weather events and which may limit the time, mobility and resources that women have to manage climate risks within their businesses or diversify their livelihoods (Agol et al., 2023; Atela et al., 2018; Awiti, 2022; Diop et al., 2022).

Gender also shapes barriers to adaptation within the business itself and the broader business enabling environment. Businesses need to have the incentives, resources, knowledge, and skills to adapt to climate change (Fankhauser et al., 1999), and the ability of businesses to adapt effectively is highly influenced by the external business enabling environment, as well as by internal firm characteristics. This includes businesses' ability to access supportive policies, information, technologies, infrastructure, markets, and finance (Crick et al., 2018b).

In recent years, there has been a surge in political commitments focused on redressing gendered disadvantage in wide-ranging policy areas among national and international governments and development institutions. Indeed, gender-inclusion often forms a fundamental aspect of design and evaluation criteria in development programming (Lau et al., 2021). As such, adaptation and development institutions often implement actions and policies directly targeted at women. Some studies have suggested that such gender mainstreaming actions have led to women, in some contexts, having greater access to public services and other community-based and government-funded development and entrepreneurship programmes than men (e.g. Ado et al., 2019; Mersha and Sriram, 2019).

Nevertheless, the effectiveness of gender mainstreaming in policy and development programming is often viewed as disappointing (Acosta et al., 2020; Ampaire et al., 2020; Lau et al., 2021; Odera and Mulusa, 2020). Development programming targeting the poorest and most vulnerable is often more challenging and costly to implement. Moreover, micro and small enterprises in informal (unregistered) sectors – where many women's businesses are located – have often not been well recognised as economic actors and tend to be overlooked in private sector adaptation and development policies (Gannon et al., 2020). Thus, literature suggests that women entrepreneurs in Africa continue to face a differential disadvantage in access to training (Rao et al., 2019a), finance (Adegbite and Machethe, 2020; Shibia, 2024; Singh and Belwal, 2008), markets (Stevenson and St-Onge, 2005), assistance (Ado et al., 2019; Mersha and Sriram, 2019), technology (Achandi et al., 2018; Witinok-Huber et al., 2021), and climate information (Carr and Onzere, 2018) among other factors.

The effects of concurrent forms of inequality often add up to more than the sum of their parts. This is manifest in gender differential vulnerability to climate change within the private sector where differential disadvantage across multiple facets of business enabling conditions for adaptation interact and compound (Gannon et al., 2022c.f. Ayanlade et al., 2023). For example, women's more limited mobility to travel within and between regions means they are often less likely to attend trainings and observe climate-resilient business practices directly, or to access large and diverse social and business networks which support access to new information and the acquisition of new business and adaptation skills (Mayoux, 1995; Nyantakyi-Frimpong, 2019; World Bank, 2014). These challenges are also likely to constrain business growth, as well as the financial resources and collateral to access technologies for adaptation or business development and will be amplified and mediated by the concurrent effects of other forms of intersectional inequality.

These factors led Gannon et al., (2022: 1) to suggest that women entrepreneurs face a "triple differential vulnerability" to climate change, wherein they: 1) are often more sensitive to climate risk as a result of their concentration in certain sectors, activities, geographies and types of enterprises (e.g. micro businesses in agricultural production in remote regions); 2) face additional barriers to adaptation across policy, institutional, regulatory and financial environments and in accessing supportive infrastructure, markets, technology, data, information and training; and 3) are also on the frontline of managing climate risk at household levels.

2.2. Gender shapes adaptation choices and preferences

Alongside literature which suggests that women are especially vulnerable to climate change, is a parallel and integrated thesis

which indicates women's potential as strategic actors in strengthening inclusive resilience and suggests that women may also be especially valuable in adaptation. Much of the literature that focuses on the role of women's empowerment in fostering resilience is grounded in traditional participation rationales which propose that incorporating diverse knowledges, experiences, and values into adaptation efforts fosters innovation and leads to more robust outcomes (e.g. Kaijser and Kronsell, 2014; Quisumbing et al., 2014). However, some literature goes further and begins to suggest that, in some contexts, women may be more likely to engage in adaptation actions that are comparatively more sustainable, equitable or effective than those pursued by men, based on their unique knowledges, experiences, and values.

Studies in behavioural economics and psychology have, for example, suggested that women tend to have a more precautionary approach to risk management, and stronger aversion to inequality in their policy preferences (Engel, 2011), which may mean that women are more likely to prioritise adaptation strategies that minimise uncertainties. In entrepreneurship contexts, meanwhile, literatures have linked female and gender-diverse business leadership with adoption of more environmentally responsible business practices (Kassinis et al., 2016; Lu and Herremans, 2019) and greater innovation (Wu et al., 2021).

These literatures have been concentrated in WEIRD – Western, Educated, Industrialized, Rich and Democratic – countries (e.g. Arun and Rojers, 2020), and there can be no assumption of transferability of findings across culturally and contextually diverse contexts. Indeed, research indicates strongly that gender differences in individual and social risk-taking are likely to be culturally specific (Friedl et al., 2020). Nevertheless, literatures in Africa have found gender can shape different perceptions of climate change (Habtemariam et al., 2016; Mason and Agan, 2015) and different adaptation preferences, knowledges, and responses (Codjoe et al., 2012; Kom et al., 2020; Smucker and Wangui, 2016).

Some literature in African contexts has also begun to suggest that gendered adaptation knowledge and preferences may position women well for finding equitable, resilient and nature-based solutions to socio-climatic risks in Africa. Djoudi and Brockhaus, (2011), for example, posit this thesis within their study of women in livestock-dependent communities in northern Mali. They suggest that women's focus on ensuring household wellbeing results in a long-term perspective in their adaptation preferences, which leads them to focus on adaptation options oriented around household educational investments and decreasing livelihood dependency on natural resources. Codjoe et al. (2012) similarly find that women's traditional roles as providers of household food and water security motivates them to implement adaptation actions that prioritise household needs. A case study of small-scale farmers in South Africa, meanwhile, found that households headed by female farmers are more likely to employ new crops and crop diversification in response to climate variability and change (Kom et al., 2020).

Notably, literatures link women's potential contribution in climate change adaptation, inclusive development and disaster risk reduction to their experiences of historical exclusion, social disadvantage and longstanding advocacy for social justice (Enarson, 2013; Smucker and Wangui, 2016). Moreover, caution is needed to avoid essentialising characteristics as inate and universal qualities of being female, which would fail to account for the intersectional differences that shape gendered vulnerabilities and resilience and may have unintended and even counterproductive consequences on progress towards gender equality (Lau et al., 2021; Leach, 2007). Nevertheless, our study departs from these literatures recognising that empirical evidence on women's roles in shaping sustainable or equitable adaptation or development outcomes in Africa is generally linked to their societal roles as caretakers, rather than considered in the context of entrepreneurship.

Contributing to this gap in existing literature, this study analyses how gender-differentiated businesses adapt to extreme climate events. We do this considering sustainable adaptation an indicator of adaptive capacity and unsustainable adaptation a potential indicator of coping capacity, but also of more limited long-term resilience. Moreover, we look at the effect of access to key aspects of business enabling environments for adaptation on business adaptation behaviours. We focus this latter part of the analysis on business access to adaptation assistance and training, which the literature suggests can be highly gendered.

The existing literature suggests that gender – and its interactions with other determinants of vulnerability – may enable *or* constrain firm-level adaptive capacity and sustainable adaptation. Nevertheless, evidence on gender barriers to business development and adaptive capacity is widespread, historically persistent and varied in its forms. Thus, broadly speaking, we anticipated the resulting impacts of weather extremes on adaptive capacity to be more strongly conditioned by gender-differentiated barriers in the enabling environment, than by any strategic role that women may play in supporting sustainable adaptation behaviour. For these reasons, we embarked on this study not only expecting gender to shape adaptation behaviour at firm-level, but also expecting businesses with female leadership to have more limited adaptive capacity.

3. Research design and methodology

3.1. Empirical strategies

The adoption of sustainable and unsustainable adaptation strategies by SMEs is shaped by their exposure to climatic events in addition to their adaptive capacity (Crick et al., 2018a). According to Crick et al., 2018b, adaptive capacity is represented by a set of internal firm characteristics and factors within the external business environment. We built on this premise to investigate how female representation in the leadership of micro and small businesses affects their adoption of adaptation strategies. Specifically, we empirically investigate: 1) how female representation in the ownership and management structures of micro and small businesses in semi-arid regions of Kenya and Senegal affects their adoption of sustainable and unsustainable adaptation strategies, with exposure to extreme climate events; and 2) the mitigating effects of training and adaptation assistance.

First, in the context of their respective adaptive capacity, exposure to climate events and gender representation, businesses decide how many sustainable and unsustainable adaptation strategies to adopt. Here, our outcome variables are count variables: numbers of

sustainable and unsustainable strategies. While the population regression that we estimate takes the form $E(y|x)$, the linear model $E(y|x) = x\beta$ might not provide the best fit over all values of the explanatory variables. Although the outcome variables are strictly non-negative, there can be values of x such that the predicted value of y can be negative, i.e., $x'\widehat{\beta} < 0$. In this case, the ideal approach is to adopt a Poisson regression model that possesses the desirable features especially in count data contexts. In fact, conditional maximum likelihood estimators are fully efficient if $E(y|x)$ follows a Poisson distribution.

Therefore, we fit the following Poisson regression model:

$$y_{id} = \exp\left(\beta_1 N_{id} + \beta_2 N_{id}^2 + \beta_3 F_{id} + \beta_4 N_{id} \times F_{id} + \beta_5 N_{id}^2 \times F_{id} + \alpha_d + \boldsymbol{z_{id}}\delta + u_{id}\right), \tag{1}$$

where y_{id} represents the number of sustainable (or unsustainable) strategies by the business i in district d, N_{id} denotes the number of extreme weather events experienced, and F_{id} denotes female representation in management or ownership. α_d are district fixed effects and $\boldsymbol{z_{id}}$ includes a set of controls representing internal firm characteristics and the external business environment. We elaborate on these variables in the following section. The error u_{id} is further allowed to be heteroskedastic and correlated within district and distance-to-market groups.[1]

Since $\exp(.)$ is always positive, equation (1) ensures that predicted values for y_{id} will also be positive. We are interested in the joint effect of the estimated coefficients of the interaction terms, i.e., $\widehat{\beta}_4$ and $\widehat{\beta}_5$, that shows the additional number of adaptation strategies the business experiences due to female representation when exposed to climate events.

Using the Poisson distribution necessarily assumes that the conditional variance and mean are equal. That is, $Var(y|x) = E(y|x)$. However, this Poisson variance assumption of the variance-mean equality often does not hold. Appendix Table A3 reports the results of the test for overdispersion, concluding that our main specification does not suffer from it. Nonetheless, we also report negative binomial and zero-inflated Poisson regression results as robustness tests that would address this potential overdispersion problem, if any.

We next investigate the potential mitigating or exaggerating effects of adaptation assistance and training. Both these variables are included in z_{id} in equation (1), which are now excluded from z_{1id}. We include additional interactions to equation (1) according to:

$$y_{id} = \exp\left(\beta_1 N_{id} + \beta_2 N_{id}^2 + \beta_3 F_{id} + \beta_4 N_{id} \times F_{id} + \beta_5 N_{id}^2 \times F_{id} + \gamma_1 N_{id} \times M_{id} + \gamma_2 N_{id}^2 \times M_{id} + \gamma_3 F_i \times M_{id} + \gamma_4 N_{id} \times F_i \times M_{id} + \gamma_5 N_{id}^2 \times F_{id} \times M_{id} + \alpha_d + \boldsymbol{z_{1id}}\delta + u_{id}\right), \tag{2}$$

Here in equation (2), γ_3, γ_4 and γ_5 denote the mitigating or exaggerating effects of adaptation assistance or training (M_{id}). All other variables and estimation strategy are as described for equation (1).

3.2. Data

We use the dataset collected in 2016 by Crick et al., (2018a) that comprises 325 SMEs. The dataset covers the Senegalese regions of Louga, Saint Louis and Kaolack and the county of Laikipia in Kenya. These are semi-arid regions with annual rainfall between 500 and 800 mm. These regions experience high climate variability and extremes, which are expected to increase in the coming decades (IPCC, 2014). Semi-arid lands in Kenya (Ouma et al., 2018) and Senegal (Wade et al., 2015) are experiencing decreasing annual rainfall and steady warming patterns. Our data records self-reported weather extremes that SMEs experienced in the previous five years, and shows that SMEs in the sample are mostly affected by drought. Other types of events in the dataset are flooding; extreme rainfall events and storms; extreme heat; extreme cold; and extreme windstorms and dust. Diop et al. (2022) and Agol et al. (2023) interviewed women entrepreneurs in some of these regions, and found consistent overlap between the events identified in the survey and those that the interviewed women highlighted as the most severe events affecting their businesses.

For our analysis, we restricted the sample to relatively homogenous businesses in terms of size, exposure to climate events, and ownership structures. We excluded businesses that were exposed to more than 8 extreme events in the previous five years (this only removed one outlier), and/or have more than 10 employees and/or more than 5 owners. The final estimating sample consisted of 205 micro and small businesses: 125 in Kenya and 80 in Senegal, distributed among 10 districts.

The World Bank Enterprise survey methodology defines 'small' businesses as those that have 5–19 employees (World Bank, 2022). However, it is common practice in the literature to restrict this to 10 employees (e.g. Brixiová et al., 2020). Given the diversity in our original sample, we followed this convention to make the sample of businesses within the dataset more comparable, since medium firms have quite different profiles in terms of physical capital, adaptive capacity, etc. Moreover, as discussed, micro and small enterprises represent a significant portion of total employment in Africa (Dougherty-Choux et al., 2015) and are more representative of the African business landscape. Smaller businesses also tend to have lower barriers to entry, operate in local markets and make entrepreneurship more accessible to women, youth and other disadvantaged groups. Therefore, a focus on adaptation in smaller businesses is also more relevant to inform action designed to enhance inclusive climate resilient employment and economic growth agendas, as set out under the Sustainable Development Goals (SDGs) (SDG8 on Decent Work and Economic Employment; SDG 10 on Reduced Inequalities; and SDG13 on Climate Action).

[1] This is a more conservative choice than the usual assumption that the errors u_{id} are all independent and identically distributed.

3.3. Variables

Following Crick et al., (2018a), we categorize adaptation strategies into sustainable and unsustainable strategies. Sustainable strategies are defined as those which are aimed at business preservation and reduction of the risk and negative impacts of extreme climate shocks. We classify uptake of loans and insurance, switching to different commodities or crops, trading or farming additional commodities or crops, and switching to different varieties of the same commodities or crops as sustainable adaptation strategies. On the other hand, unsustainable strategies are defined as actions that, taken as a response to an extreme climate event, help businesses to *cope* with an event, but result in a temporary or permanent contraction in business activity. Such actions reported within our data set include reducing the number of employees, selling productive assets, selling assets at lower prices, and mortgaging assets. We define our outcome variables for equation (1) as the number of these sustainable and unsustainable strategies adopted by businesses. Table 1 reports the average number of sustainable and unsustainable strategies adopted by businesses in our sample.

Surveyed firms reported the number of extreme weather events that they had experienced in the previous five years. Examples of such events include drought, floods, extreme rainfall, storms, extreme heat, extreme cold, extreme windstorms, and major dust events. Equations (1) and (2) include the squared number of climatic extremes, to control for the potential nonlinearity in the relationship between adaptation and exposure. Most businesses experienced between 0 and 2 extreme events (76.1 %), with the average number of events experienced being 1.78, as shown in Table 1.

We construct the gender variable in terms of representation of women in the ownership and management of the business. The variable takes the value of 1 if there is at least one female owner and/or if the main manager of the firm is a woman, and 0 otherwise. The maximum number of owners in our sample is 5. Therefore, according to this definition, a firm has female representation in its leadership if at least 20 % of owners are female, and/or the firm is managed by a woman. This definition allows us to have a balanced sample, where around half of the businesses in the sample have female representation in their leadership. Moreover, this is consistent with the common measures of gender representation in SMEs such as the gender of the top manager (Ayalew et al., 2020), presence of at least one female manager (Castiglione et al., 2022) or both (Brixiová et al., 2020), and female ownership and management (as captured in the World Bank Enterprise Surveys, (World Bank Group, 2024)).

The vector of controls includes different indicators of adaptive capacity such as financial barriers, assistance, training, membership of a professional or gender-specific organisation, and market distance. These are all factors that literature has acknowledged as being not only key for adaptive capacity (Crick et al., 2018b), but that are also shaped by gender dynamics and socio-cultural roles of men and women in society (Gannon et al., 2022).

Financial barriers take the value of 1 in the dataset if the firm reported encountering any financial barriers when exposed to climate events, and 0 if not. Examples of such financial barriers include not being able to access sufficient, or any, finance, including access to finance having a condition that the business could not satisfy, like a requirement for collateral.

Businesses were asked whether they had received support of any kind (financial, material, technical or other) in the previous five years from a set of possible sources (national government, local administrations, insurance companies, NGOs, family and friends, and other businesses) to deal with the impact of extreme weather events. Our *assistance* variable takes the value of 1 if the business reports having received at least one form of financial, technical or material adaptation support from at least one source, and 0 otherwise. Table 1 shows that almost half of the firms in our sample (47.8 %) reported receiving some kind of support.

Surveyed businesses also reported whether any owner or manager received any relevant professional or vocational training since starting with this business. The dummy variable, training, is denoted as 1 if the business had received any relevant training, and 0 if

Table 1
Summary Statistics.

Variables	Description	[1] No female representation	[2] Female representation	Difference ([2] – [1])
No. of events	No. of extreme events encountered by the surveyed firms	1.806 (1.307)	1.755 (1.459)	−0.051 [0.193]
No. of sustainable practices	No. of sustainable adaptation practices adopted by the surveyed firms	0.777 (1.228)	1.127 (1.318)	0.351** [0.178]
No. of unsustainable practices	No. of unsustainable adaptation practices adopted by the surveyed firms	0.291 (0.636)	0.510 (0.865)	0.219** [0.106]
Financial barriers	If the firm encounters any financial barriers, 0 if otherwise	0.699 (0.461)	0.843 (0.365)	0.144** [0.058]
Assistance	If the firm receives any adaptation assistance	0.359 (0.482)	0.598 (0.493)	0.239*** [0.068]
Training	If the owners receive any training	0.485 (0.502)	0.559 (0.499)	0.073 [0.070]
Membership	If the firm owners have any membership to professional or gender-specific organization	0.524 (0.502)	0.539 (0.501)	0.0145 [0.070]
Market distance	Distance to market (in kilometers)	5.794 (8.479)	4.750 (7.094)	−1.044 [1.096]
No. of Observations		103	102	

Notes. We restrict the summary statistics to our estimating sample of 205 micro and small businesses with 10 or fewer employees, 5 or fewer owners, and 8 or fewer extreme weather events. Standard deviations are reported in parentheses, whereas standard errors are reported in brackets. There are 102 businesses with female representation in their management and/or ownership, and the remaining 103 businesses do not have any female representation.

not. Similarly, the membership variable takes the value of 1 if the firm owners have any membership to a professional or gender-specific organization, and 0 if not. Finally, market distance measures the reported distance, in kilometres, from the closest market.

4. Results and findings

4.1. Adaptation behaviour and gender representation in the business leadership

Our analysis combines two separate factors affecting adaptation choices: the number of extreme events that each business has experienced, and the presence of women in the firm leadership. Columns (1) and (2) of Table 2 present results where the roles of these variables are investigated separately after controlling for common district characteristics.

First, the baseline results show that as businesses experience more extreme weather events, like floods or droughts, they change the way that they adapt or respond to these challenges. Indeed, there is an inverse *U*-shaped relationship between the number of extreme events and how much businesses engage in both sustainable and unsustainable adaptation practices. These findings are supported by Crick et al., (2018a). Secondly, once we control for covariates, we see that female representation in the business leadership structure is not a significant explanatory variable by itself. As discussed in section 2, literature suggests that gender and exposure can influence adaptation choices and capacities and also that exposure can influence and be influenced by gender dynamics. Thus, to understand the extent to which gender plays a role in adaptation choices, in the context of varying exposure, our main econometric specification interacts these two variables ("Female representation" and "Number of events"). This allows us to estimate the difference female representation makes in the context of exposure to various numbers of events. All the following results control for common district characteristics, and various business-level variables, including experience of financial barriers, participation in assistance or training programs, membership of a professional or gender-specific organization, distance to the closest market, and whether all owners have an educational level below secondary education.

Table 2 also reports the Poisson regression results according to our main specification in equation (1). The dependent variables are the number of sustainable and unsustainable adaptation strategies a business reported having adopted. Although we report all the coefficients, we mainly focus on our coefficients of interest. Specifically, we are interested in understanding how gender representation in the businesses leadership influences adaptation choices in the context of varying exposure to extreme events. We use standard errors clustered at the district by distance-to-market[2] level (39 clusters) in all the specifications.

Our main results show that in the absence of any exposure to extreme events, businesses with female representation are less likely to undertake unsustainable adaptation strategies than businesses without female representation. The coefficients are visible in Table 2, but the marginal effects, which are visually easier to interpret, can be seen in Fig. 1. This gendered effect does not hold, however, as when firms are exposed to an increasing number of extreme events businesses with female representation initially become similarly likely to adopt unsustainable adaptation strategies to cope with climate shocks as businesses without female representation. This changes again within our dataset, however, when firms are faced with 5 or more extreme events. Among these firms, results again show that businesses with female leadership representation adopt a lower *number* of unsustainable strategies than firms without female representation when faced with 5 or more extreme events (see Table 2, Fig. 1).

Considering next the effects of gender and exposure to extreme events on the adoption of *sustainable* adaptation strategies, in most cases our main results do not signal clear, statistically significant gendered differences in the adoption of sustainable adaptation strategies. However, among firms that have experienced 3–4 extreme events, we do find that women-led businesses are more likely to adopt sustainable adaptation strategies. This is a relatively high number of events experienced by a firm within our sample, but it is not an outlier.

To test the strength of our results, we first considered alternative estimation strategies for equation (1). Within the Appendix, reports results for negative binomial and zero-inflated Poisson regression models. Also in the Appendix, report the results and marginal effects with plain OLS. These results are consistent with our main results in Table 2. Additionally, we considered a specification that does not assume a functional form, but models the number of extreme weather events as 3 categorical groups (0–1, 2–3, and 4–6). This more flexible non-parametric approach also yielded similar results to our main specification (see Appendix). We therefore conclude that our results are robust to alternative specifications.

As an additional robustness test, we plotted *countfit* graphs for both the number of sustainable and unsustainable adaptation strategies for the estimated results according to equation (1) and reported in Table 2. As shown in the Appendix, each of the specifications predicts the actual counts almost perfectly, suggesting that our results are not biased by the presence of outliers.

Finally, we considered the possibility that the businesses make simultaneous decisions about adopting both sustainable and unsustainable adaptation strategies. This was modelled using seemingly unrelated regression (Zellner, 1962), which estimates Equation (1) for sustainable and unsustainable strategies jointly. The results, reported in the Appendix, are consistent with our main results in Table 2 and thus show that our results reported above are robust to this change in model assumption.

4.2. Mitigating effects of assistance and training

We analysed whether assistance and training mitigate some of the adversities that businesses, with and without female leadership,

[2] To construct these clusters with the limited geographical data available we categorize distance-to-market into 5 equally sized groups: 0——0.5 km, 0.5——3 km, 3——9 km, and 9——42 km. These are then combined with the district of the business (10 in total).

Table 2
Main Results.

Variables	Baseline Results		With covariates		Main results	
	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable
No. of events	1.467***	0.588*	1.422***	0.690*	2.311**	−0.012
	(0.231)	(0.328)	(0.245)	(0.396)	(0.904)	(0.438)
(No. of events)^2	−0.264***	−0.075	−0.252***	−0.096	−0.500**	0.034
	(0.047)	(0.068)	(0.052)	(0.080)	(0.227)	(0.083)
Females	0.472***	0.591**	0.126	−0.204	0.714	−1.481**
	(0.181)	(0.282)	(0.192)	(0.288)	(0.857)	(0.672)
Females × No. of events					−1.018	1.363**
					(0.944)	(0.537)
Females × (No. of events)^2					0.289	−0.254**
					(0.233)	(0.099)
Financial barriers			−0.243	0.796	−0.304	0.704
			(0.246)	(0.568)	(0.241)	(0.587)
Assistance			0.530***	0.053	0.528***	0.079
			(0.200)	(0.293)	(0.198)	(0.293)
Training			0.428***	0.209	0.442***	0.278
			(0.163)	(0.276)	(0.169)	(0.256)
Membership			−0.256	−0.093	−0.236	−0.083
			(0.162)	(0.243)	(0.158)	(0.243)
Market distance			0.028***	0.059***	0.028***	0.061***
			(0.010)	(0.013)	(0.009)	(0.013)
Constant	−1.754***	−1.968***	−2.024***	−4.531***	−2.642***	−3.878***
	(0.295)	(0.436)	(0.497)	(1.142)	(0.856)	(1.100)
No. of Obs.	205	205	204	204	204	204
District FE	YES	YES	YES	YES	YES	YES
Pseudo-R^2	0.104	0.0417	0.216	0.234	0.226	0.251

Notes: Poisson regression coefficients are estimated according to equation (1). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the businesses. Robust standard errors clustered at district by distance-to-market group are in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

experience due to exposure to extreme events. We did this according to the econometric specification in Equation (2) and report the results in Table 3. To ease interpretation, Fig. 2 calculates the marginal effects and reports the number of additional sustainable or unsustainable strategies applied by businesses that received assistance or training (relative to those that have not), by the number of extreme events experienced, separately for those with or without female representation.

From Fig. 2.I. we can see that female-led businesses who were affected by between 2 and 3 extreme weather events (most of our sample) *and* received assistance to overcome these adversities, adopted a higher number of sustainable strategies than those that did not receive this assistance. On the other hand, among female-led businesses that received assistance, only those that faced 5 or 6 events adopted a higher number of unsustainable strategies, than those that did not receive assistance. For non-female-led businesses, receiving assistance had no effect on adoption of sustainable strategies among firms within our dataset, while there is a significant drop in unsustainable strategies when faced with 3 or more extreme weather events.

Fig. 2.II describes the differences between firms with or without training, again, separately for those with or without female representation. As shown in Panel C, we find that businesses without female representation seem to have a higher adoption of sustainable strategies when faced with only 1 extreme weather event. We find no statistical differences for businesses with female representation. On the other hand, Panel D shows that having training is linked with adopting a higher number of unsustainable strategies for those businesses that faced 2–4 extreme weather events. This is similar for firms with and without female representation, but only significant for those with it. Finally, we find that training reduces the overall number of adaptation strategies adopted among businesses without female leadership that faced 5 or 6 extreme weather events.

5. Discussion

5.1. The role of gender representation in business level adaptation behaviour and the mitigating effects of assistance and training – Implications for future research and policy

Findings in this study suggest that female representation in the ownership or management of micro and small businesses in our sample shapes firm-level adaptation behaviour. This section discusses these findings in the context of the broader literature on gender and climate change adaptation in the private sector. Here we consider what these results may indicate about how gender-specific vulnerabilities and capabilities shape sustainable adaptation decision-making practices in micro and small businesses in Africa and consider their implications for future research and policy. Specifically, we propose an interpretation of the main results (seen in Table 2 and Fig. 1), in the context of literature that, at times, depicts women in Africa as both particularly vulnerable to climate change and particularly valuable for sustainable adaptation.

These insights provide valuable perspectives – and contribute to the limited empirical evidence base – on the role of gender in

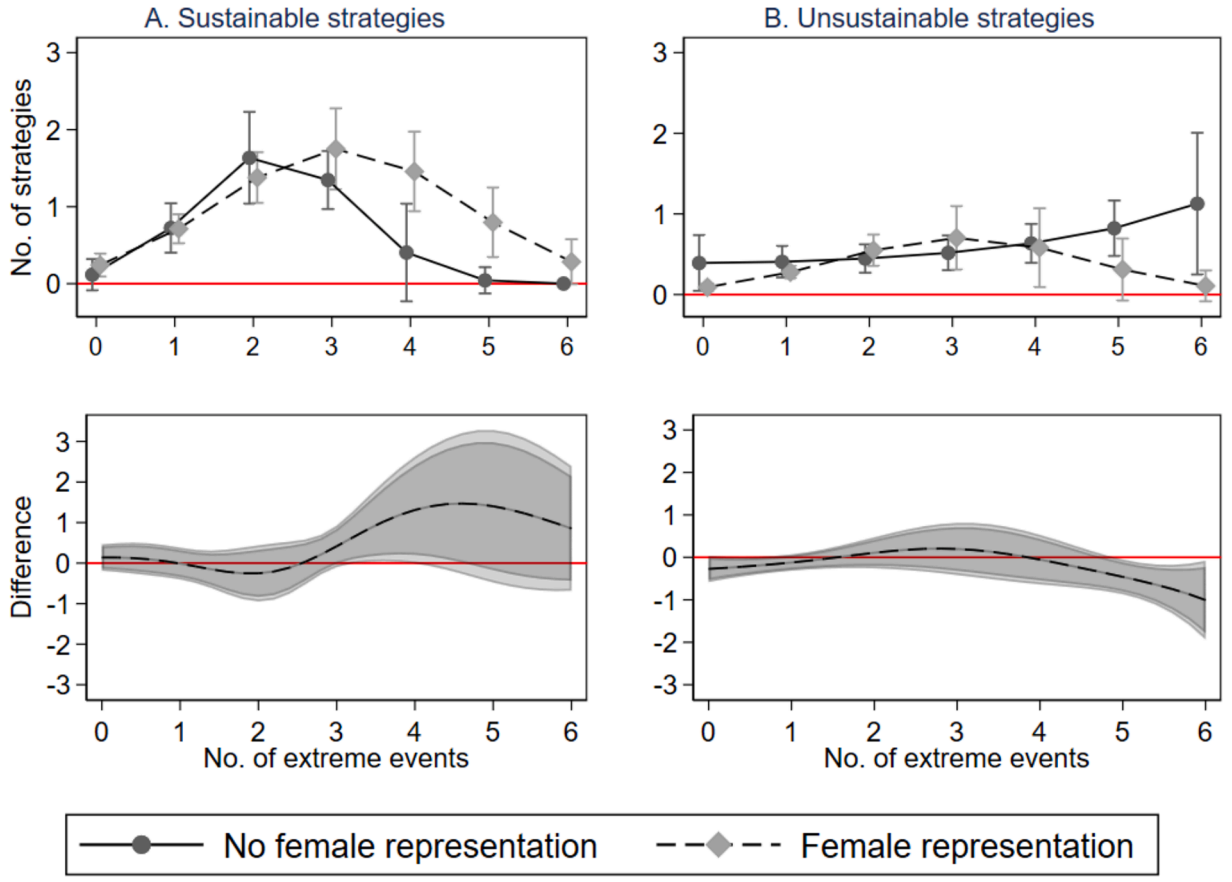

Fig. 1. Marginal effects of gender.

business adaptation, especially in the context of developing economies like Senegal and Kenya. Results must be interpreted with caution, given the study's limitations (see limitations section below). Yet, despite these constraints, results in this study highlight key avenues for further investigation and support several potential hypotheses that suggest that investments in inclusive business enabling environments for adaptation, and targeted adaptation support that addresses the specific needs of women entrepreneurs, could serve as a fruitful avenue for upscaling climate resilience within African economies. This underscores the need for further research to explore and validate these opportunities.

Our results show that, after experiencing three extreme events, businesses in our dataset with female representation in their leadership are more likely to adopt sustainable adaptation behaviours than firms without female representation. This result may initially appear surprising in the context of the literature on the differential vulnerability to climate change experienced by female entrepreneurs within the business environment. From this literature, discussed in section 2.1, gender determinants of differential vulnerability can be associated with characteristics of female-led businesses, which are not specified as control factors, and a starting assumption for this work was that women-led businesses are likely to face additional obstacles to accessing resources for adaptation.

The unprecedented political commitment at national and international levels to promote gender equality, and the adoption of gender mainstreaming policies, is one factor which the literature suggests could be interacting with this result. In this landscape, development and adaptation institutions and programmes often design targeted actions that seek to support gender equality. These actions could have led to *some* progress in mitigating gender barriers to adaptation in the business environment. Yet, as summarised in section 2.1, the extent of any such progress still appears very limited, relative to the differential disadvantage within the business enabling environment (Moser and Moser, 2005; Nhamo, 2014; Sweetman, 2012), and literature suggests that there is a significant ongoing gender gap in access to a range of enablers of business level adaptation. This is especially the case in the countries considered in this study, where the integration of gender in adaptation policy is still limited (Crick et al., 2016). Thus, gender-responsive adaptation and development programming is unlikely to entirely explain the increased propensity for sustainable adaptation among businesses with female representation observed among our sample of businesses.

Instead, we note that this finding aligns with suggestions in wider literatures that women's roles in ensuring family livelihoods, or their experiences of overcoming gender-based barriers in entrepreneurship, may make women more likely to adopt a longer-term perspective in their adaptation preferences (e.g. Djoudi and Brockhaus, 2011). It aligns with behavioural literatures which suggest that in taking a more cautious approach to risk management, women may prioritise long-term resilience over short-term gains. It also

Table 3
Mitigating effects of assistance and training.

Variables	Role of assistance		Role of training	
	Sustainable	Unsustainable	Sustainable	Unsustainable
No. of events	4.299***	0.411	5.736**	−0.625
	(1.002)	(0.541)	(2.329)	(0.666)
(No. of events)^2	−0.908***	−0.029	−1.267**	0.150
	(0.240)	(0.099)	(0.565)	(0.099)
Females	2.929**	−1.723	4.894**	−1.363
	(1.145)	(1.175)	(2.210)	(1.003)
Females´ No. of events	−3.345***	1.602	−4.864**	1.426*
	(1.106)	(1.074)	(2.361)	(0.839)
Females´ (No. of events)^2	0.770***	−0.358*	1.143**	−0.295**
	(0.256)	(0.215)	(0.571)	(0.130)
Financial barriers	−0.231	0.719	−0.434*	0.577
	(0.242)	(0.572)	(0.241)	(0.625)
Assistance	4.072***	0.071	0.530***	0.080
	(1.230)	(1.176)	(0.192)	(0.282)
Training	0.480***	0.302	5.014**	−0.920
	(0.168)	(0.239)	(2.256)	(0.933)
Membership	−0.240	−0.134	−0.222	−0.190
	(0.166)	(0.247)	(0.165)	(0.248)
Market distance	0.032***	0.061***	0.030***	0.063***
	(0.009)	(0.013)	(0.010)	(0.013)
Assistance × No. of events	−3.585***	0.105		
	(1.229)	(1.185)		
Assistance × (No. of events)^2	0.754**	−0.163		
	(0.293)	(0.283)		
Females × Assistance	−3.958***	0.772		
	(1.405)	(1.592)		
Females × Assistance × No. of events	4.180***	−1.031		
	(1.372)	(1.540)		
Females × Assistance × (No. of events)^2	−0.890***	0.400		
	(0.318)	(0.344)		
Training × No. of events			−4.191*	1.523*
			(2.418)	(0.825)
Training × (No. of events)^2			0.910	−0.322**
			(0.588)	(0.140)
Females × Training			−5.553**	−0.099
			(2.352)	(1.199)
Females × Training × No. of events			5.003**	−0.405
			(2.501)	(1.021)
Females × Training × (No. of events)^2			−1.094*	0.169
			(0.603)	(0.177)
Constant	−4.767***	−4.147***	−6.042***	−3.384***
	(1.086)	(1.166)	(2.196)	(1.174)
No. of Obs.	204	204	204	204
District FE	YES	YES	YES	YES
Pseudo-R^2	0.243	0.270	0.253	0.271

Notes: Poisson regression coefficients are estimated according to equation (2). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the businesses. Robust standard errors clustered at district by distance-to-market group are in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

resonates with literatures, in Africa and beyond, which have suggested that female firm-level leadership can support innovation (e.g. Arun and Rojers, 2020) and enhance productivity (e.g. Castiglione et al., 2022). Notably many sustainable adaptation strategies – such as switching to different commodities or crops – may require lower upfront financial investment and may be more accessible to businesses with more limited financial or material capital, than unsustainable adaptation strategies, such as selling productive assets or reducing the number of employees, which inherently require a firm to possess these assets or resources in the first place. Thus sustainable adaptation strategies, as categorised within our study, may be able to be adopted by innovative, dynamic or motivated business leaders, even if they have more limited access to resources.

We suggest that the increased propensity for businesses in our sample with female leadership to adopt sustainable adaptation strategies may also be influenced by the way we define and capture female representation in business leadership in this study. It was not possible to distinguish between female-only led and gender-diverse businesses within our dataset, or through any other publicly available dataset on adaptation in small businesses that we were able to find and access for this study. The metric used for capturing female representation within a business (at least one female owner out of a maximum of five and/or a female manager), therefore, does not isolate the experience of entirely female-led firms. Greater adoption of sustainable adaptation behaviour among businesses with female representation within their leadership may therefore reflect an advantage in adaptive capacity (such as diversity of perspectives

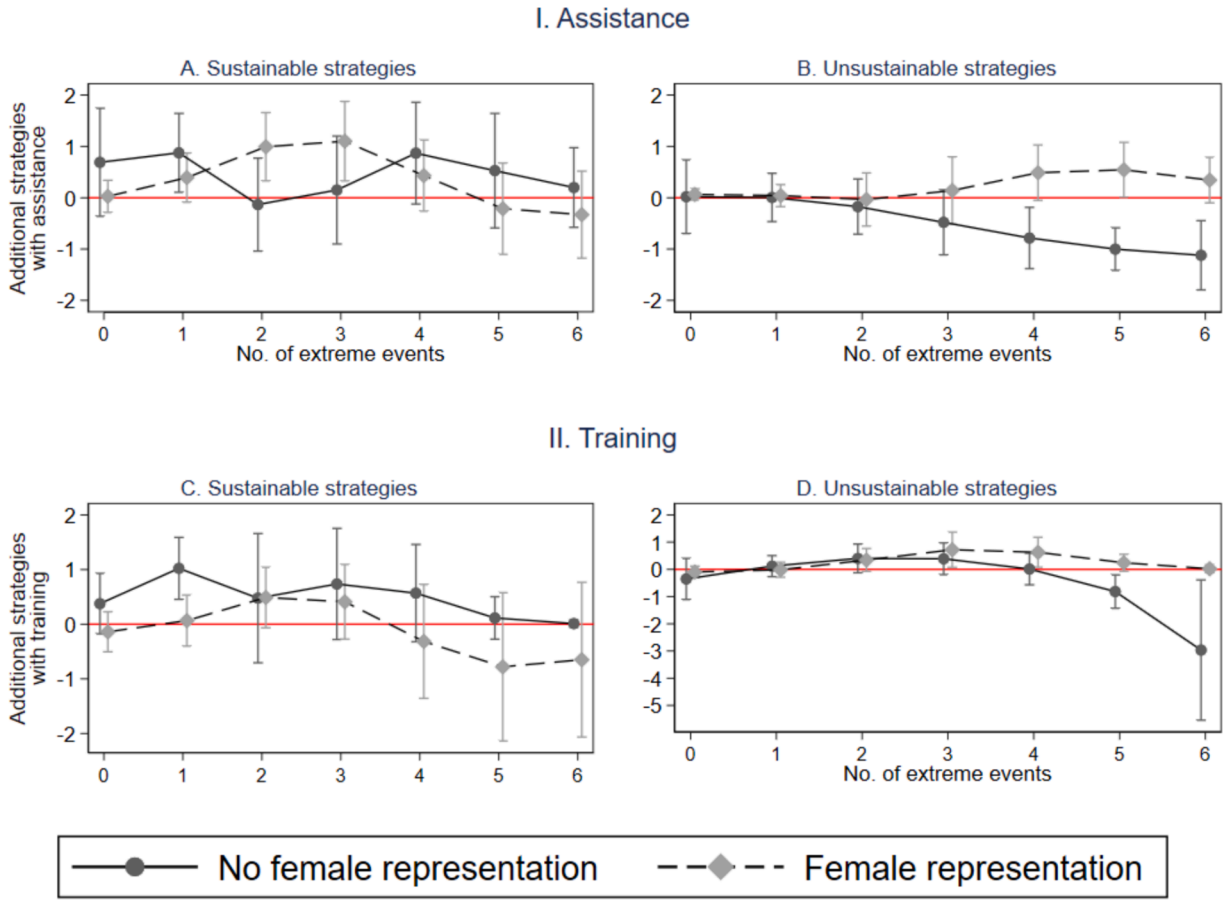

Fig. 2. Marginal effects of assistance and training.

enhancing problem-solving and creative solutions) obtained through many firms within this group having a gender-*diverse* leadership team, rather than female leadership per se.

Another striking result of our study is that male-only-led businesses in our sample are more likely to adopt unsustainable adaptation strategies, especially under increasing exposure to extreme events. Businesses with female representation in their leadership, meanwhile, appear to be initially (without exposure to extreme climate events) less likely to adopt unsustainable adaptation strategies. Recall that unsustainable coping strategies, as categorised in this paper, are likely to reduce the resources available to a business to cope with future shocks and thus have the potential to undermine longer-term business resilience. This finding, therefore, provides further opportunity to advance the hypothesis that women – or gender-diverse leadership teams – may prioritise business adaptation strategies that support the stability, sustainability and longer-term health of the business.

Our data, nevertheless, suggests that any differential propensity to avoid adopting unsustainable adaptation strategies that contract business activities, which may exist among businesses with gender-diverse leadership, does not persist once they become exposed to extreme climate events. This is to say that our data suggest that businesses with female representation in their leadership may be similarly likely to resort to coping strategies, such as selling or mortgaging assets or reducing their workforce, when they face the pressures of exposure to climate shocks. This is unsurprising in contexts where adaptive capacity, and resources to support adaptation, are generally highly constrained.

We find additional gender differentiation in the use of unsustainable adaptation responses, however, when businesses are exposed to five or more extreme events. For these businesses, those with female leadership adopt a lower number of unsustainable strategies than firms without female leadership. This finding could be interpreted in line with literature on gender differential vulnerability since unsustainable *coping* strategies such as selling or mortgaging assets or reducing numbers of employees require a business to have employees or assets to scale back or sell in the first place. Unsustainable adaptation can therefore also be interpreted as an indication of coping capacity. Businesses that have more assets to leverage or sacrifice may be more likely to engage in unsustainable adaptation strategies. In this context, our results could indicate higher coping capacity among male-only-led businesses within our sample, while women-led businesses – which are often poorer and have fewer assets (Gannon et al., 2022) – may have less ability to take these actions, if they do not have resources to liquidate in times of crisis.

The results additionally indicate that assisting businesses with female leadership in some scenarios seems to be more effective in

increasing the number of adaptation strategies that a firm is likely to adopt, than for businesses without female representation. This is generally true for both sustainable and unsustainable adaptation strategies.[3] Possible interpretations of this result could include female entrepreneurs being more receptive to assistance, or that women gain more from business assistance because of the structural disadvantages that they face in the business environment, that otherwise make it harder for them to implement adaptation.

At a low number of extreme events (0–1), assistance and training also increase the number of sustainable strategies that firms that do not have women owners or managers adopt, highlighting a more general potential for training and assistance to enhance business level innovation. But this positive effect of assistance and training disappears as the number of extreme events increases. When faced with 2 or 3 extreme weather events, female-led businesses that reported receiving assistance increased their implementation of sustainable adaptation practices. This is not the case for their male-only led counterparts. A similar result emerges for unsustainable strategies when an business faced a large number of extreme weather events (4–6), with female led businesses with training or assistance adopting a higher number on unsustainable strategies their only-male led counterparts. This suggests assistance and training may also additionally enhance the coping capacity of businesses with female leadership.

These findings indicate the importance of investments in policies and activities that support private sector adaptation, as well as the potential for these to contribute to fostering sustainable adaptation among women-led businesses. Our analysis highlights that adaptation assistance and training can support adaptation not only at the individual or household level, but at the business level as well. Additionally, our results suggest that businesses with female leadership demonstrate a higher use of adaptation strategies when provided with adaptation assistance as compared to male-only led businesses. This suggests that providing targeted adaptation assistance to female-owned or managed businesses, may be an efficient way to upscale sustainable adaptation and yield greater returns in terms of resilience-building. Women entrepreneurs often face additional structural barriers to adaptation based on broader inequalities in the business environment (Gannon et al., 2022). Investing in gender-inclusive adaptation enabling conditions and business support therefore, may offer a strategic means to address climate justice concerns while optimising the effectiveness of adaptation investments, ensuring that resources generate the most sustained and widespread resilience benefits. These conclusions are also in line with the extensive literature advocating for the importance of gender mainstreaming from substantive, instrumental and normative perspectives (c.f. Fiorino, 1989).

5.2. Limitations

Despite the robustness tests carried out within our analysis, there are various statistical, epistemological and methodological reasons why our results need to be interpreted cautiously. First, the study faces several data limitations due to the context of studying SMEs in semi-arid regions of sub-Saharan Africa. Gathering high quality datasets on adaptation practices and extreme weather impacts is costly, which led to our use of secondary data from Crick et al. (2018a). This was the best available dataset that we could find, which explored the necessary outcomes in sufficient depth. However it had a limited number of firms in the cross-section, with a limited geographic scope of semi-arid regions in Kenya and Senegal. As a result, we are limited to a relatively low number of observations, which constraints the precision of our estimates and which, although well distributed geographically (Crick et al., 2018a), are not a representative sample of businesses in Senegal and Kenya. This implies that although the results apply to these observations, the average in the population of businesses in these two countries, sub-Saharan Africa, or other developing countries might be different.

Secondly, we do not aim for our estimates to be interpreted as causal relationships. In other words, the differences that we find are not representative of the change we would expect if an individual firm went from having, to not having, female representation in its ownership or management, but the differences between both groups, at the point of data collection, after controlling for various internal business characteristics and external business environment conditions.

Third, we use self-reported exposure to extreme events and adaptation strategies. This allows individual firms to report the same physical event or business action differently based on their perceptions and exposure. Notably, this can also be seen as a strength, as it lets us directly understand how businesses react to their actual perception of climate risk, and the number of strategies implemented that have been sufficiently relevant to be remembered. However dependence on reported extreme events and adaptation strategies serves as a relevant, but imperfect, proxy for the actual occurrence of extreme events and adopted adaptation strategies and does not allow us to adopt a more ambitious causal econometric strategy.

Additionally, our dataset did not allow us to identify female-only-led businesses, but only to differentiate businesses with gender-diverse leadership, from those with male-only leadership. This has limited our ability to conduct a direct comparison between male-led and female-led firms and to isolate the specific influence of women's leadership on adaptation outcomes. These challenges are common in the literature, where there is a lack of high-quality disaggregated data on the effects of climate change on women (Awiti, 2022; Shibia, 2024). Provision for gender considerations in longitudinal panel surveys and additional datasets, that allow for comparison of adaptation behaviour among businesses with women-only leadership teams, will allow for a more comprehensive analysis of the mechanisms, causality and generalisability of gender effects on business-level adaptation.

A broader understanding of gender in adaptation research, beyond its frequent conflation with *cis*-gender women, is also needed. Adaptation datasets generally lack the granularity needed to account for the ways in which gender intersects with other dimensions of vulnerability in shaping adaptation behaviour. Findings in this study also raise a number of important questions about the factors shaping adaptation decisions in male-led businesses, particularly those which might drive them towards short-term coping strategies

[3] The only case this does not apply is for the case of SMEs that faced 5 or 6 extreme weather events (close to the 95th percentile) and received training, and thus are not very representative of the average effect.

such as selling assets or downsizing at times of climate shock. Gendered norms around masculinity, risk perceptions, resource management priorities and attitudes to long-term planning may all play a role in adaptation decision making. But research remains very limited, especially in African contexts. Additionally, development and research communities are going to need to find new, more inclusive ways to account for gender diversity in ways that are contextually appropriate, and do not alienate or put respondents at risk, if we are to help inform more tailored, gender-responsive adaptation policies that reflect the needs of all individuals.

To generate deeper insights into the role of gender in business adaptation and help inform more tailored, gender-responsive adaptation policies and interventions for people of all genders, we consider it imperative to prioritise gender differentiation and intersectional considerations in research. These should be embedded in the core of future research design and survey tools used in the collection of datasets on adaptation and entrepreneurship in Africa. The World Bank Enterprise Surveys, which are widely considered to constitute the most comprehensive and well known dataset on SMEs globally, could make a particular contribution here, by also collecting information on hazard exposure, perceptions of climate risk and business level adaptation behaviour, alongside gender-disaggregated enterprise characteristics that also account for other dimensions of intersectional vulnerability.

6. Conclusions

Businesses in Senegal and Kenya with female leadership are less likely to have implemented unsustainable adaptation strategies when they either haven't been exposed to climate shocks, or when they have been exposed to a very large number of extreme weather events, compared to businesses with only male leadership. This result may simultaneously suggest both greater reluctance among firms with female leadership to undertake adaptation behaviours that may undermine the longer-term resilience of the business, *and* more limited coping capacity, as shaped by more limited access to business assets and resources.

Nevertheless, in our dataset, businesses with female leadership that have faced a relatively high number of extreme climate events, have generally adopted more sustainable adaptation practices than firms without female representation in their ownership or management teams. This finding aligns with literatures, from Africa and elsewhere, which suggest that women may be more likely to adopt a long-term perspective in their adaptation preferences and which suggest that female business leadership can support innovation.

Additionally, access to adaptation assistance appears to have a larger influence on the likelihood of a business undertaking adaptation action among businesses with female leadership, than among those with only male leadership. This finding suggests women's potential as strategic actors in strengthening resilience and indicates that targeting support for private sector adaptation at businesses with female leadership may be an efficient way to upscale sustainable adaptation.

Although we have taken care to outline the limits of our analysis in this paper, we suggest that our results are persuasive enough to suggest that these hypotheses all warrant further investigation in future research. However, to test the strength of our findings including in wider geographies there is an urgent need for additional high-quality, gender-disaggregated datasets on business level adaptation behaviour.

CRediT authorship contribution statement

Kate Elizabeth Gannon: Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization. **Shaikh M.S.U. Eskander:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Antonio Avila-Uribe:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Elena Castellano:** Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Mamadou Diop:** Writing – review & editing, Project administration, Funding acquisition, Data curation, Conceptualization. **Dorice Agol:** Writing – review & editing, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

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Table A1
Summary Statistics.

Variables	Description	Mean	S.D.	Min.	Max.
No. of events	No. of extreme events encountered by the surveyed firms	1.78	1.38	0	6
No. of sustainable practices	No. of sustainable adaptation practices adopted by the surveyed firms	0.95	1.28	0	4
No. of unsustainable practices	No. of sustainable adaptation practices adopted by the surveyed firms	0.40	0.76	0	3
Females	If there is female representation of females in ownership and management of the firm	0.49	0.50	0	1
Financial barriers	If the firm encounters any financial barriers, 0 if otherwise	0.77	0.42	0	1
Assistance	If the firm receives any assistance	0.47	0.50	0	1
Training	If the owners receive any training	0.52	0.50	0	1
Membership	If the firm owners have any membership to professional or gender-specific organization	0.53	0.50	0	1
Market distance	Distance to market (in kilometers)	5.27	7.82	0	42

Notes. We restrict the summary statistics to our estimating sample of 205 micro and small firms with 10 or fewer employees, 5 or fewer owners and 8 or fewer extreme weather events. There are 102 SMEs with female representations and the remaining 103 SMEs do not have any female representation.

Table A2
Different adaptation practices by female representation.

Variables	No female representation	Some female representation	Difference [Female − Male]
A. Sustainable adaptation strategies			
Did you get a loan?	0.078	0.225	0.148***
	(0.269)	(0.420)	[0.049]
Did you get insurance?	0.107	0.010	−0.097***
	(0.310)	(0.099)	[0.032]
Did you switch to a different commodity / good or crop?	0.165	0.245	0.080
	(0.373)	(0.432)	[0.056]
Did you start trading or farming an additional commodity/good or crop?	0.223	0.363	0.139**
	(0.418)	(0.483)	[0.063]
Did you switch to a different variety of the same commodity / good or crop you were operating before?	0.204	0.284	0.080
	(0.405)	(0.453)	[0.060]
B. Unsustainable adaptation strategies			
Did you reduce the number of employees?	0.136	0.167	0.031
	(0.344)	(0.375)	[0.050]
Did you sell assets?	0.097	0.196	0.099**
	(0.298)	(0.399)	[0.049]
Did you sell assets at a lower price?	0.0583	0.118	0.059
	(0.235)	(0.324)	[0.040]
Did you mortgage / rent out assets?	0	0.029	0.029*
	(0)	(0.170)	[0.017]
	103	102	

Notes. We restrict the summary statistics to our estimating sample of 205 micro and small firms with 10 or fewer employees, 5 or fewer owners and 8 or fewer extreme weather events. There are 102 SMEs with female representations and the remaining 103 SMEs do not have any female representation. Classifications of sustainable and unsustainable adaptation strategies follow Crick et al. (2018a). ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

Table A3
Test for overdispersion.

Variables	Baseline Results		Effects of gender		Main results	
	Sustainable adaptation	Unsustainable adaptation	Sustainable adaptation	Unsustainable adaptation	Sustainable adaptation	Unsustainable adaptation
No. of sustainable adaptation practices (est.)	0.394***		0.080		0.052	
	(0.119)		(0.101)		(0.085)	

(*continued on next page*)

Table A3 (*continued*)

Variables	Baseline Results		Effects of gender		Main results	
	Sustainable adaptation	Unsustainable adaptation	Sustainable adaptation	Unsustainable adaptation	Sustainable adaptation	Unsustainable adaptation
No. of unsustainable adaptation practices (est.)		0.799** (0.331)		0.095 (0.174)		0.048 (0.132)
No. of Obs.	205	205	204	204	204	204
R^2	0.051	0.028	0.003	0.001	0.002	0.001

Notes: The test of overdispersion is implemented by an auxiliary regression of the generated dependent variable, $\left\{(y-\widehat{y})^2-y\right\}/\widehat{y}$, on estimated dependent variable $\widehat{y}$. The dependent variables are the estimated number of sustainable and unsustainable adaptation strategies obtained from Poisson regressions according to equation (1). Statistically insignificant coefficients support equidispersion ($Var(y|x) = E(y|x)$) whereas statistically significant support overdispersion ($Var(y|x) > E(y|x)$). ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

Table A4
OLS Results.

Variables	Baseline Results		With covariates		Main results	
	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable
No. of events	1.041***	0.210*	0.886***	0.170	0.758***	−0.117
	(0.141)	(0.121)	(0.144)	(0.133)	(0.206)	(0.184)
(No. of events)^2	−0.180***	−0.025	−0.150***	−0.023	−0.138***	0.031
	(0.025)	(0.028)	(0.026)	(0.031)	(0.035)	(0.045)
Females	0.446***	0.235**	0.101	−0.021	−0.188	−0.455**
	(0.167)	(0.111)	(0.203)	(0.129)	(0.272)	(0.200)
Females × No. of events					0.208	0.542**
					(0.270)	(0.220)
Females × (No. of events)^2					−0.017	−0.104**
					(0.050)	(0.051)
Financial barriers			−0.074	0.123	−0.096	0.111
			(0.221)	(0.103)	(0.222)	(0.104)
Assistance			0.589***	0.051	0.597***	0.039
			(0.183)	(0.113)	(0.182)	(0.112)
Training			0.303**	0.034	0.319**	0.056
			(0.153)	(0.107)	(0.154)	(0.106)
Membership			−0.259	−0.053	−0.239	−0.043
			(0.162)	(0.093)	(0.166)	(0.094)
Market distance			0.030**	0.026***	0.030**	0.027***
			(0.015)	(0.010)	(0.015)	(0.010)
Constant	−0.210	0.037	−0.376	−0.631**	−0.240	−0.408
	(0.152)	(0.125)	(0.624)	(0.269)	(0.643)	(0.260)
No. of Obs.	205	205	204	204	204	204
R^2	0.153	0.050	0.324	0.243	0.328	0.269
District FE	YES	YES	YES	YES	YES	YES

Notes: OLS regression coefficients are estimated using a similar specification to equation (1). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the SMEs. Robust standard errors are in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

Table A5
Alternative empirical specifications.

Variables	Negative Binomial Regressions		Zero-inflated Poisson Regressions		Seemingly Unrelated Regressions	
	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable
No. of events	2.259**	−0.009	1.776***	−0.240	0.758***	−0.117
	(0.884)	(0.436)	(0.681)	(0.456)	(0.249)	(0.155)
(No. of events)^2	−0.485**	0.033	−0.399**	0.087	−0.138***	0.0306
	(0.224)	(0.083)	(0.175)	(0.084)	(0.0459)	(0.0286)
Females	0.622	−1.504**	−0.229	−1.863***	−0.188	−0.455**
	(0.843)	(0.682)	(0.700)	(0.723)	(0.364)	(0.226)

(*continued on next page*)

Table A5 (*continued*)

Variables	Negative Binomial Regressions		Zero-inflated Poisson Regressions		Seemingly Unrelated Regressions	
	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable
Females × No. of events	−0.912	1.375**	−0.403	1.760***	0.208	0.542***
	(0.937)	(0.541)	(0.741)	(0.572)	(0.335)	(0.209)
Females × (No. of events)^2	0.265	−0.257***	0.178	−0.337***	−0.0165	−0.104***
	(0.231)	(0.100)	(0.184)	(0.107)	(0.0634)	(0.0394)
Financial barriers	−0.310	0.718	−0.505**	0.434	−0.0957	0.111
	(0.247)	(0.565)	(0.241)	(0.529)	(0.186)	(0.116)
Assistance	0.539***	0.071	0.556***	−0.080	0.597***	0.0389
	(0.204)	(0.292)	(0.205)	(0.358)	(0.172)	(0.107)
Training	0.448**	0.288	0.213	0.315	0.319**	0.0559
	(0.175)	(0.258)	(0.169)	(0.267)	(0.158)	(0.0985)
Membership	−0.244	−0.095	−0.239	−0.218	−0.239	−0.0431
	(0.164)	(0.237)	(0.145)	(0.260)	(0.164)	(0.102)
Market distance	0.028***	0.062***	0.025***	0.070***	0.0298***	0.0270***
	(0.010)	(0.014)	(0.009)	(0.016)	(0.0106)	(0.00660)
Observations	204	204	204	204	204	204
District FE	YES	YES	YES	YES		

Notes: Negative Binomial and Zero-inflated Poisson regression coefficients are estimated according to equation (1). Seemingly unrelated regressions consider three-stage least squares regression strategy where both the dependent variables are determined simultaneously and follow the specification in equation (1). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the SMEs. Robust standard errors clustered at district by distance-to-market group are in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

Table A6
Results with revised classifications.

Variables	Baseline Results		With covariates		Main results	
	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable
No. of events	1.841***	0.843**	1.743***	0.966**	3.114***	0.309
	(0.295)	(0.340)	(0.333)	(0.412)	(0.779)	(0.702)
(No. of events)^2	−0.371***	−0.139	−0.345***	−0.166*	−0.715***	−0.030
	(0.067)	(0.085)	(0.079)	(0.098)	(0.186)	(0.174)
Females	0.484***	0.612**	0.105	−0.188	1.269	−1.128
	(0.181)	(0.276)	(0.190)	(0.274)	(0.828)	(0.750)
Females × No. of events					−1.738**	0.992
					(0.845)	(0.764)
Females × (No. of events)^2					0.469**	−0.200
					(0.201)	(0.185)
Financial barriers			−0.260	0.760	−0.308	0.748
			(0.242)	(0.565)	(0.234)	(0.585)
Assistance			0.551***	0.022	0.554***	0.057
			(0.204)	(0.302)	(0.195)	(0.300)
Training			0.421**	0.221	0.428**	0.233
			(0.165)	(0.268)	(0.170)	(0.263)
Membership			−0.271*	−0.126	−0.243	−0.121
			(0.161)	(0.242)	(0.158)	(0.240)
Market distance			0.027***	0.059***	0.028***	0.058***
			(0.010)	(0.013)	(0.010)	(0.013)
Constant	−2.015***	−2.161***	−2.237***	−4.698***	−3.277***	−4.094***
	(0.327)	(0.404)	(0.508)	(1.118)	(0.840)	(1.153)
No. of Obs.	205	205	204	204	204	204
District FE	YES	YES	YES	YES	YES	YES
Pseudo-R^2	0.101	0.0450	0.213	0.236	0.227	0.239

Notes: Poisson regression coefficients are estimated according to equation (1), where more than 3 extreme weather events are classified as 4. The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the SMEs. Robust standard errors clustered at district by distance-to-market group are in parentheses.***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

Table A7
Results with revised gender definition.

Variables	Baseline Results		With covariates		Main results	
	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable
No. of events	1.462***	0.591*	1.417***	0.703*	2.263***	0.022
	(0.231)	(0.327)	(0.243)	(0.393)	(0.811)	(0.428)
(No. of events)^2	−0.262***	−0.076	−0.251***	−0.098	−0.500**	0.031
	(0.047)	(0.068)	(0.051)	(0.080)	(0.206)	(0.082)
Females	0.462**	0.617**	0.143	−0.090	0.558	−1.326*
	(0.181)	(0.279)	(0.187)	(0.287)	(0.776)	(0.691)
Females × No. of events					−0.931	1.335**
					(0.858)	(0.540)
Females × (No. of events)^2					0.288	−0.253**
					(0.213)	(0.099)
Financial barriers			−0.242	0.786	−0.315	0.723
			(0.246)	(0.565)	(0.240)	(0.577)
Assistance			0.530***	0.033	0.521***	0.050
			(0.200)	(0.290)	(0.195)	(0.287)
Training			0.423***	0.221	0.471***	0.290
			(0.163)	(0.274)	(0.170)	(0.261)
Membership			−0.261	−0.093	−0.212	−0.083
			(0.163)	(0.254)	(0.159)	(0.255)
Market distance			0.029***	0.058***	0.028***	0.060***
			(0.010)	(0.013)	(0.009)	(0.013)
Constant	−1.737***	−1.977***	−2.023***	−4.539***	−2.573***	−3.922***
	(0.303)	(0.433)	(0.496)	(1.140)	(0.788)	(1.088)
No. of Obs.	205	205	204	204	204	204
District FE	YES	YES	YES	YES	YES	YES
Pseudo-R^2	0.104	0.0436	0.216	0.233	0.229	0.249

Notes: Poisson regression coefficients are estimated according to equation (1), where female representation has been defined as 1 if any female owners and 0 if no female owners (without considering managers as is the main definition). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the SMEs. Robust standard errors clustered at district by distance-to-market group are in parentheses.***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively.

Table A8
Results by assistance and training.

Variables	Role of assistance				Role of training			
	Sustainable		Unsustainable		Sustainable		Unsustainable	
	No assistance	Assistance	No assistance	Assistance	No training	Training	No training	Training
No. of events	4.222***	0.448	0.959	1.705*	6.650**	1.455*	−0.756	1.115*
	(0.965)	(0.624)	(0.632)	(1.023)	(2.804)	(0.786)	(0.661)	(0.589)
(No. of events)^2	−0.906***	−0.090	−0.106	−0.433**	−1.542**	−0.357*	0.191*	−0.226**
	(0.228)	(0.132)	(0.112)	(0.204)	(0.688)	(0.203)	(0.101)	(0.110)
Females	2.624**	−0.903	−1.522	−0.046	5.604**	−1.057	−1.589	−1.337
	(1.113)	(0.800)	(1.136)	(1.223)	(2.607)	(0.796)	(1.060)	(0.822)
Females × No. of events	−3.174***	0.924	1.101	−0.366	−5.817**	0.382	1.411*	0.989
	(1.087)	(0.706)	(0.947)	(1.051)	(2.787)	(0.880)	(0.842)	(0.703)
Females × (No. of events)^2	0.742***	−0.143	−0.258	0.236	1.430**	0.031	−0.307**	−0.100
	(0.248)	(0.150)	(0.182)	(0.209)	(0.690)	(0.219)	(0.135)	(0.133)
Financial barriers	−0.316	0.168	1.514**	−0.311	0.658	−0.844***	17.845***	−0.362
	(0.328)	(0.431)	(0.677)	(0.636)	(0.610)	(0.249)	(1.122)	(0.368)
Assistance					0.241	0.550**	0.853	−0.310
					(0.436)	(0.232)	(0.554)	(0.318)
Training	0.561	0.282	0.529	0.115				
	(0.407)	(0.176)	(0.520)	(0.268)				
Membership	−0.754**	0.044	0.008	−0.211	−0.438	−0.098	−0.272	−0.305
	(0.358)	(0.193)	(0.435)	(0.284)	(0.270)	(0.201)	(0.305)	(0.377)
Market distance	0.018	0.040***	0.099***	0.067***	0.044***	0.023*	0.067***	0.088***
	(0.023)	(0.010)	(0.030)	(0.015)	(0.015)	(0.013)	(0.020)	(0.019)
Constant	−3.919***	−1.025	−4.869***	−20.684***	−6.543***	−0.536	−36.360***	−3.708***
	(1.039)	(0.770)	(1.209)	(1.018)	(2.242)	(0.906)	(1.919)	(1.363)
No. of Obs.	106	98	106	98	98	106	98	106
District FE	YES	YES	YES	YES	YES	YES	YES	YES
Pseudo-R^2	0.310	0.195	0.362	0.332	0.305	0.247	0.381	0.284

Notes: Poisson regression coefficients are estimated according to equation (1). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the SMEs. Robust standard errors clustered at district by distance-to-market group are in parentheses.

***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. Adoption of both sustainable and unsustainable adaptation strategies is assessed for the SMEs with and without assistance or training, as specified in respective column headings.

Table A9
Joint mitigating effects of assistance and training.

Variables	Sustainable adaptation	Unsustainable adaptation
No. of events	−0.918	8.375***
	(0.815)	(0.727)
(No. of events)^2	0.195	−2.094***
	(0.155)	(0.089)
Females	−2.902***	5.159***
	(0.981)	(1.186)
Females × No. of events	2.886***	−6.982***
	(0.891)	(1.001)
Females × (No. of events)^2	−0.600***	1.911***
	(0.179)	(0.090)
Financial barriers	−0.363	−0.499
	(0.436)	(0.513)
Membership	0.104	−0.529
	(0.274)	(0.573)
Market distance	0.030**	0.061***
	(0.014)	(0.021)
Constant	1.570	−25.736***
	(1.258)	(1.517)
No. of Obs.	58	58
District FE	YES	YES
Pseudo-R^2	0.248	0.324

Notes: Poisson regression coefficients are estimated according to equation (1). The dependent variables are the number of sustainable and unsustainable adaptation strategies as reported by the SMEs. Robust standard errors clustered at district by distance-to-market group are in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. The estimating sample is restricted to 58 SMEs who received both assistance and training.

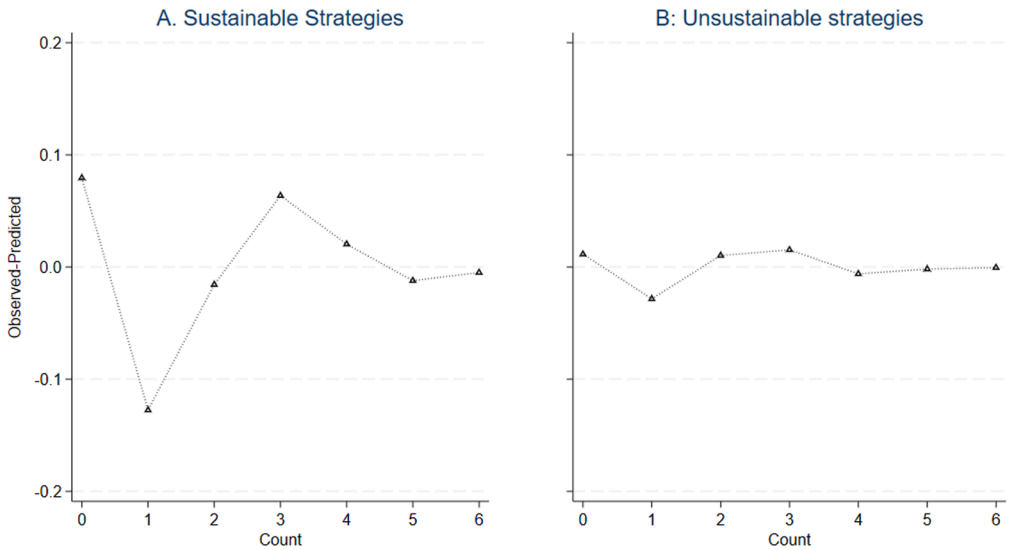

Fig. A1. *Countfit* graphs. *Notes.* Countfit graphs plot the residuals for both the sustainable and unsustainable adaptation strategies from main results reported in Table 2.

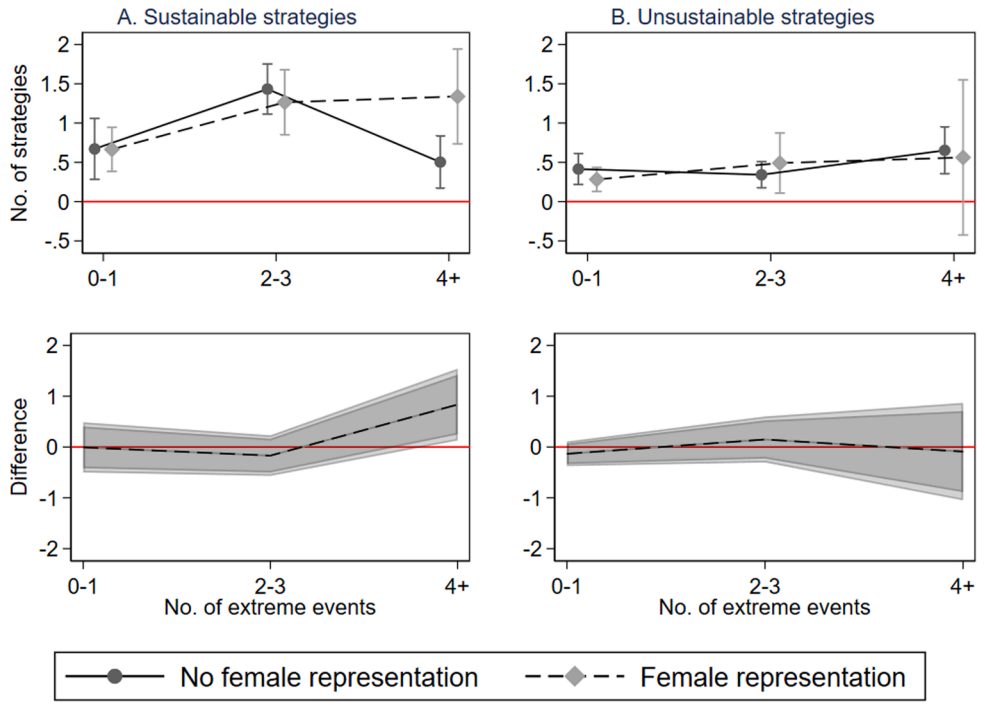

Fig. A2. Marginal effects of gender (non-parametric) *Notes.* Panels A and B show the number of sustainable and unsustainable adaptation strategies, respectively, that the SMEs with and with female representations have adopted for 3 groups of reported extreme events. The shaded area represents the 90 and 95 % C.I. of the difference between marginal effects of gender representation.

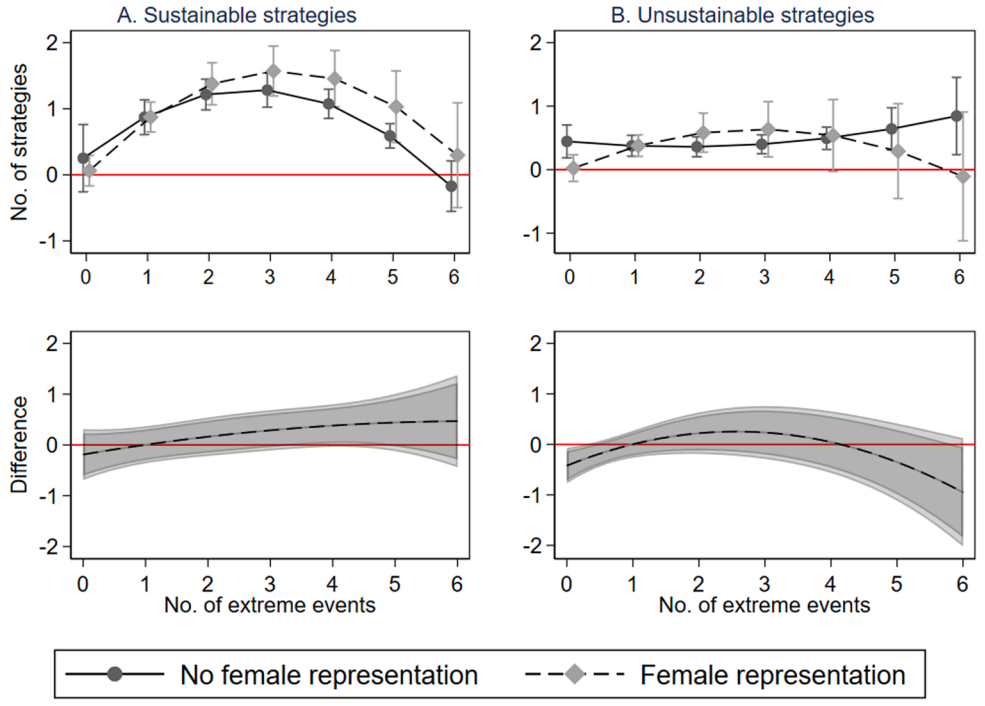

Fig. A3. Marginal effects of gender (linear regression). *Notes.* Panels A and B show the number of sustainable and unsustainable adaptation strategies, respectively, that the SMEs with and with female representations have adopted for various "groups" of reported extreme events. The shaded area represents the 90 and 95 % C.I. of the difference between marginal effects of gender representation.

Data availability

Data will be made available on request.

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