Food and Agriculture
Organization of the
United Nations

The unjust climate

Measuring the impacts of climate change
on rural poor, women and youth

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Food and Agriculture Organization of the United Nations
Rome, 2024

Required citation:
FAO. 2024. *The unjust climate – Measuring the impacts of climate change on rural poor, women and youth.* Rome. https://doi.org/10.4060/cc9680en

ISBN 978-92-5-138590-6

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Foreword

We cannot eliminate poverty and end hunger without addressing the impacts of climate change on the livelihoods of marginalized rural people and communities. This report provides, for the first time, concrete evidence from 24 countries on the magnitude of the challenge posed by the climate crisis for rural people in socially and economically vulnerable positions due to their wealth status, gender, and age. It demonstrates clearly that extreme weather events and long-run climate change are disproportionately affecting the incomes of rural people living in poverty, women, and older populations. As a result, climate change is widening even further existing income gaps in rural areas, pushing vulnerable people towards maladaptive coping strategies and ultimately making it harder for these groups to escape cycles of poverty and hunger.

The report shows that the magnitude of the challenge posed by climate change for vulnerable rural people is staggering. For example, in low and middle income countries floods widen the gap in incomes between poor and non-poor households by more than 4%, amounting to a reduction compared to non-poor households of $18 per capita or $21 billion a year in aggregate across all low and middle income countries.

We estimate that a 1° C increase in long-term average temperatures reduces the average income of female-headed households by 34 percent compared to that of male-headed households. Additionally, households headed by older people are found to lose 3 percent of their income due to floods and 6 percent due to heat stress per year, relative to households headed by younger people. Addressing these disparities requires adequate financial support, concerted policy attention and programmatic actions that are tailored to the needs of diverse and vulnerable rural people.

The global community must do more to tackle the impacts of climate change on rural people and focus resources and policy support on the specific needs of socially and economically marginalized populations. Currently, only a small fraction of global climate financing reaches rural people, and even less of these resources provide support for climate adaptation. It

is estimated that only 1.7 percent of tracked climate financing in 2017/18 reached small-scale producers. Moreover, rural people and their climate vulnerabilities are barely visible in national climate policies. For example, new analysis included in this report shows that in the nationally determined contributions and national adaptation plans of the 24 countries analysed, only 6 percent of the 4 164 climate actions proposed mention women, while less than 1 percent of actions address poor people and 6 percent refer to farmers in rural communities.

Inclusive climate actions are embedded in FAO's Strategy on Climate Change and in the FAO Strategic Framework 2022–2031, where tackling the impact of climate change is mainstreamed in efforts to achieve the four betters: better production, better nutrition, better environment and better life for all. With this report, FAO deepens its commitment to placing people at the center of its climate actions, and to provide actionable evidence and technical support to achieve this objective. This includes advocating policy frameworks that acknowledge the distinct risks posed by climate change for rural women, older populations, youth and people living in poverty, and for programmatic interventions that address the unique challenges these groups face in adapting to a rapidly changing climate.

Transitioning to a just, sustainable and climate-resilient development pathway depends on inclusive climate actions in rural spaces and agrifood systems. We cannot tackle the challenges of inequality, poverty and hunger separately from our efforts to address the climate crisis. These global challenges are inextricably linked. We encourage all stakeholders to make a commitment to join us in pursuing and financing climate actions that are people-centered and that leave no one behind.

Maximo Torero Cullen
FAO Chief Economist

Acknowledgements

Authors: This report was prepared by a team from the Rural Transformation and Gender Equality Division (ESP) of FAO led by Nicholas Sitko and Romina Cavatassi and composed of: Irene Staffieri, Esther Heesemann, Jan Martin Rossi, Luis Becerra Valbuena, Priti Rajagopalan, Jessika Kluth and Carlo Azzarri (IFPRI). The report was prepared with the support of Benjamin Davis (ESP Director) and Lauren Phillips (ESP Deputy Director), under the overall guidance of Máximo Torero (FAO Chief Economist).

The authors would like to extend their deepest gratitude to a number of individuals whose expertise and insights have been invaluable in the development of this work. Their contributions across various stages of this project have been instrumental in shaping the final outcome.

Technical Support: Our sincere thanks to Krystal Krumpler (OCB), Jorge Beltran (OCB), Veronica Boero (ESS), Flavia Pelegrini (FAO), Daniel Bordi (FAO), Ratih Dewi (FAO), Hideki Kanamaru (OCB), Alvar Beltran, Jorge (OCB), Alashiya Gordes (OCBD), Piero Conforti (ESS), Erdgin Mane (ESP), Vanya Slavchevska (ESP), Mario Zappacosta (EST), Riccardo Soldan (OCBD), Nidhi Chaudhary (ESS), and Veronica Boero (ESS) for their technical support and invaluable assistance.

We are immensely grateful to Gianluigi Nico (World Bank), Giuseppe Maggio (Università degli Studi di Palermo), Shouro Dasgupta (Università Ca' Foscari Venezia), Julian Rameriz-Villegas (Bioversity/CIAT), Nancy McCarthy (LEAD Analytics), Adriana Paolantonio (World Bank), and Nicolò Gebbani (Università Ca'Foscari Venezia) for their external perspectives, insights, and contributions which have greatly enriched this work.

Review: Special thanks are due to Leslie Lipper (Independent consultant), Shouro Dasgupta (Università Ca' Foscari Venezia), Aslihan Arslan (FAO), Clara Park (FAO), Mariola Acosta Frances (FAO), Garima Bhalla (FAO), Marco Knowles (FAO), Marwan Benali (FAO), and Adriano Bolchini (FAO) for their thorough and insightful reviews. Their feedback has been crucial in refining our work and ensuring its quality and integrity.

Editorial, administrative & communications support: Viviana Di Bari and Virginie Matterne led the production of the report and communications. The publication was greatly enhanced by Bruce Ross-Larson (Communications Development, Inc.) who provided content-structuring support. Ellen Pay led copy-editing. Art&Design Srl supported with the layout and graphic design.

Abbreviations

AFOLU	agriculture, forests and other land use
CGIAR	Consultative Group on International Agricultural Research
ECMWF	European Centre for Medium-Range Weather Forecasts
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gas emissions
HHI	Herfindahl–Hirschman Index
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
LSMS-ISA	Living Standards Measurement Study–Integrated Surveys on Agriculture
NAP	national adaptation plans
NDC	nationally determined contributions
RuLIS	Rural Livelihoods Information System
SDG	Sustainable Development Goal
STEM	science, technology, engineering and mathematics
TLU	tropical livestock unit
UNDP	United Nations Development Programme
URCA	urban–rural catchment area
VIIRS	Visible Infrared Imaging Radiometer Suite
WFD	WATCH Forcing Data
WMO	World Meteorological Organization

ETHIOPIA – A young mother holding her son in the Somali region during a drought. Climate change is increasing the frequency and severity of drought events in many parts of the world.

Executive summary

Numerical highlights

- In an average year, poor households lose 5 percent of their total income due to heat stress relative to better-off households, and 4.4 percent due to floods.
- Floods widen the income gap between poor and non-poor households in rural areas by approximately USD 21 billion a year, and heat stress by more than USD 20 billion a year.
- Long-term temperature rises lead to an increase in poor households' dependency on climate-sensitive agriculture relative to that of non-poor households. A 1° C increase in average long-term temperatures leads to a 53 percent increase in the farm incomes of poor households and a 33 percent decrease in their off-farm incomes, relative to non-poor households.
- Every year, female-headed households experience income losses of 8 percent due to heat stress, and 3 percent due to floods, relative to male-headed households.
- Heat stress widens the income gap between female-headed and male-headed households by USD 37 billion a year, and floods by USD 16 billion a year.
- A 1° C increase in long-term average temperatures is associated with a 34 percent reduction in the total incomes of female-headed households, relative to those of male-headed households.
- In an average year, households headed by young people see their total incomes increase by 3 percent due to floods, and by 6 percent because of heat stress, relative to older households.
- Heat stresses cause young rural households in low- and middle-income countries to increase their annual off-farm income by USD 47 billion relative to that of other households.
- Extreme temperatures push children to increase their weekly working time by 49 minutes relative to prime-aged adults, mostly in the off-farm sector, closely mirroring the increase in the work burden of women.
- Rural people and their climate vulnerabilities are barely visible in national climate policies. In the nationally determined contributions (NDCs) and national adaptation plans (NAPs) of the 24 countries analysed in this report, only 6 percent of the 4 164 climate actions proposed mention women, 2 percent explicitly mention youth, less than 1 percent mention poor people and about 6 percent refer to farmers in rural communities.
- Of the total tracked climate finance in 2017/18, only 7.5 percent goes towards climate change adaptation; less than 3 percent to agriculture, forestry and other land uses, or other agriculture-related investments; only 1.7 percent, amounting to roughly USD 10 billion, reached small-scale producers.

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Policy highlights

Rural people's multidimensional climate vulnerabilities demand multifaceted policies and programmes that address both the farm and off-farm sources of rural people's vulnerabilities, and reduce farmers' reliance on maladaptive coping strategies.

These policies and programmes must also address the specific constraints faced by vulnerable populations, including limited access to productive resources, low risk tolerance, constrained access to information and extension services, and limited capacities to exercise agency in economic and social domains.

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EFFECTIVE CLIMATE ACTIONS must tackle the diverse drivers of **people's climate vulnerability**

Linking social protection programmes to advisory services can encourage adaptation and compensate farmers for losses. Access to cash-based social assistance programmes increases the productive asset holdings of rural people, encourages them to use improved inputs and farm practices, and enables a shift away from casual wage labour arrangements. These positive impacts can be enhanced by bundling this assistance with climate advisory services and extension support.

The ability to act on climate-related agricultural advice depends on people's economic agency and decision-making power. Gender-transformative methodologies, which use social behaviour change methodologies to directly challenge discriminatory gender norms, can tackle entrenched discrimination that often prevents women from exercising full agency over economic decisions that impact their lives.

Participatory extension methodologies can boost the participation of vulnerable people and result in a greater uptake of improved practices. These methods enable groups of farmers to experiment with different approaches to address shared challenges in their farm systems, while limiting the individual risks associated with trying new practices. These approaches also increase people's sense of agency and self-efficacy in the face of climate risks.

To maximize the positive impact of off-farm opportunities, complementary services are essential. In addition to providing technical and vocational education, it is important to strengthen people's non-cognitive skills. This can be done through programmes that challenge gender stereotypes in the workforce, as well as mentorship programmes focused on building socioemotional skills.

Investing in the collection of disaggregated data is essential to assess the impacts of different climate actions on vulnerable populations. The rapid increase in climate projects and programmes provides a unique opportunity to collect evidence that can guide current and future climate actions.

Overview

Global efforts to tackle the climate crisis must address its impacts on people, particularly the most vulnerable. Because of their reliance on weather-dependent agriculture and agrifood systems, climate change has a profound impact on the incomes and livelihoods of rural people living in low- and middle-income countries. However, policy attention and funding for vulnerable rural people falls woefully short of actual needs. In 2017/18, only 1.7 percent of global tracked financing reached small-scale producers, while only 3 percent supported climate adaptation in agriculture, forestry and other land uses.

Rural people's vulnerabilities to climate change are strongly influenced by a person's wealth, gender and age. These factors also affect their abilities to manage the impacts of climate stressors on their livelihoods and determine the type of adaptive actions they take. Meanwhile, different climate stressors — heat stress, floods, droughts or long-term temperature increases — affect different groups of rural people in very dissimilar ways.

The design and implementation of effective people-centred climate actions requires an understanding of the diverse drivers of climate vulnerability in rural areas. These drivers include barriers to the access to the resources, services and employment opportunities that rural people can leverage to adapt to and cope with climate change. For example, discriminatory norms and policies place a disproportionate burden on women for care and domestic responsibilities, limit their rights to land, prevent them from making decisions over their own labour and hamper their access to information, finance and other essential services. Overcoming these challenges requires specific interventions to enable diverse rural populations to take climate-adaptive actions and avoid maladaptive coping strategies.

Evidence is critical to guide policies and programmes that address diverse climate vulnerabilities in rural areas. While climate policies often acknowledge that women, youth and people living in poverty are more vulnerable to climate impacts, there is very little evidence to understand the magnitude and nature of the vulnerabilities these groups face. Moreover, there is virtually no evidence from diverse low- and middle-income countries on how various climate stressors affect rural women, youth and people living in poverty.

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VULNERABILITIES to climate change are strongly influenced by **wealth, gender and age**

This report assembles an impressive set of data from 24 low- and middle-income countries in five world regions to measure the effects of climate change on rural women, youth and people living in poverty. It analyses socioeconomic data collected from 109 341 rural households (representing over 950 million rural people) in these 24 countries. These data are combined in both space and time with 70 years of georeferenced data on daily precipitation and temperatures. The data enable us to disentangle how different types of climate stressors affect people's on-farm, off-farm and total incomes, labour allocations and adaptive actions, depending on their wealth, gender and age characteristics.

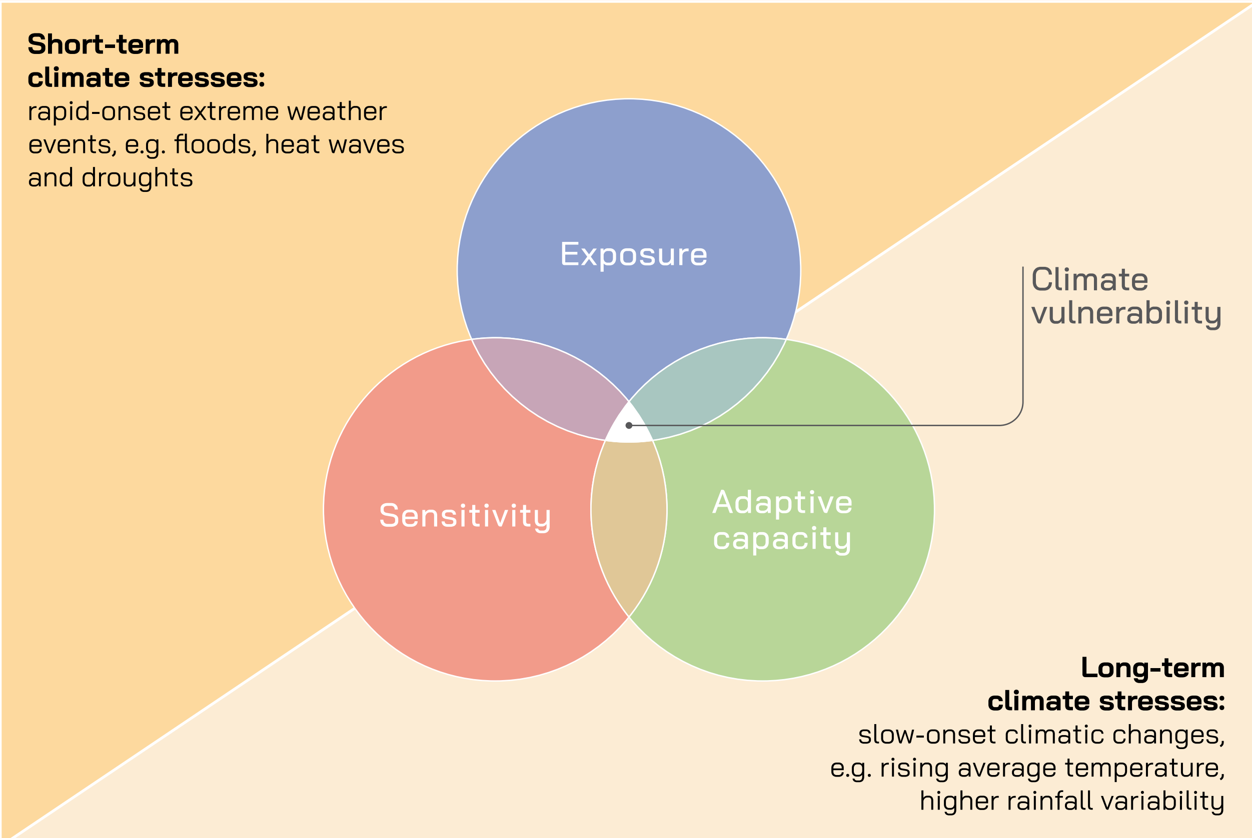
Conceptual framing

Climate change has both direct and indirect effects on the livelihoods and well-being of rural people. Rising temperatures and extreme weather events directly undermine the productivity of the agricultural systems rural people rely on, with global warming estimated to have reduced the yields of major cereal crops by an estimated 2 to 3 percent between 1981 and 2002. Indirectly, reductions in agricultural productivity ripple through the rural economies and agrifood systems that rural people depend on, limiting non-agricultural income opportunities, increasing food prices and disrupting agricultural markets. Assessments of the climate vulnerability of rural people must therefore pay attention to both the farm and non-farm dimensions of people's livelihoods.

A person's vulnerability to climate change is strongly influenced by their agency, socioeconomic endowments and degree of access to support services. This report conceptualizes climate vulnerability as consisting of three elements (see **Figure S1**). Exposure is the type, frequency and intensity of the climate variations, or climate stressors, that affect a person. Sensitivity is the degree to which a person is susceptible to harm due to exposure to climate stressors. Adaptive capacity refers to the ability of a person to adjust to climate change, taking advantage of potential opportunities and responding to its consequences. A person's wealth, gender and age influence their exposure to climate stressors, the sensitivity of this exposure and the capacity to adapt.

FIGURE S1

Climate Vulnerability



Source: authors' elaboration.

Wealth-related disparities in climate vulnerability

Extreme weather events disproportionately affect poor rural households, leading to significant reductions in their incomes and widening income inequality. With every day of extreme heat, poor rural households lose 2.4 percent of their on-farm incomes, 1.1 percent of the value of the crops they produce, and 1.5 percent of their off-farm income relative to non-poor households. Similarly, every day of extreme precipitation causes poor households to lose 0.8 percent of their incomes relative to non-poor households, mostly driven by losses in off-farm incomes. In an average year, poor households lose 5 percent of their total incomes due to heat stress, and 4.4 percent due to floods, relative to non-poor households.

Floods and heat stress widen the income gap between rural poor and non-poor households by approximately USD 21 billion and USD 20 billion a year, respectively. These estimates highlight the massive challenge that extreme weather events pose for global efforts to reduce poverty and inequality. This challenge will only become more acute as the frequency and intensity of these events increase because of climate change.

Extreme weather events push poor rural households to adopt maladaptive coping strategies, including reducing income sources, liquidating livestock and redirecting expenditures away from their farms. Indeed, poor households tend to reduce the diversity of their income sources when exposed to heat stresses, relative to better-off households. Meanwhile, floods and heat stress cause poor households to lose livestock holdings relative to non-poor households, either through distress sales of animals or higher levels of livestock mortality. And poor households reduce their investments in agriculture relative to non-poor households when faced with floods and droughts, as they redirect their scare resources away from agricultural production towards immediate consumption needs. These maladaptive coping strategies are likely to make them more vulnerable to future climate stressors than non-poor rural households.

In addition, long-term increases in temperatures push poor rural households to rely more on weather-dependent agriculture for their livelihoods, thereby increasing their climate vulnerability. Agricultural production is highly sensitive to climate change. But as temperatures rise, poor households tend to become more reliant on agriculture for their incomes and less able to access off-farm income relative to non-poor households. A 1° C increase in average temperatures is associated with a 53 percent increase in the farm incomes of poor households and a 33 percent decrease in their off-farm incomes, relative to non-poor households. Thus, while better-off households adapt to rising temperatures by diversifying into off-farm sectors, poor households do not. This likely increases their overall vulnerability to the impacts of climate change.

Heat stresses widen the income gap between rural poor and non-poor households by

USD 20 BILLION A YEAR

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Gender disparities in climate vulnerability

Female-headed households lose significantly more of their incomes than male-headed households when extreme weather events occur. A day of extreme temperature or extreme precipitation is associated with a 1.3 percent and 0.5 percent reduction, respectively, in the total incomes of female-headed households, relative to that of male-headed households. This translates into an annual income gap of 8 percent due to heat stress, and of 3 percent due to floods, compared with male-headed households. Across low- and middle-income countries, heat stresses widen the income gap between rural female-headed households and male-headed households by USD 37 billion a year, and floods by USD 16 billion a year.

Different types of extreme weather events affect female-headed households in different ways. Floods cause female-headed households to lose off-farm income relative to male-headed households, but do not cause a significant loss in farm income. Conversely, droughts and heat stress lead to a significant relative reduction in the farm incomes of female-headed households. An additional day of drought or extreme temperatures reduces the farm incomes of female-headed households by 0.4 and 1.1 percent, respectively, relative to male-headed households. In case of drought, female-headed households can compensate their losses in farm income with off-farm income.

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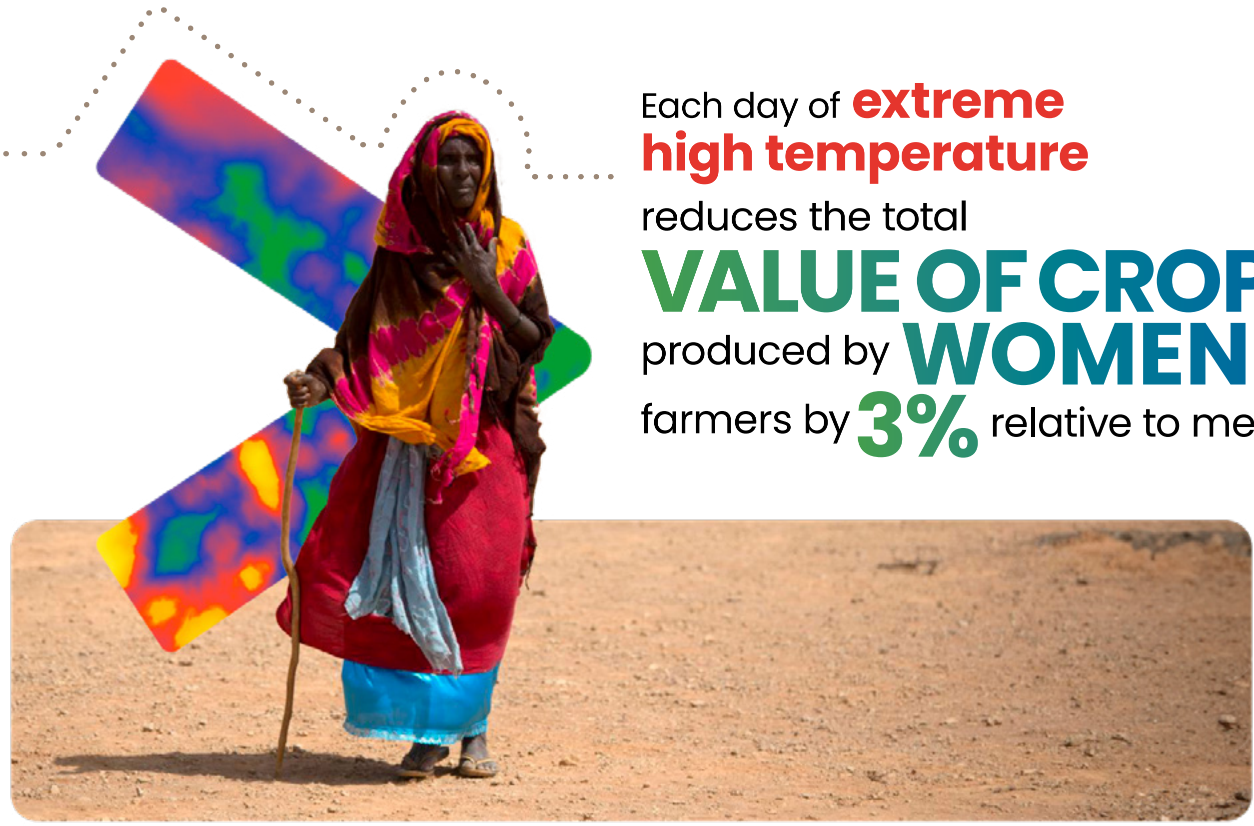
Female-headed households respond to extreme weather events in diverse ways, but these strategies do not reduce their vulnerability. In case of floods, female-headed households intensify their agricultural activities by acquiring more livestock and spending more on their agricultural systems, relative to male-headed households. This is likely due to the fact that they lose more off-farm income opportunities relative to male-headed households. Conversely, droughts and heat stress cause a significant reductions in the livestock holdings and agricultural expenditures of female-headed households relative to male-headed households. Given that these events are associated with a significant relative reduction in the overall incomes of female-headed households, these strategies do not appear to be effective at enhancing their resilience.

Women take on an additional work burden compared to men when extreme weather events occur, but also lose more income opportunities. Floods and droughts cause rural women to take on more work relative to men. They also significantly increase the hours that they work per week relative to men. With floods and droughts, women tend to work significantly more on their own farms compared to men, while the opposite is true for heat stress, which causes women to dedicate relatively more of their time to work away from their farms. The increase in women's work highlights their critical role in sustaining family livelihoods during extreme weather events. However, without significant changes in gendered norms concerning women's role in care and domestic activities, this additional work likely adds to the already disproportionate work burden that rural women shoulder.

Women plot managers are as capable as men to adopt climate-adaptive agricultural practices, but often lose more income and off-farm



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opportunities when exposed to extreme weather events. Each day of extreme high temperature reduces the total value of crops produced by women farmers by 3 percent relative to men. At the same time, there are few statistically significant differences between plots managed by women and those managed by men in terms of the adoption of climate-adaptive agricultural practices in response to extreme weather events. Therefore, a critical programmatic and policy concern is how to support women farmers to translate their adaptive actions into meaningful improvements in their agricultural systems. Gender-responsive agricultural extension services are likely to be an important element in such efforts.

Plots managed by women withstand the adverse effects of floods relatively better than plots managed by men. A day of flooding increases the total value of crops produced on women's plots by 1.6 percent compared to men's plots. The adoption of simple irrigation systems in flood zones may explain this result.

Long-term increases in temperature widen the income gap between female- and male-headed households. An increase of 1° C in long-term average temperatures is associated with a 34 percent reduction in the total incomes of female-headed households relative to male-headed households. This result is mainly driven by a relative reduction in the farm incomes of female-headed households, which decrease by 23.6 percent compared to those of male-headed households. Female-headed households also spend relatively more on agricultural investments than men. Thus, global warming causes women to invest relatively more in agriculture, but also to lose relatively more than men. This points to an urgent need to support female-headed households to better adapt their agricultural systems to climate change.

Age-based differences in climate vulnerability

Households headed by young people are better able to access off-farm employment opportunities in the face of extreme weather events than older households, which makes their incomes less vulnerable to such events. A day of extreme precipitation or extreme heat is associated with a 0.6 or 1 percent increase, respectively, in the total incomes of young households relative to older households. In an average year, young households increase their total income by 3 percent due to floods, and 6 percent due to heat stresses, compared to older households. Indeed, while these events reduce the farm income of young households relative to that of older households, the former compensate these losses with additional income from off-farm sources. For example, a day of extreme heat is associated with a 2.9 percent increase in the off-farm incomes of young households, relative to older households. Therefore, while global discussions tend to focus on young people's vulnerability to climate change, this analysis shows that older rural households are substantially more vulnerable to extreme weather events.

Young rural households are more likely to access off-farm income sources to **MANAGE THE IMPACTS OF EXTREME WEATHER**

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Contrary to poor or female-headed households, which often reduce their livestock holdings to cope with extreme events, households headed by young people take advantage of extreme weather events to acquire livestock. In rural areas, livestock typically serves multiple functions, including providing food and income and serving as a store of value. By increasing their livestock holdings during extreme weather events, young households expand their asset base and increase their abilities to generate income in the future, enabling them to better cope with future stressors.

Households headed by young people contribute significantly to rural off-farm economies when extreme weather events occur. Young rural households in low- and middle-income countries increase their off-farm income by approximately USD 47 billion a year relative to other households when exposed to heat stress. Leveraging the contributions of young people to rural off-farm economies should thus be a priority in global climate actions.

Extreme temperatures lead to a relative increase in children's work. For each day of extreme temperature, the number of hours worked by children per week increases by seven minutes compared to prime-aged adults. Given that children experience about seven days of heat stress per year on average, this effect translates into a relative increase in children's weekly labour time of 49 minutes. This increase is driven by a rise in children's off-farm work. These results closely mirror those for rural women, suggesting that women's and children's work are often closely connected in a context of extreme weather events.

Long-term increases in temperature result in a relative increase in the diversification of young people's incomes. This is likely due to an increased reliance on off-farm income sources, with agricultural options becoming more limited as places become hotter. This finding reinforces the overall finding that young rural households are generally better able to adapt to climate stressors than older households, and that they do this by exploiting off-farm income sources.

Policy priorities for inclusive climate action

The evidence in this report confirms that rural people are adversely affected by climate stressors through a variety of channels, including reductions in both on-farm and off-farm incomes and the adoption of maladaptive - and counterproductive - coping strategies. Therefore, policies and programmes must be developed to address rural people's climate vulnerabilities. Given the multidimensional nature of these vulnerabilities, it is crucial to develop and implement multifaceted policies and interventions.

Poor households and those headed by women and young people tend to experience farm income losses as a result of climate stressors relative to other rural groups. This reflects their generally lower climate-adaptive capacity and points to the need for interventions that enable them to adopt adaptive farming practices and technologies.

A wide range of farming practices and technologies can be tailored to different agroecological contexts. However, promoting their adoption by vulnerable and resource-constrained farm households requires programmatic interventions to address key adoption barriers and constraints.

First, there are constraints to accessing and mobilizing the resources required for adoption. These may include the financial resources needed to acquire new technologies, such as improved seed varieties, irrigation equipment and technologies, as well as other factors of production, such as land and labour.

Second, farmers may have limited access to extension, technical assistance and weather advisory services that would enable them to anticipate climate stressors and identify potentially effective solutions. Because of the low farmer-to-extension worker ratios in many countries, extension services often target larger land holders, neglecting poorer and land-constrained producers.

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A third barrier are the risks associated with the adoption of adaptive practices. Many of these practices, particularly those focused on strengthening natural processes to build more resilient agricultural systems, take time to generate describable benefits and may even lead to a short-term drop in productivity. The uncertainty and long-time horizons of these practices constitute a serious impediment to adoption.

Addressing the multiple and diverse constraints to farm-level climate adaptation by vulnerable people requires multidimensional and integrated approaches. While the evidence on the most effective approaches for enabling and sustaining the adoption of farm-level adaptation practices remains quite limited, the literature points to several areas for prioritization.

Multiple sources of vulnerability require MULTIFACETED INTERVENTIONS

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Leveraging social protection

The evidence of the productive benefits of social protection programmes for rural people suggests that such programmes can be successfully integrated into broader climate adaptation and agricultural development strategies, to boost the uptake of climate-adaptive practices and minimize reliance on maladaptive practices.

Social protection measures are particularly well-suited for supporting vulnerable groups because they are often unable to access traditional risk management mechanisms, such as credit or insurance services. In addition, social protection mechanisms can be tailored to address the specific vulnerabilities of women, children, older people and poorer people living in rural areas.

To unlock the potential of social protection measures for inclusive climate actions, several issues must be taken into consideration. First, the development of climate policies is typically led by ministries for the environment, which tend to pay little attention to the important role that social policies can play towards climate objectives. Indeed, based on our analysis of the nationally determined contributions (NDCs) and national adaptation plans (NAPs) of the 24 countries in this report, social protection is mentioned in only 1.74 percent of all actions, and these are concentrated in only two countries. A second element is the lack of public funding for social protection programmes. This challenge may be addressed by using climate financing to fund climate-focused social protection programmes, thus helping to boost the degree of social protection of vulnerable rural people.

Tailoring extension services to the needs of vulnerable people

To promote the widespread implementation of climate-adaptive actions by rural people, access to adequate advisory services is critical. How such services are delivered, and the types of support that are associated with them, determines the degree to which they reach vulnerable groups.

Participatory extension methodologies, such as farmer field schools, increase the participation of vulnerable people and promote the uptake of improved practices. These methodologies enable farmers to experiment with different approaches to address shared challenges in farm systems, while limiting the individual risks associated with trying new practices. While the evidence remains thin, participatory methods for addressing climate impacts have proven effective in increasing the awareness of climate risks and promoting the adoption of climate-adaptive practices among poor and vulnerable producers in Bangladesh and Malawi.

The inclusiveness of climate actions is also determined by who delivers the extension services. Increasing the number of female extension agents, for example, was found to boost the adoption rate of sustainable land management practices by women farmers in Mozambique. Meanwhile, peer-to-peer mentorship programmes have been shown to help young farmers develop social networks to share information on best practices and strategies to improve farm incomes.

Of course, people's ability to act on information depends on their economic agency and decision-making power. Women often face discriminatory norms that limit their ability to exercise agency over economic decisions that are relevant to their lives. Incorporating gender-transformative methodologies, which employ social behavioural change approaches to directly challenge discriminatory gender norms, is crucial to tackle entrenched discrimination that prevents women from exercising full agency over their economic lives. Such methodologies typically involve both women and men, and use participatory methods for social change that can be integrated into agricultural advisory systems and value chain interventions.

Enabling off-farm opportunities

Sustaining and increasing off-farm income opportunities for vulnerable groups requires interventions that tackle both the macro- and micro-level factors that limit people's access to decent off-farm income opportunities.

At the macro-level, issues related to education, disparate time burdens and mobility all influence the types and quality of off-farm income opportunities that people can access. Social and economic factors that limit children's access to education, particularly for those living in economically marginalized rural households, must be identified and addressed. Low education levels limit people's options for off-farm employment and restrict their capacity to build and grow enterprises, thereby pushing many marginalized people into work that is precarious, informal and badly paid.

The impacts of climate change may exacerbate educational inequalities, as exposure to extreme weather events can push economically marginalized households to withdraw their children from school. This effect is particularly worrisome for girls. Public policies must therefore strive to prevent the gender gap in educational attainment from growing as a result of climate change. In Malawi, school feeding programmes have been shown to reduce the probability that girls are withdrawn from school when droughts occur.

The green economy is often promoted as a solution to create decent employment opportunities, while simultaneously tackling local and global environmental challenges. However, many green jobs favour men over women, given that they tend to focus on science, technology, engineering and mathematics (STEM), fields in which women are generally underrepresented. Thus, measures to improve access to education must go hand in hand with efforts to tailor curricula to emerging employment needs. This includes focusing on improving the participation of girls in STEM curricula.

Addressing gender disparities in the burdens of domestic work and care responsibilities is critical to improve the access to and participation in remunerative off-farm work opportunities in rural areas. The provision of childcare, for example, has been shown to have a considerable positive impact on women's - employment.

Supporting the development of markets for climate-adaptation services can create important opportunities in the off-farm sector, while at the same time addressing farm-level constraints to adaptation.

The creation of employment and the formation of enterprises in agrifood systems are particularly important, particularly for women and young people. Agrifood enterprises enable rural youth and other people to diversify their income sources and reduce their dependency on climate-sensitive primary agricultural production.

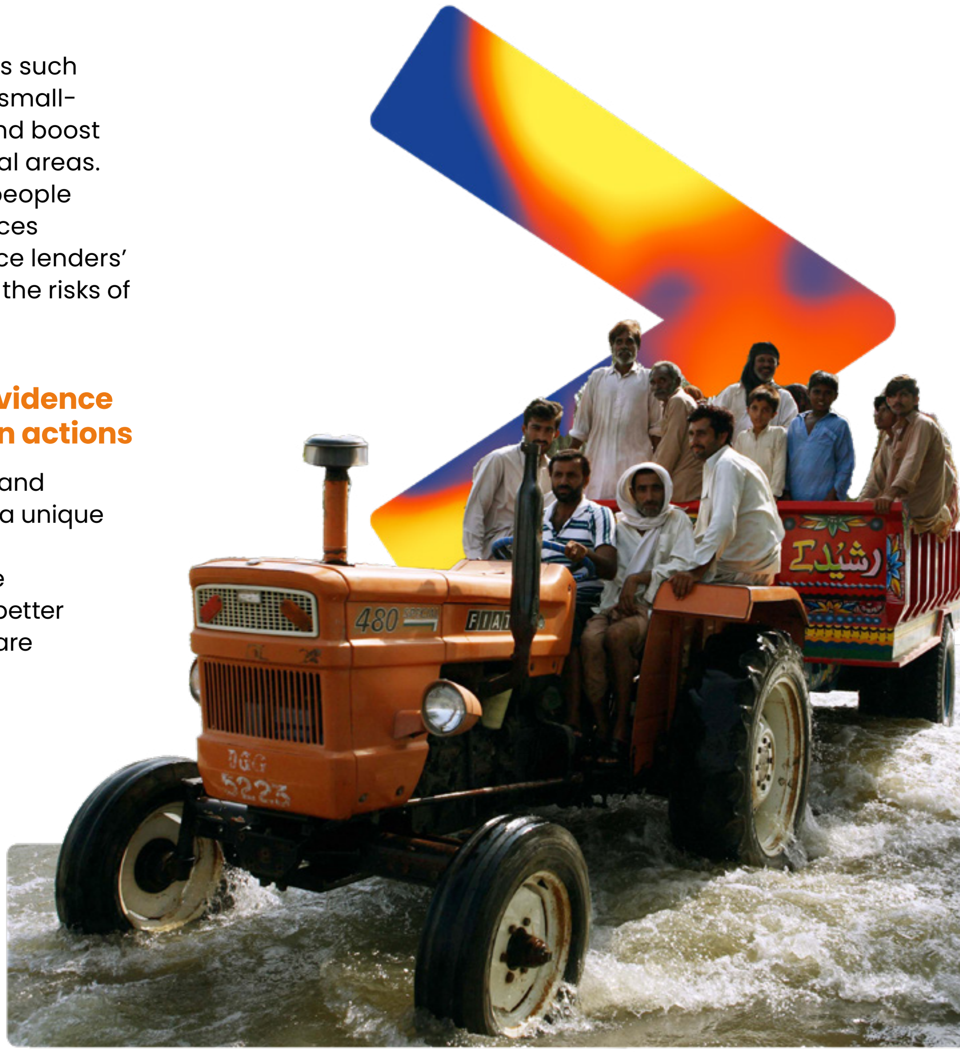
The provision of complementary services is essential to maximize the positive impact of off-farm opportunities. In addition to providing technical and vocational education, efforts should be made to strengthen people's non-cognitive skills. For example, personal initiative training, which focuses on building participants' socioemotional skills, has a greater impact on both male and female entrepreneurs' profits than traditional business training.

Expanding access to financial services such as loans for agrifood enterprises and small-scale producers is crucial to create and boost non-farm income opportunities in rural areas. Enabling young people, women and people living in poverty to access these services requires innovative strategies to reduce lenders' requirements for collateral and offset the risks of loan repayment failure.

Compiling data and building evidence on inclusive climate adaptation actions

The rapid increase in climate projects and programmes in recent years provides a unique opportunity to build evidence to guide future and current climate actions. The analysis of climate actions enables a better understanding of which interventions are most effective at supporting climate adaptation in rural areas, particularly among vulnerable populations who are at risk of being left behind. Without actionable evidence, the scarce resources available for climate actions may be wasted on ineffective approaches.

While data granularity has progressed over the past decade, the lack of data that can be disaggregated at the level of individuals hampers efforts to identify critical social vulnerabilities and target these with effective actions. For the analysis in this report, for example, gender- and age-disaggregated data on individual-level labour outcomes, and plot-level productivity and adaptation outcomes were only available for six and seven countries, respectively, out of a total of 24 countries. Other vulnerable groups, such as indigenous communities or individuals with disabilities, could not be analysed due to the lack of relevant data. Furthermore, individuals often belong to multiple vulnerable groups simultaneously, resulting in an intricacy of different types and intensities of vulnerabilities. Intersectionality is therefore a crucial aspect that deserves further research to gain a more holistic understanding of the complex dynamics of climate-related vulnerabilities.



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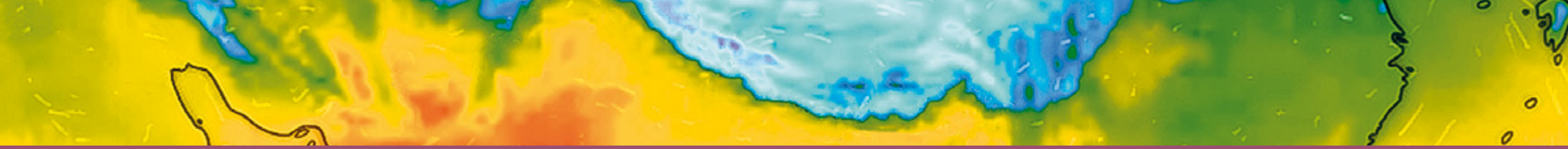


Part I

Climate vulnerability in rural areas: evidence on the role of wealth, gender and age

AFGHANISTAN - A farmer shovels dirt in his field around a village in the south of Kandahar. Recurrent droughts have adverse impacts at both household and community levels in terms of food and livelihood security.

1. Introduction

While climate change is a global crisis, its impacts on different countries, communities and individuals are highly unequal. Low- and middle-income countries contribute the least to greenhouse gas (GHG) emissions, yet suffer the most from the impacts of climate change (Birkmann and Welle, 2015; Eastin, 2018; Fankhauser and McDermott, 2014; Otto *et al.*, 2017). Inequalities are also great within countries: differences in resource endowments, livelihood orientations, biophysical environments and access to services, markets and institutions make some people considerably more vulnerable to climate change than others (Azzarri and Signorelli, 2020; Korir *et al.*, 2021). Many of these differences are rooted in historically and socially embedded processes of exclusion and marginalization, which result in stark disparities in people's abilities to cope with and adapt to climate change (Bezner Kerr, 2023). Climate change is, therefore, not only exposing the social and economic inequalities between people and communities, but also perpetuating and deepening them (Dasgupta, Emmerling and Shayegh, 2023; Paglialunga, Coveri and Zanfei, 2022).

Rural people living in low- and middle-income countries are often found to be particularly vulnerable to the adverse impacts of climate change (although the degree of their vulnerability is often inferred rather than robustly demonstrated with data or other evidence). This vulnerability is due to several factors that plague these regions, including the importance of climate-dependent agriculture in livelihoods, high rates of poverty and food insecurity, and the weakness and limited availability of markets, services and institutions (Otto *et al.*, 2017; Thornton *et al.*, 2014).

Moreover, people in rural areas face a diversity of social and economic challenges, which leads to substantial differences in climate vulnerability within rural areas. Structural inequalities related to wealth, gender and age, among other social identities, can shape people's access to resources and information, decision-making power and the social agency required to respond to a rapidly changing climate. As a result, some groups of people are much more vulnerable to climate change than others.

Effectively addressing the inequalities in climate vulnerabilities in rural areas requires solid evidence. However, this evidence is sorely lacking. The bulk of the existing evidence on the differential impacts of climate change on people and communities originates from two primary sources. First, a number of microeconomic and qualitative country case studies explore the unequal impacts of climate change (Asfaw *et al.*, 2019; De Silva and Kawasaki, 2018; Flatø, Muttarak and Pelser, 2017; Gaisie, Adu-Gyamfi and Owusu-Ansah, 2022; Korir *et al.*, 2021; Quisumbing, Kumar and Behrman, 2018). However, these studies tend to be highly context-specific, which makes it difficult to draw general conclusions about the microlevel effects of climate change on the lives and livelihoods of different rural populations.

Second, several studies use general equilibrium models to assess how climate change may influence people's incomes and consumption across countries (Arndt *et al.*, 2012; Conway *et al.*, 2015; Hallegatte, Fay and Barbier, 2018; Otto *et al.*, 2017). These models rely on numerous assumptions about markets, prices and the distribution of resources across populations, which limits their utility for understanding the microlevel dynamics that create conditions of exclusion and marginalization in the context of climate change.

There are virtually no multicountry microeconomic studies that examine how climate vulnerabilities vary in rural areas across key social dimensions related to wealth, gender or age.[1]

[1] Exceptions include Azzarri and Signorelli (2020), with a focus on sub-Saharan Africa; Paglialunga, Coveri and Zanfei (2022) on inequalities within countries, but without an explicit focus on rural people; Cooper *et al.* (2021) for sub-Saharan Africa, with a focus on intimate partner violence; and Baez *et al.* (2017), focusing on youth migration in Latin America.

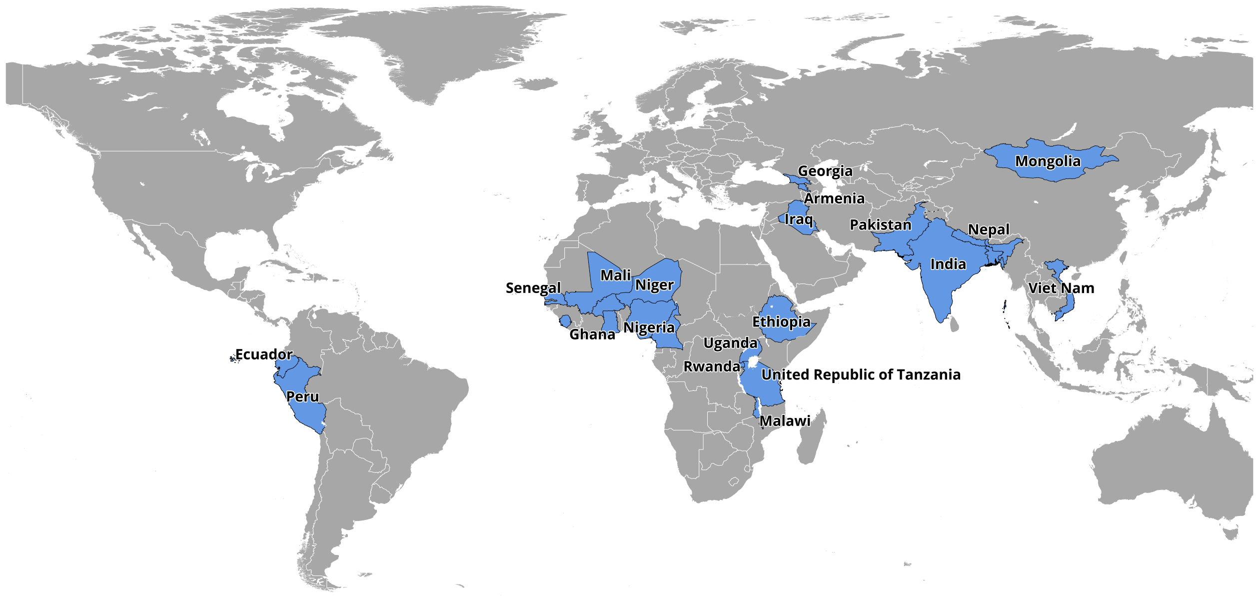
This report seeks to fill this important gap by analysing the impact of climate change on diverse rural populations. For this purpose, we bring together a new and vast dataset combining socioeconomic data collected from 109 341 rural households in 24 countries, representing over 950 million individuals. These household data are merged with georeferenced, daily observation data of precipitation and temperature spanning 70 years.

Using these data, the report empirically examines how social differences based on wealth, gender and age influence rural people's vulnerability to climate stresses. In particular, it analyses how exposure to extreme weather events and longer-term climatic changes differentially affects the incomes, livelihoods, labour allocations and adaptive responses of poor and better-off people, men and women, and young and older individuals. By so doing, the report sheds light on the different ways in which climate change affects marginalized segments of rural societies; these insights can guide policies and climate financing toward effective solutions.

The empirical evidence presented is this report clearly demonstrates that climate change and its associated extreme weather events are widening income gaps within rural communities and limiting prospects for inclusive growth and poverty reduction. It shows that extreme weather events such as floods and heat stress reduce the incomes and well-being of poor and female-headed households more than those of other segments of the rural population. The magnitude of these losses is staggering. It is estimated that in one year, floods and heat stress increase the income gap between rural poor and non-poor households in low- and middle-income countries

FIGURE 1

Countries included in this report



Note: Dashed lines on maps represent approximate border lines for which there may not yet be full agreement. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. The final boundary between the Sudan and South Sudan has not yet been determined.

Source: authors' own elaboration based on: **United Nations Geospatial.** 2020. Map geodata UNmap25_shp. New York, USA, United Nations.

by approximately USD 21 billion and USD 20 billion, respectively. For female-headed households in low- and middle-income countries, these same events increase the income gap by USD 16 billion and USD 37 billion per year, respectively, compared to male-headed households. Given the already large and persistent gaps in agricultural productivity and wages between women and men in low- and middle-income countries, the report demonstrates that if left unaddressed, climate change will dramatically increase these gaps over the coming years.

The evidence also demonstrates that vulnerabilities in rural areas are diverse. For example, we find that while young rural households are more likely than older households to lose agricultural income when exposed to extreme weather events, they are also better able to compensate this loss by generating off-farm income.[2] In low- and middle-income countries, the contribution of young people to rural off-farm economies during extreme weather events is considerable. For example, we estimate that when exposed to heat stress, young households increase their off-farm incomes by approximately USD 47 billion per year, relative to older households. This finding is indicative of the substantial contribution that young people make to sustaining and expanding rural economies in a context of climate change.

The findings provide a strong empirical foundation for elevating the needs of vulnerable rural populations in climate policy debates and guiding investments to address disparities in climate vulnerability to foster more inclusive, just and climate-resilient development pathways (IPCC, 2022a).

The evidence is clear: failure to address the unequal impacts of climate change on rural people will intensify the already large gap between the haves and have-nots and between men and women, and will make it impossible to achieve Sustainable Development Goal (SDG) 1 (No Poverty), SDG 2 (Zero Hunger) and 5 (Gender Equality and Women's Empowerment) by 2030.

As a global community, we are failing to acknowledge and adequately address the needs of vulnerable rural people. Current climate financing for small-scale producers is estimated to be just 1.7 percent of all tracked climate financing (Chiriac, Naran and Falconer, 2020), while the needs of vulnerable people are rarely acknowledged in national climate policies. We find that of the 4 164 specific actions included in the nationally determined contributions (NDCs) and national adaptation plans (NAPs) of the 24 countries we consider, less than 21 percent make an explicit mention of people and their livelihoods. Moreover, only about 6 percent explicitly acknowledge the needs of women, less than 3 percent explicitly mention vulnerable people, less than 1 percent mention poor people and about 6 percent refer to farmers living in rural communities. In addition, only about 2 percent explicitly mention youth, whereas very few actions explicitly target indigenous people (1.2 percent) or migrants, older people or people with disabilities (less than 1 percent).

It is hoped that this report invigorates discussions within global climate and development communities on the importance of placing people at the centre of climate actions in rural areas. This entails acknowledging that rural people are not a homogenous group, and that they face diverse vulnerabilities to climate change that are rooted in socioeconomic structures. Placing people at the centre of climate actions must go hand in hand with a substantial increase in climate financing for the most vulnerable segments of the population, and the identification of climate actions that address the diverse vulnerabilities these populations face in the context of climate change. Only through these actions can we transition to a just and climate-resilient development path that leaves no one behind.

[2] Contrary to non-farm income, which excludes income from any agricultural activity, off-farm income includes agricultural wage income from work on non-household farms (Barrett, Reardon and Webb, 2001). The farm in "off-farm" hence refers specifically to the household farm, and not to farming activities in general.

MONGOLIA – A woman tends to her livestock in a region affected by dzuds, a unique disaster affecting steppe, semi-desert, and desert regions in Central Asia. Large numbers of livestock die, primarily due to starvation and being unable to graze because of the increasingly severe climatic conditions.

2. Conceptual framework: understanding how climate change affects rural people

KEY FACTS

- Rural people in low- and middle-income countries are particularly vulnerable to climate change.
- Climate change affects rural people directly through reductions in agricultural production, and indirectly through effects on non-farm incomes and food prices.
- People's vulnerability to climate change is conditioned by their exposure to climate stressors, their sensitivity to these stressors and their capacities to adapt.
- Differences in socioeconomic endowments and access to institutions and services, as well as discriminatory social norms, make some people more vulnerable to climate change than others.

The global climate is changing rapidly, which is producing a range of new risks and vulnerabilities for rural people. The sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC) finds that because of human activity, global temperatures have already increased by 1.1 °C compared to the pre-industrial era, and this increase is projected to reach or exceed 1.5 °C within the next 20 years, if not sooner (IPCC, 2022a). As a result of climate change, extreme weather events are intensifying and becoming more frequent: heat waves are increasing in intensity and duration, seasons are changing and global water cycles are intensifying, leading to more frequent and severe droughts and floods. Studies show that these changes have profound effects on agricultural systems (Emediegwu and Ubabukoh, 2023; Lesk, Rowhani and Ramankutty, 2016; Thornton and Gerber, 2010) and on the livelihoods of the rural people who depend on them (Adenle *et al.*, 2017; Lloyd *et al.*, 2018; Solaymani, 2018). The most direct effect is the impact on agricultural production and productivity. Agricultural systems have been adapted over millennia to a wide range of climate conditions, and rapid changes in these conditions can outpace adaptation, leading to dramatic reductions in productivity.

Among the key challenges posed by climate change to agriculture are the effects of global warming. Crop production (Chung, Jintrawet and Promburom, 2015; Gornall *et al.*, 2010; Kumar *et al.*, 2021; Lobell and Gourdji, 2012), livestock production (Emediegwu and Ubabukoh, 2023) and fish production (Sarkar *et al.*, 2021) are all highly sensitive to extreme temperatures. Lobell and Field (2007) show that global warming between 1981 and 2002 led to considerable reductions in the yields for wheat, maize and barley. It is estimated that, in the absence of the observed climate trends, global production of these three crops would have been roughly 2 to 3 percent higher in 2002 (Lobell and Field, 2007). These figures imply production losses of roughly 40 million tonnes per year, for a value of about USD 5 billion. More recently, Chandio *et al.* (2023) estimate that a 1 percent increase in temperature led to a 1.93 percent reduction in crop production in South Asia between 1991 and 2016.

For livestock production, Emediegwu and Ubabukoh (2023) find that between 1961 and 2017, a 1 °C increase in temperature was associated with a 19 percent reduction in global beef production. In poor countries, where adaptive management practices are limited, productivity losses were as high as 27 percent. As temperatures rise, the spatial distribution of many diseases and pests expands into new regions, where systems to cope with them are not available (Mora *et al.*, 2022). Finally, high temperatures can have a strong negative effect on the labour productivity of people working in exposed environments, with older people being particularly sensitive to heat stress (Armstrong *et al.*, 2019; Orlov *et al.*, 2020).

In addition to long-term changes in average temperatures, short-term temperature variability, and particularly heat waves, have detrimental effects on crop production and productivity. Lesk, Rowhani and Ramankutty (2016) find that extreme heat events were associated with a 9 percent to 10 percent reduction in cereal production worldwide between 1964 and 2007, due to reductions in yields and area harvested. For Africa, Lobell *et al.* (2011) show that each day with a temperature that was both hotter than average and above 30 °C reduced maize yields by 1 percent under optimal rain-fed conditions, and by 1.7 percent under drought conditions, between 1999 and 2007.

In addition to rising temperatures, climate change is associated with more frequent and intense precipitation events, notably droughts and floods. These events pose important threats to agricultural production. For example, exposure to droughts during the sensitive phases of a crop's production cycle can diminish yields by stunting growth, reducing grain filling and hampering reproduction (Iqbal, Singh and Ansari, 2020). Droughts reduce the availability of feed for livestock, leading to lower productivity and elevated mortality and morbidity. Meanwhile, floods and excessive rains destroy crops and undermine future productivity by damaging productive infrastructure, leaching key nutrients (such as nitrogen) from the soil and reducing water quality (Kaur *et al.*, 2020).

The effects of climate change and associated weather anomalies on agricultural productivity interact with socioeconomic factors, directly influencing people's livelihood choices and options. For vulnerable people, this interaction can reinforce and perpetuate conditions of poverty and marginalization in two primary ways. First, reductions in productivity caused by climate-related events can undermine people's economic capacity to invest in future production and adaptation measures, including investments in farm inputs, technologies, labour and equipment (Antonelli, Coromaldi and Pallante, 2022; Ochieng, Kirimi and Mathenge, 2016). Second, frequent exposure to climate-related events has important psychological effects, and can make people less willing to make new investments in their agricultural systems and push them to prioritize short-term investments over longer-term ones (Alem and Colmer, 2022; Kosec and Mo, 2017; Makate *et al.*, 2022). These effects are, of course, strongly influenced by the resources and services (including credit and insurance services) that are available to a person to mitigate income losses and adapt to future climate stresses.

The effects of climate change on agricultural productivity are not confined to farm households. Indeed, these impacts ripple through local and national economies to generate a wide range of indirect effects on all rural people. One of the most important indirect effects is that on agricultural commodity prices. Widespread reductions in agricultural production due to rising temperatures and extreme weather events constrain local food supplies, thereby leading to higher prices (Escalante and Maisonnave, 2022; Solaymani, 2018; Yen *et al.*, 2019). While higher prices can benefit producers with an available surplus to sell, it adversely affects the ability of net food buyers to access food, including a large number of small-scale producers (Molua and Ayuk, 2021; Nguyen, Ngo and Nguyen, 2022; Yen *et al.*, 2019).

Agricultural prices are also affected by the strategies producers adopt to cope with climate-induced stresses. For example, without access to functional insurance markets, small-scale producers may sell livestock to compensate income losses and smooth consumption (Assan *et al.*, 2018; Mishra and Mishra, 2010; Wouterse, Andrijevic and Schaeffer, 2022). These sales can trigger rapid reductions in livestock prices in local markets. For example, in northwest China, distress livestock sales following adverse weather events led to a 60 percent reduction in livestock prices (Zhang *et al.*, 2022).

Another important indirect effect is related to the impacts on non-farm income opportunities, including wage employment and non-farm businesses. In rural areas, people often have diversified livelihood strategies that blend farm and non-farm income sources (Winters *et al.*, 2009). However, many of these non-farm income sources are closely tied to agrifood systems, either directly through wage labour on farms and in the trade and processing of agricultural commodities, or indirectly through non-farm enterprises that rely on expenditures from agricultural producers. As a result, disruptions in agricultural production due to climate stresses can have indirect effects on the availability of non-farm income options and earnings from these sources (Coulibaly *et al.*, 2015; Escalante and Maisonnave, 2022; Mahajan, 2017). Moreover, a lack of earning opportunities can be a disincentive for people to remain in rural areas, and therefore act as a push factor for migration to cities and abroad (Cattaneo and Peri, 2016). Together, these direct and indirect impact channels shape the specific vulnerabilities of rural people to climate change.

What is climate vulnerability?

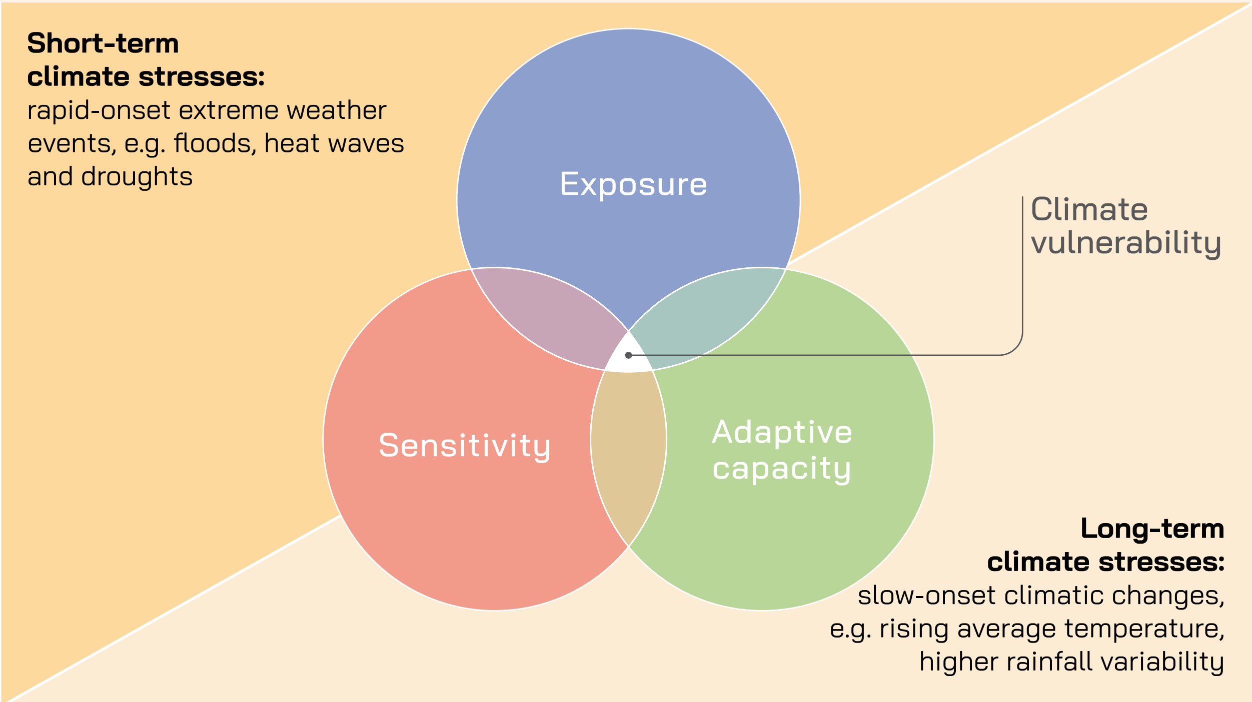
The extent to which climate-induced changes in agricultural productivity, prices and labour market dynamics affect people's lives and livelihoods is a function of their underlying vulnerability to these events. The IPCC defines climate vulnerability as:

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2022a, p. 43).

Drawing on this definition, this report applies a conceptual framework in which climate vulnerability is shaped by the combination of three factors: exposure, sensitivity and adaptive capacity (see **Figure 2**).[3] These elements of climate vulnerability provide a useful lens to empirically examine how and to what extent climate change differentially affects rural populations based on differences in wealth, gender and age.

FIGURE 2

Climate Vulnerability



Source: authors' own elaboration, adapted from: **IPCC.** 2022a. *Climate change 2022: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, USA, Cambridge University Press.

[3] The concept of vulnerability used in this report coincides only partially with that of one of the latest IPCC assessment reports. The IPCC has embedded its discussion on climate vulnerability within a broader framing of climate risk, which is defined as "the potential for adverse consequences for human or ecological systems" (IPCC, 2022a, p. 43). This risk results from the interaction between a) the potential occurrence of a physical event or trend (hazard); b) the presence of people, livelihoods, species or ecosystems that could be adversely affected (exposure); and c) their propensity to be adversely affected (vulnerability, which is shaped by sensitivity and adaptive capacity) (IPCC, 2022a). While the concept used in this report is slightly less complex, it is easier to operationalize empirically. Moreover, contrary to the future-oriented notion of climate risk, this report focuses on past trends and events related to climate change.

BOX 1

Measuring climate stressors

- **Floods**
  The number of extreme precipitation days. Extreme precipitation occurs when precipitation exceeds the 95th percentile of daily precipitation.
- **Heat stress**
  The number of extreme temperature days. Extreme temperature occurs when the maximum temperature exceeds the 99th percentile of daily maximum temperatures.
- **Drought**
  The number of days exceeding an extreme dry spell. An extreme dry spell is an event with a length that exceeds the 95th percentile of consecutive dry days.
- **Climate change**
  Long-term change in average temperature between two periods of time: 1951–1980 and the 30 years prior to the survey.

The term *exposure* refers to the type, frequency and intensity of the climate variations, or climate stressors, that affect a person. Exposure is thus external to the system, as it is determined by exogenous climate events and stresses. It includes slow-onset changes in climate systems, such as rising temperatures and changes in the length of agricultural seasons, as well as rapid-onset events, such as floods, heat waves and droughts. The nature and extent to which people are exposed to climate stressors shape the effects on their lives and the ways in which they adapt to and cope with them. For example, producers can autonomously adopt adaptive practices to mitigate the long-term impacts of gradual increases in mean temperatures, up to certain biological limits (Eakin *et al.*, 2014). Conversely, there may be few short-term actions producers can take to modify their production systems to withstand rapid-onset events such as floods.

Moreover, the spatial extent of a climate shock can influence its impacts on local prices and labour market dynamics. While the effects of extreme weather events on food prices that occur at a subnational level can be mitigated through local trade, widespread events can have effects on national and even global food prices (Amaechina *et al.*, 2022; Solaymani, 2018; Yen *et al.*, 2019). Finally, the socioeconomic conditions of a person can strongly influence their exposure to climate events, as Chapter 3, Chapter 4 and Chapter 5 will illustrate.

In this report, we measure exposure to various climate stressors using long-term, daily georeferenced precipitation and temperature data. Box 1 summarizes these climate stressors and our approach to measuring them. More information on the construction of the climate stressors and data sources are described in Part II of the report, with further details in the Annex 1.

Sensitivity is defined as the degree to which a person is susceptible to harm due to exposure to climate stressors. Differences in sensitivity are driven by both socioeconomic and biophysical factors. For example, people with diversified agricultural production systems or diversified livelihoods that blend farm and non-farm income sources are often better able to withstand the adverse effects of climate stressors on their incomes (Antonelli, Coromaldi and Pallante, 2022; Motsholapheko, Kgathi and Vanderpost, 2011; Mugari, Masundire and Bolaane, 2020; Shisanya and Mafongoya, 2016). In addition, access to well-functioning markets for food, credit, agricultural inputs, labour and insurance can strongly affect the extent to which exposure to climate stressors leads to a reduction in income and well-being (Arslan *et al.*, 2018; Kidane *et al.*, 2022; Maggio and Sitko, 2019; Motsholapheko, Kgathi and Vanderpost, 2011).

The biophysical context of a production system also affects sensitivity. Evidence suggests that agricultural production systems are more resilient to climate stresses when they are integrated into complex and well-functioning ecosystems (Altieri *et al.*, 2015). Soil quality is particularly important for reducing the sensitivity of agricultural systems. High-quality soils that are rich in organic matter are able to retain moisture longer and have a higher water filtration capacity than degraded soils, making them more resilient to droughts and excessive rain (Lal, 2011).

Socioeconomic factors interact with biophysical processes in ways that can increase the sensitivity of some rural populations. For example, producers with limited access to land and capital are often forced to mine soil nutrients and continuously cultivate a small range of crops over multiple years to meet immediate food security needs. In turn, these practices degrade agricultural soils and make producers more sensitive to future climate stressors (Vanlauwe *et al.*, 2015).

In this report, we measure sensitivity to climate stressors among rural people using survey data that measure households' on-farm, off-farm and total incomes, as well as labour dynamics. Box 2 summarizes the sensitivity outcomes. These variables and associated data sources are described in Part II of the report.

Together, exposure and sensitivity describe the potential impacts of climate change and associated extreme weather events on people. However, high exposure or sensitivity does not necessarily imply that a household or individual is more vulnerable: overall vulnerability is also determined by the capacity to adapt to and cope with climate change.

The IPCC defines *adaptation* as a "process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities" (IPCC, 2022a, p. 43). Meanwhile, *adaptive capacity* refers to "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2022a, p. 2899). Adaptation strategies can take various forms, including anticipatory or reactive strategies, or autonomous or planned strategies.

In rural contexts, *anticipatory adaptation* involves *ex ante* modifications or changes to livelihoods and productions systems with the intention of reducing the adverse effects of climate change and capturing benefits, where feasible. These strategies may be adopted autonomously by individuals as they seek to identify effective adaptation options, or they may be planned strategies that are promoted as part of a climate adaptation policy or programme.

Meanwhile, *reactive adaptations* are *ex post* strategies that people adopt to moderate the adverse impacts of climate stresses on their livelihoods over a timeframe of usually less than one year (Engle, 2011). While anticipatory adaptation is driven primarily by previous experiences and information, reactive adaptation occurs during or immediately following a climate-related event.

BOX 2

Measuring the sensitivity of rural livelihoods to climate stressors

- **Value of crop production**
  Total value of crops produced by a household, calculated based on harvested quantities and corresponding local prices over the past agricultural year.
- **On-farm income**
  Total net household income derived from on-farm activities (crop and livestock production, forestry and fisheries) over the past agricultural year.
- **Off-farm income**
  Any income derived from agricultural and non-agricultural wage employment, self-employment, public and private transfers, as well as income from financial and real estate assets over the past agricultural year.
- **Total income**
  Sum of on-farm income and off-farm income.
- **Labour force participation**
  Whether an individual worked at least one hour over the past seven days.
- **Total weekly labour hours**
  Sum of weekly hours worked in main and secondary jobs.
- **Share of labour hours dedicated to farm activities**

Source: authors' elaboration.

In this report, we will examine both short-term strategies adopted to cope with extreme events (reactive adaptation) and adaptive responses to long-term climatic changes (anticipatory adaptation). Box 3 provides an overview of the variables used to measure different adaptive actions; more details are given in Part II of the report.

BOX 3

Adaptive actions considered in this report

- **Total tropical livestock unit (TLU)**
  Average TLUs owned by livestock-keeping farms at the time of the interview. One TLU corresponds to 250 kg of live weight.
- **Agricultural expenditure**
  Sum of a household's expenditures related to crop production. This includes expenditures on chemicals, seeds (including improved seeds), inorganic fertilizers, land and machinery rental and labour inputs.
- **Income concentration index**
  Herfindahl-Hirschman Index (HHI), measuring the weight of different income sources (crop and livestock production, fisheries, forestry, agricultural wages, non-agricultural wages, self-employment, transfers, other income) in the total income.
- **Intercropping of maize and legumes**
- **Irrigation of agricultural plots**
- **Use of organic fertilizers**
- **Soil or water conservation infrastructure**

Source: authors' elaboration.

It is important to note that some of the strategies adopted to cope with climate stressors in the short run may be maladaptive in the long run. For example, vulnerable people often liquidate productive assets, limit food consumption, reduce productive investments, deplete ground water reserves or withdraw children from school to counter the immediate impacts of climate-related events on consumption and income, but this can undermine their capacity to address future stresses (Bezner Kerr, 2023). Some maladaptive actions only effect certain people. For example, exposure to some extreme weather events has been shown to increase the incidences of forced or early marriage of young girls (Asadullah, Islam and Wahhaj, 2021).

The literature demonstrates that adaptive capacity in rural areas is strongly influenced by individual socioeconomic conditions. Numerous studies investigating the determinants of climate-adaptive actions in rural areas find that factors such as the level of education, access to land, years of farming experience, social networks, gender-related norms and expectations, previous exposure to climate stresses and access to extension services and early warning systems all affect people's abilities to take effective adaptive actions in the face of climate variability (see, among others, Motsholapheko, Kgathi and Vanderpost, 2011; Ngigi and Muange, 2022; Ofoegbu *et al.*, 2016; Shisanya and Mafongoya, 2016; Villamayor-Tomas and García-López, 2017; Wouterse, Andrijevic and Schaeffer, 2022). Moreover, subjective factors, including perceptions about climate change, expectations about the future and risk tolerance, as well as social norms and policies, also influence the likelihood of taking actions to adapt to climate change (Alem and Colmer, 2022; Kosec and Mo, 2017).

Figure 3 summarizes how climate vulnerability can differ in rural spaces. It shows how exposure to climate stresses generates direct and indirect impacts that are mediated by the micro- and macrolevel economic and social capabilities that individuals within a household possess. These capabilities are, in turn, shaped by societal structures and cultural and social norms that influence people's ability to access resources, services and institutions, as well as to exercise agency in productive and economic spheres. A person's wealth, gender and age are factors that influence relative sensitivity and adaptive capacity to climate change in important and distinct ways.

Chapter 3, Chapter 4 and Chapter 5 provide novel empirical evidence that measures disparities in the climate vulnerability of rural people associated with differences in wealth, gender and age. Descriptions of the data, variables and methods used are provided in the second part of the report, while further details on the methodology, the main regression outputs and robustness checks are available in Annex 2, Annex 3 and Annex 4, respectively.

Before proceeding, we want to highlight that intersectional vulnerabilities are beyond the scope of the analysis presented in this report. Rural populations do not fall neatly into distinct social categories based on wealth, gender and age: for many people, these categories overlap, and their combinations magnify intersectional vulnerabilities. For example, young women living in poverty are constrained by the same discriminatory gender norms as older women, but also face additional social and economic challenges related to their wealth and age (Chant, 2004; Huynh and Resurreccion, 2014). Other key social identities related to ethnicity and caste interact with wealth, gender and age in ways that magnify people's climate vulnerability (Ahmed and Fajber, 2009). Therefore, by focusing on the vulnerabilities associated with wealth, gender and age, the analysis in this report obscures the important ways in which the intersection of these and other categories produces unique and often compounding vulnerabilities to climate change.

BOX 4

Definition of household- and individual-level groupings

Household groups

- Wealth: a household is defined as poor if it falls within the bottom 25th percentile of the cumulative deprivation distribution of the multidimensional wealth index.
- Gender: the household head is male or female.
- Age: a household is defined as young if the household head is younger than 35.

Age definition in the analysis at the individual level

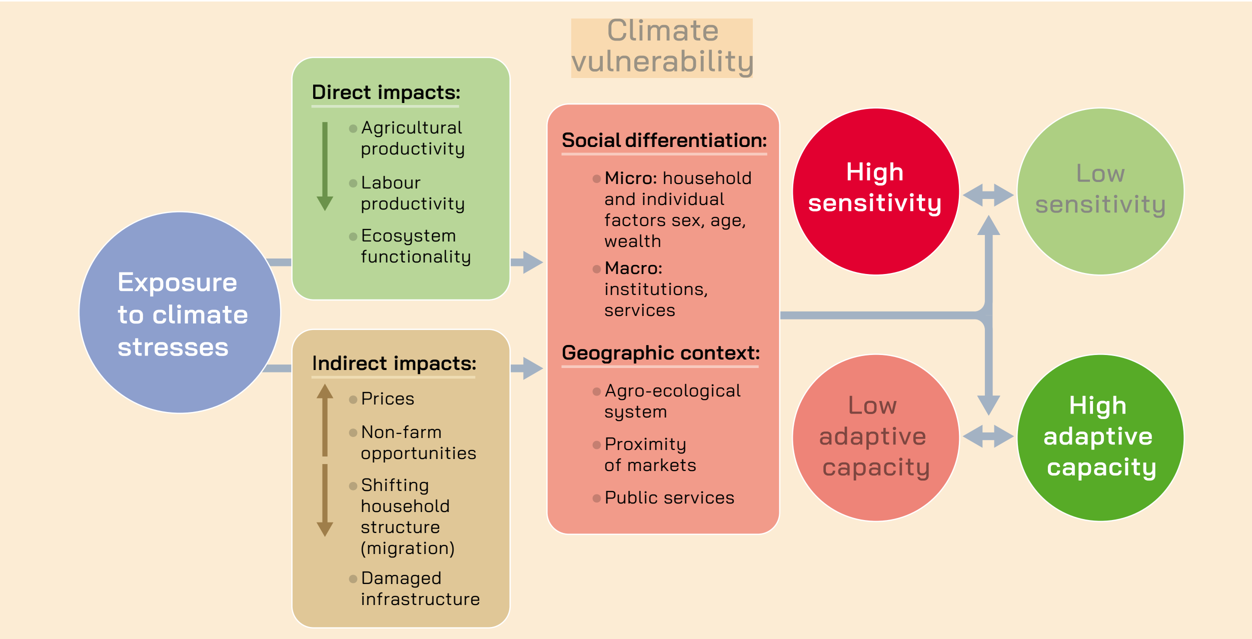
- Children: between 10 and 14 years.
- Youth: between 15 and 24 years.
- Prime-age adults: between 25 and 54 years.
- Seniors: 55 years and above.

Gender definition in the analysis at the level of the plot

Source: authors' own elaboration.

FIGURE 3

Visualizing heterogeneous climate vulnerabilities in rural areas



Source: authors' own elaboration.

ECUADOR - A shellfish and crab gatherer wades through the mud among the roots of mangroves. Mangroves are vital to millions of fishers. Climate change threatens their livelihoods by causing the loss of mangroves.

3. Wealth-related disparities in climate vulnerability

KEY FACTS

- Extreme weather events disproportionately affect poor rural households, leading to significant reductions in their incomes and widening income inequality.
- In an average year, poor households lose 5 percent of their total incomes due to heat stress relative to better-off households, and 4.4 percent due to floods.
- Extreme precipitation and temperature events increase the income gap between rural poor and non-poor households in low- and middle-income countries by approximately USD 21 billion and USD 20 billion per year, respectively.
- A 1 °C increase in average temperatures pushes poor households to depend more on climate-sensitive agriculture and lose off-farm opportunities. Such a rise is associated with a 53 percent increase in the farm incomes of poor households, and a 33 percent decrease in off-farm incomes relative to non-poor households.
- Extreme weather events push poor rural households to adopt maladaptive coping strategies, including liquidating livestock and redirecting expenditures away from their farms.

Rural men and women living in poverty face acute vulnerabilities to climate change that are driven by the lack of resources and economic opportunities, and the precarity of their livelihoods. The literature shows that these factors elevate their levels of exposure to climate stressors and their sensitivity to these stressors, and limit their adaptive capacities.

Poor people are often concentrated in areas that are more exposed to climate stressors (De Silva and Kawasaki, 2018; Hallegatte, Fay and Barbier, 2018; Khadka *et al.*, 2022). This circumstance partially reflects the fact that places with suboptimal climate conditions and limited market access have lower average agricultural productivity levels, leading to lower farm incomes and higher concentrations of people living in poverty (Dixon *et al.*, 2019; Giller *et al.*, 2021). At the same time, localized land markets and land access dynamics often force poorer people to occupy land in high-risk areas, such as flood zones and steep terrains (De Silva and Kawasaki, 2018; Hallegatte, Fay and Barbier, 2018; Khadka *et al.*, 2022).

The livelihoods and production systems of rural people living in poverty exhibit distinct features that can increase their sensitivity to climate change. People living in poverty are more likely to rely on agriculture for their livelihoods. Moreover, they tend to operate production systems that are very small-scale and make limited use of capital-intensive inputs such as improved seeds, technology and fertilizers. They also often operate under rain-fed conditions, which are becoming more uncertain and erratic due to climate change. As a result, labour and land productivity are generally low among these populations, with production oriented primarily toward own consumption rather than sales. Indeed, lower-income agricultural producers are often net buyers of food, and therefore particularly sensitive to food price increases caused by climate stresses (Jayne, 2012).

Furthermore, the production systems and livelihoods of poor rural people are often less diversified than those of the better-off (Asfaw *et al.*, 2019). Poorer segments of rural populations often dedicate most of their limited farmland and labour to the production of a small range of staple foods in an effort to achieve short-term food security objectives (Amare *et al.*, 2018). When climate stresses occur during sensitive periods of these crops' development, such as droughts during the grain filling stage, the effects on total farm output are much more severe than in more diversified systems.

BOX 5

Interpreting the figures

The results of our analysis are presented in bar and whisker graphs to facilitate their comparison.

While the bars represent the point estimates, the whiskers show the confidence intervals around these point estimates. If the whisker bars cross the zero line, it means that the data point or estimate is not statistically significantly different from zero. When the whisker bars do not touch the zero axis, there is a statistically significant result, either positive or negative.

The graphs present the coefficient estimates for the interaction of the climate stressor with the social category analysed. They only measure the difference between the social category of interest and the comparison group. For example, for poor households, the results illustrated in the graphs show the effect of climate stress relative to non-poor households. They do not represent absolute gains or losses of either of the groups. For these net effects, readers should refer to the full regression output tables, which are presented in Annex 2.

For extreme weather events, the interaction term can be interpreted as a percent difference in outcome (e.g. total income) associated with an additional day of exposure to a climate stressor, while for long-term climate change, it is interpreted as the effect of an additional degree Celsius in the long-term average temperature.

People living in poverty also have more limited options in terms of non-farm employment, as well as access to credit and income, than better-off farmers (Banerjee and Duflo, 2007). First, poorer people have lower average levels of education, which limits the range of non-farm employment opportunities they have. As a result, the primary source of wage employment available to the rural poor is temporary agricultural employment, the availability of which is also sensitive to climate variations (Winters *et al.*, 2009). Second, people living in poverty lack the resources to invest in non-farm enterprises that could help them stabilize their incomes when climate shocks occur. However, because poor producers have limited resources and operate relatively more stable, yet unproductive farming systems, some studies have found that the absolute magnitude of income and production losses due to climate stresses is lower among poor producers compared to their better-off peers (Aryal *et al.*, 2020).

Finally, poverty has a strong adverse effect on a household's adaptive capacity. Poverty often pushes individuals and households to prioritize productive and economic choices that minimize their short-term risks of income loss and food insecurity, but generate low returns in the long run and can lock them into low-equilibrium poverty traps (Carter and Barrett, 2006; Kraay and McKenzie, 2014). This can seriously limit their capacity to take *ex ante* actions to adapt to the uncertainties of climate change, leading to a vicious cycle of low adaptation and high relative losses from climate stresses that become more entrenched and acute over time.

Poor people also have access to fewer productive resources, such as land and labour, which limits their capacity to experiment with new adaptive practices. Studies of the determinants of adopting a wide range of climate-adaptive practices suggest that land and labour are often strong predictors of adoption (Arslan *et al.*, 2018; Naz and Saqib, 2021; Wouterse, Andrijevic and Schaeffer, 2022). The lack of land and labour, coupled with very limited access to capital, limits the range of adaptive actions that are available to the rural poor (Kidane *et al.*, 2022). As a consequence, this group disproportionally relies on maladaptive coping strategies, such as reducing food consumption and withdrawing children from school, when disasters occur (Schipper, 2020). As climate change drives rising temperatures and more frequent extreme weather events, reliance on maladaptive coping strategies to address these challenges contributes to self-reinforcing cycles that leave poor households increasingly vulnerable to these stressors and unable to withstand them.

Drawing on data from 24 countries, this section provides novel evidence on the magnitude of the climate vulnerabilities of rural populations living in poverty, relative to populations with high levels of wealth. This section focuses specifically on key findings from the empirical analysis. Further details on the empirical strategy and on how differences in wealth are defined are found in Part II of this report.

Extreme weather events cause considerable income losses for the rural poor

Poorer rural households are significantly more likely to suffer income losses due to extreme weather events than non-poor households. The results depicted in **Figure 4** show that exposure to **heat stress** adversely affects all dimensions of the income portfolios of the rural poor. Not only are the agricultural systems of the poor more affected by extreme temperatures, so are their off-farm income-earning strategies. These factors tend to be mutually reinforcing. As extreme temperatures disrupt agricultural production, poor households are forced to seek off-farm employment opportunities to compensate this loss. This creates competition for the limited off-farm work available in rural areas for unskilled labour or for agricultural wage labour, which pushes down wages.

Thus, for every additional day of extreme temperatures, poor households lose 2.4 percent of their on-farm incomes, 1.1 percent of the crop value they produce, and 1.5 percent of their off-farm income, compared to non-poor households. The interactions between on-farm and off-farm income losses lead to an estimated total income loss for poor rural households of 0.9 percent for each day of extreme high temperatures, relative to non-poor households. Over an average year, poor households thus lose 5 percent of their total incomes due to heat stress compared to better-off households.

Poor rural households are also acutely sensitive to **floods**. The evidence shows that for every additional day of exposure to extreme precipitation, poor households lose 0.8 percent of their total income, relative to non-poor households. On average, poor households lose 4.4 percent of their total annual income because of floods relative to non-poor households.[4] These adverse effects are primarily felt in the form of losses in off-farm income. For every additional day of extreme precipitation, poor households lose 2.4 percent of their off-farm income relative to non-poor households, with no discernible difference for on-farm income. This finding suggests that the off-farm work poor households rely on is often lost when floods occur. This is likely due to the fact that much of the work available to poor rural households is directly tied to agrifood systems, which are themselves sensitive to flooding.

To put the magnitude of the total income losses caused by heat stress and floods into perspective, we extrapolate the above estimates to the total rural population in low- and middle-income countries. Using the average number of flood and heat stress events over the past ten years, we estimate that these events increase the income gap between rural poor and non-poor households by approximately USD 21 billion and USD 20 billion per year in low- and middle-income countries, respectively.[5] These figures highlight the massive challenge posed by extreme weather events for global efforts to reduce poverty and inequality, which will become only more acute as the frequency and intensity of these events increase because of climate change.

Finally, our results show that while exposure to **drought** is not associated with a significant difference in the total incomes of poor versus non-poor households, important differences in farm and off-farm incomes are observed. When exposed to droughts, poor households lose relatively more of their farm incomes and value of crop production than non-poor households. However, they seem to compensate for this loss by increasing their off-farm income relatively more.

Taken together, the results suggest that the rural poor are sensitive to extreme weather events across multiple livelihoods dimensions, including on-farm and off-farm income-generating activities. Any climate actions targeting the rural poor will therefore require multidimensional approaches. Sectoral strategies that target a

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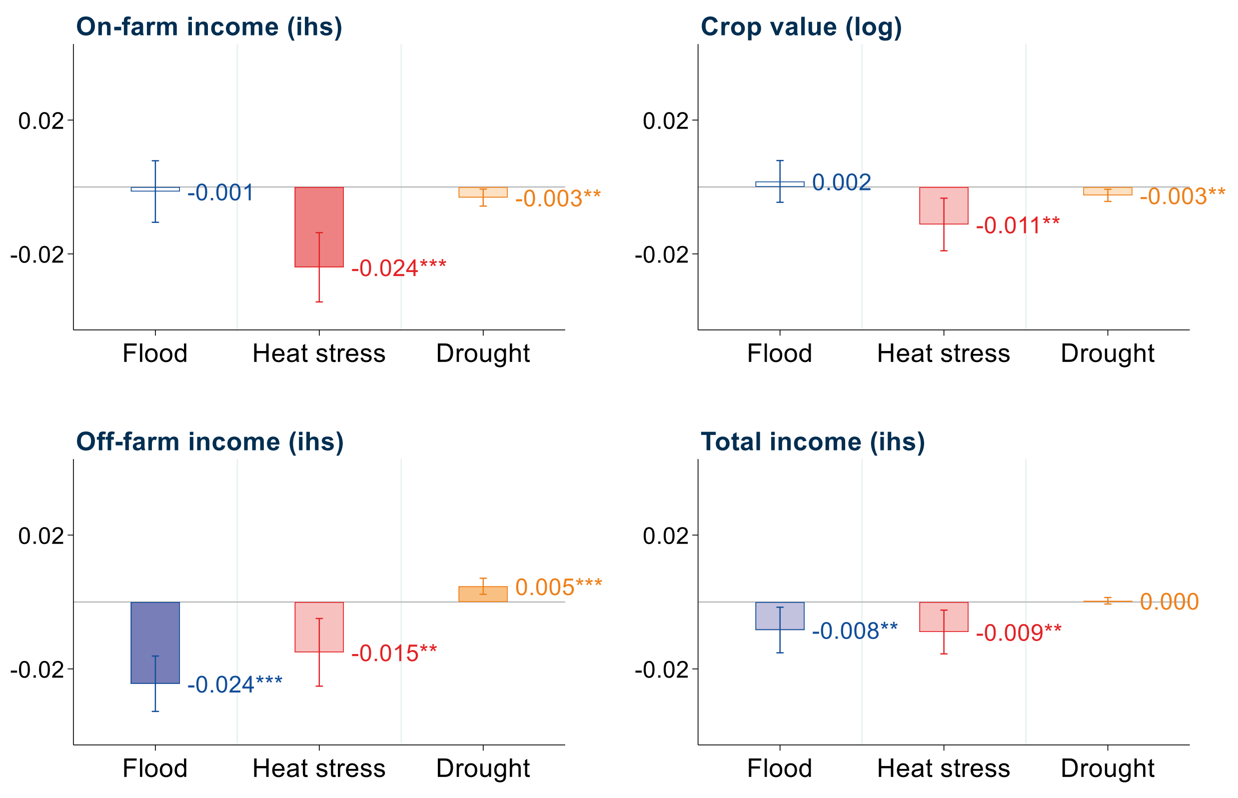
[4] The average yearly weather extreme event exposure for flood and heat stress is about five days.

[5] The global estimates are extrapolated for the rural equivalent of the subgroup in low- and middle-income countries. They are calculated as follows: the estimate of the climate stressor on the subgroup is multiplied by the average number of climatic events in the past ten years, the predicted average outcome of households that were not affected by the climate stressor and the total population of a given subgroup in low- and middle-income countries. More details on the calculation of the income gap can be found in Annex 2.

FIGURE 4

Extreme weather events significantly reduce the incomes of the poor relative to the non-poor



Note: ihs = inverse hyperbolic sine transformation, log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

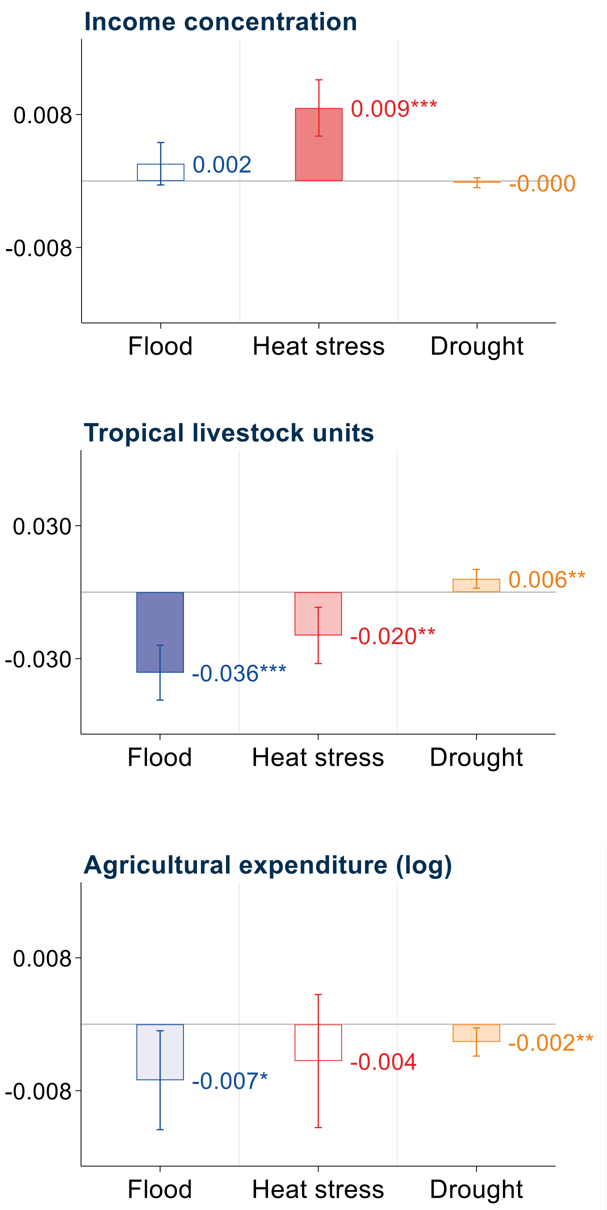
single dimension of the challenge are unlikely to prove as effective and sustainable in building climate resilience as multisectoral or integrated approaches that address challenges and create opportunities in both farm and non-farm sectors.

Extreme weather events push poor rural households to adopt maladaptive coping strategies

The results in **Figure 5** show that extreme weather events tend to push poor rural households to adopt maladaptive coping strategies, including reducing their livelihood diversification, liquidating livestock and diverting expenditures away from agriculture. In particular, the results show that when exposed to heat stress, poor households tend to concentrate their incomes on fewer activities, which is likely due to the loss of off-farm income sources. **Figure 5** shows that poor rural households tend to reduce their livestock holdings relative to non-poor households when exposed to flood and heat stress. This may be driven by two factors. First, poor households may be forced to sell livestock to compensate for income losses from other sources. Second, they may also experience higher levels of livestock mortality when these events occur. The reduction in livestock numbers by poor households is worrisome, as it deprives them of critical sources of food and income, and of assets needed to manage future climate stresses. Poor households are slightly more likely to increase their livestock holdings when exposed to contemporaneous droughts compared to non-poor households, though the absolute effect is very small.

FIGURE 5

Extreme weather events drive the adoption of maladaptive coping strategies by the rural poor, relative to the non-poor



Note: log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

Finally, the results show that floods and droughts are associated with significant reductions in agricultural expenditures by poor households relative to non-poor households. This outcome likely reflects the fact that in the face of these shocks, poor households must redirect their limited resources toward maintaining their consumption. However, this comes at the expense of productive investments in their farms, which can lock them into a low-equilibrium poverty trap that is very difficult to escape (Barrett *et al.*, 2007; Leichenko and Silva, 2014).

Poor rural households become more reliant on agriculture as long-term temperatures increase

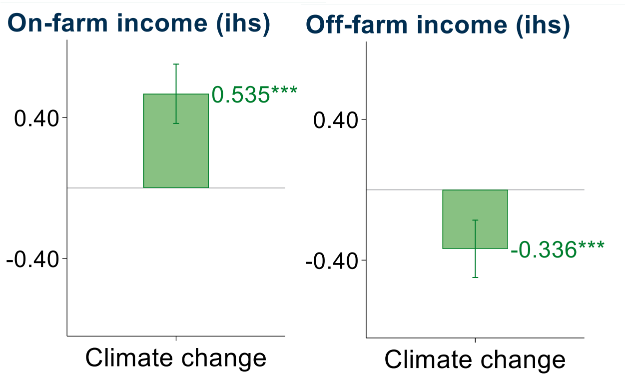
Exposure to long-term climate change, defined as the absolute increase in average temperatures, can erode households' capacities to absorb additional stressors, leaving them more vulnerable over time. Given poor households' already low resource base, these dynamics can make it more difficult to participate in economic activities that may enable an exit from poverty.

The results in **Figure 6** show that in places where average temperatures have increased more, poor households are more likely to rely on agriculture for their livelihoods and earn less from off-farm sources than non-poor households. In particular, an additional 1 °C in average temperatures is associated with a 54 percent increase in the farm incomes of poor households and a 34 percent decrease in off-farm incomes, compared to non-poor households. Reductions in off-farm employment opportunities for poor households in places where temperatures are rising quickly, combined with a growing number of poor households competing for available jobs, may be driving this result (Boansi *et al.*, 2021; Escalante and Maisonnave, 2022). This is a worrisome finding; it suggests that climate change is pushing the rural poor to increasingly rely on agriculture for their livelihoods, a condition that is likely to increase their vulnerability over time.

This concern is further substantiated when looking at the effects of climate change on the adaptive responses of poor households. As illustrated in **Figure 7**, the results show that long-term changes in average temperatures are associated with significant increases in livestock ownership (total tropical livestock units [TLU]) and in agricultural expenditures of poor households, relative to non-poor households. The relative increase in TLUs by 0.36 corresponds to 90 kg of livestock, roughly equivalent to having one additional calf for each degree of temperature increase, compared to non-poor households. While these findings highlight the efforts by poor households to boost agricultural productivity in places exposed to rapid climate change, it also raises concerns about the riskiness of these investments under rapidly changing climatic conditions. Indeed, this outcome may reflect a relative lack of alternative investment options outside of agriculture for poor households compared to non-poor households in places where the climate is changing fast, rather than a strategic choice to increase agricultural productivity.

FIGURE 6

Long-term climate change drives poor households to rely more on agricultural and less on off-farm income sources, relative to non-poor households

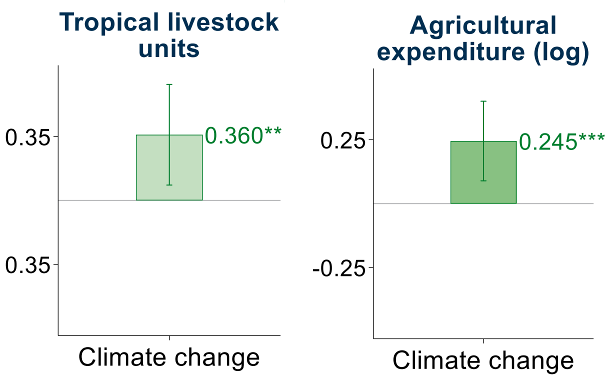


Note: ihs = inverse hyperbolic sine transformation, log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

FIGURE 7

Long-term climate change is driving a relative increase in the reliance on agriculture by the poor



Note: log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

KENYA - A Burundian refugee collects water in watering cans. This water source provides a source of food and livelihoods in the challenging climatic conditions of the area.

4. Gender disparities in climate vulnerability

KEY FACTS

- Female-headed households experience significant income losses relative to male-headed households when extreme weather events occur.
- Female-headed households experience annual average income losses of 8 percent due to heat stress and 3 percent due to floods, relative to male-headed households.
  - Exposure to flood and heat stress reduces the total incomes of rural female-headed households in low- and middle-income countries by USD 16 billion and USD 37 billion, respectively, relative to male-headed households.
- Farm plots managed by women lose significantly more in terms of crop value than those managed by men during heat stresses. However, when floods occur, plots managed by women generate more value than those of men.
- Long-term increases in temperatures lead to a reduction in the incomes of female-headed households, thereby widening the income gap with male-headed households.
  - A 1 °C increase in long-term average temperatures is associated with a 23.6 percent reduction in farm income and a 34 percent reduction in the total incomes of female-headed households, relative to male-headed households.
- Women take on an additional work burden compared to men when extreme weather events occur, but also lose more.

Differences in climate vulnerability between men and women are rooted in social structures and discriminatory norms and institutions that shape gendered patterns in resource access, time use, income opportunities and access to services in rural areas (FAO, 2023a). Among other things, these patterns manifest themselves as persistent gaps in terms of the time dedicated to care and domestic responsibilities, in wages and productivity, in the quality of jobs, in access to and ownership of agricultural land, in the use of improved agricultural inputs and technologies, and in access to extension and financial services. These gaps elevate women's climate vulnerability by undermining their adaptive capacity and pushing them into livelihood options that are more sensitive to climate change along multiple intersecting dimensions.

Discriminatory social norms, including those that place a disproportionate burden of care and domestic responsibilities on women, have negative effects on their educational attainment, as well as on their capacity to access decent non-farm employment and diversify away from climate-sensitive income sources (Afridi, Mahajan and Sangwan, 2022; Chowdhury, Parida and Agarwal, 2022; Escalante and Maisonnave, 2022). These norms also play a role in generating wage and productivity gaps (FAO, 2023a). Globally, women spend an average 4.2 hours per day on unpaid domestic and care work, compared with 1.9 hours for men (United Nations Department of Economic and Social Affairs, 2023). As a result, their non-farm employment options are often limited to part-time, informal, low-paid and precarious work (FAO, 2023a). Women are also more likely than men to be employed as casual agricultural workers, the demand for which is highly sensitive to climate variability (Arceo-Gómez, Hernández-Cortés and López-Feldman, 2020; Chowdhury, Parida and Agarwal, 2022; Escalante and Maisonnave, 2022; Shayegh and Dasgupta, 2022).

In addition, women are often more prone than men to lose non-farm employment opportunities when climate shocks occur (Mahajan, 2017). For example, the burden of care work placed on women, combined with social norms, is found to restrict their mobility more than men's, preventing them from migrating in search of alternative livelihood options to cope with climate disasters (Afridi, Mahajan and Sangwan, 2022; Mersha and Van Laerhoven, 2016).

Evidence points to persistent gaps between men and women in terms of income and assets, which reduces women's adaptive capacity relative to that of men. One of the most crucial factors is access to land. Studies of the determinants of adaptation in agriculture consistently point to the role of land security and land size in enabling farmers to bear the costs and risks of adaptation (Acosta *et al.*, 2021; Azzarri and Signorelli, 2020; Mensah, Vlek and Fosu-Mensah, 2022; Naz and Saqib, 2021; Sardar, Kiani and Kuslu, 2021). However, women are significantly less likely to enjoy secure rights to land and, when they do, the land under their control is usually smaller and of lower quality than that of men (FAO, 2023a; Quisumbing, Kumar and Behrman, 2018). Climate shocks may also exacerbate land inequalities between men and women, as women's land is more likely than men's to be sold to cope with income losses (Quisumbing, Kumar and Behrman, 2018).

Both women's land productivity and income from agricultural labour are substantially lower than those of men (FAO, 2023a). This is driven at least in part by the difference between men and women in terms of access to and control over productive resources. In particular, informal gendered norms influence the crop and livestock species controlled by women, which are often of lower value and oriented toward household consumption (Diarra *et al.*, 2021; FAO, 2023a).

Women's lower productivity and income also reflect gendered differences in terms of accessing critical agricultural and non-agricultural support services, such as farm extension, credit and insurance services (Ngigi, Mueller and Birner, 2017). Less diversified and remunerative agricultural systems and livelihood portfolios make rural women's incomes and production more sensitive to climate stresses than men's, while at the same time limiting the resources they have available to adapt to and cope with climate change (Tavenner *et al.*, 2019). For example, women are less likely to adopt adaptive practices that require hired labour or investments in capital-intensive technologies, such as improved inputs or irrigation (Acosta *et al.*, 2021; Assan *et al.*, 2018; Gaisie, Adu-Gyamfi and Owusu-Ansah, 2022; Gebrehiwot and van der Veen, 2013; Westengen *et al.*, 2019). Instead, women are more prone to resort to maladaptive strategies in response to climate stress, such as reducing food and water intake (Bethan and Serna, 2011; Segnestam, 2017). Moreover, girls often suffer disproportionately from adverse coping strategies adopted by households, for example because they are taken out of school or married off early (Doherty, Rao and Radney, 2023). Lastly, extreme weather events are associated with increased gender-based violence, often in relation to economic and food insecurity, mental stress and higher exposure to men (van Daalen *et al.*, 2022).

The specific vulnerabilities to climate change of rural women are often magnified in female-headed households. Given the structural constraints faced by women in terms of income opportunities and asset endowments, households with a woman as the head are often more economically disadvantaged than households with joint or male-only heads (Flatø, Muttarak and Pelser, 2017). Moreover, female heads are often the only working-age adults in the household, with many young and older dependent members to care for. In case female heads live together with men, there often is no husband (Mokomane and Chilwane, 2014; Saad *et al.*, 2022). As a result of these factors, female-headed households have fewer potential sources of income available to them, are less able to adopt labour-intensive adaptive practices and face substantial time constraints for productive activities due to a high care burden.

The following section presents the key empirical results on the impacts of climate stressors on women, female-headed households and female-managed plots. The bulk of the analysis focuses on female-headed households, due to limitations in gender-disaggregated data for the full dataset. However, for a subset of seven countries, differences between agricultural plots managed separately by women and men can be analysed. Moreover, individual-level labour outcomes are presented for six countries. Information on data sources (for the household, individual and plot levels), analyses, methods, variables and additional findings are presented in Part II of the report. Further information and analysis can be found in Annex 2 and 3.

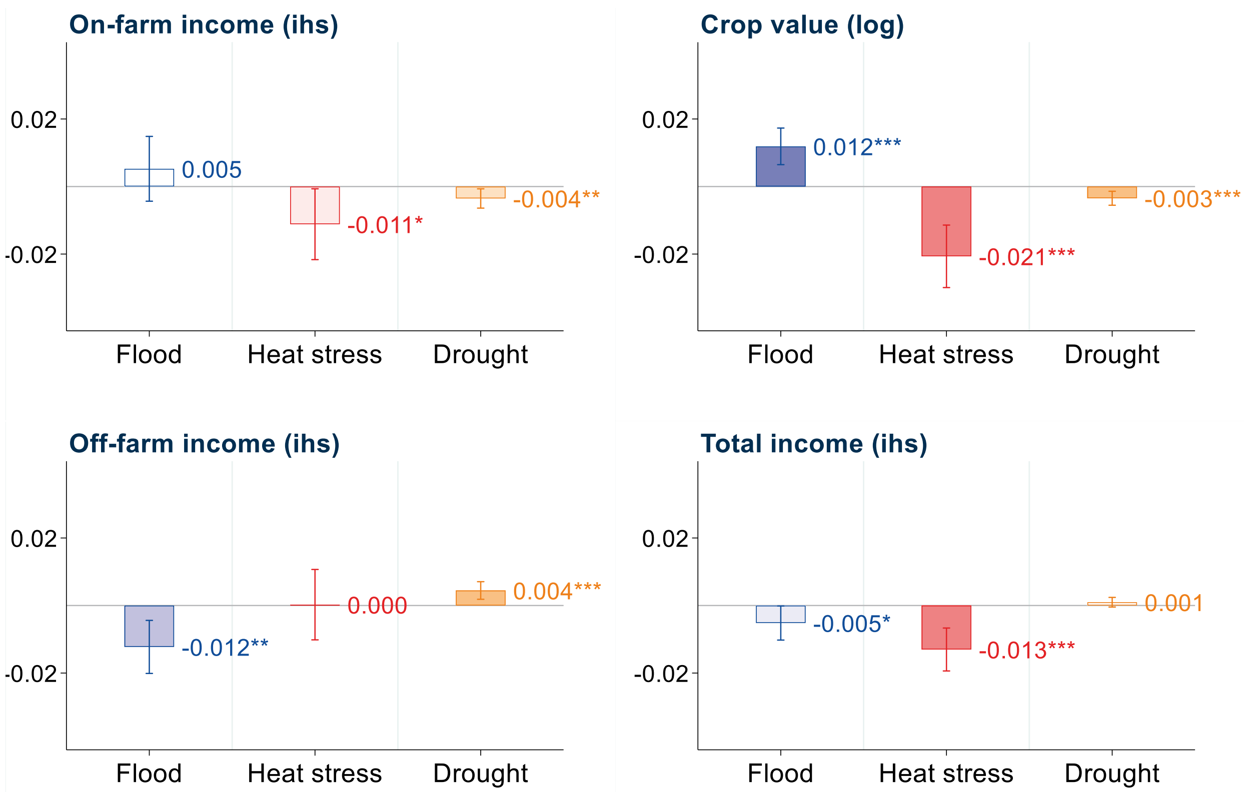
Extreme weather events reduce the incomes of female-headed households significantly more than those of male-headed households

The results of our analysis paint a concerning picture of the extent to which the welfare of female-headed households is more adversely affected by climate stressors than that of male-headed households. After controlling for a wide range of socioeconomic and geographic factors, we find that exposure to an additional day of extreme temperatures or extreme precipitation is associated with a 1.3 percent and 0.5 percent reduction, respectively, in the total income of female-headed households, compared to male-headed households (**Figure 8**). This translates into annual average income losses of 8 percent due to heat stress and 3 percent due to floods, compared to male-headed households.[6]

The loss of off-farm income is an important component of total income losses for female-headed households in case of floods. For every additional day of extreme precipitation, female-headed households lose 1.2 percent

FIGURE 8

Extreme weather events undermine the incomes of the female-headed households relative to those of male-headed households



Note: ihs = inverse hyperbolic sine transformation, log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

[6] The average yearly exposure to these extreme weather events is about six days for floods and heat stress.

of their off-farm income, compared to male-headed households. The reason for this requires further investigation; however, it may be linked to a reduction in the availability of non-farm employment for members of female-headed households, which is often informal, part-time and tied to agrifood systems. This finding is consistent with research findings from Pakistan, where men were found to increase the hours spent working as hired labourers more than women when floods occur. This is linked to the types of jobs available after floods, which include rebuilding damaged homes and infrastructure (Akter, 2021).[7]

Interestingly, when exposed to extreme precipitation, female-headed households experience an increase in the value of their crop production of 1.2 percent, compared to male-headed households. Thus, some of the relative losses in off-farm income due to floods are compensated by improvements in crop production; however, these improvements are not sufficient to offset losses in total income.

The farm incomes of female-headed households are more sensitive to heat stress exposure than those of male-headed households. For every additional day of extreme temperature exposure, female-headed households lose 1.1 percent of their on-farm income compared to male-headed households. This is driven primarily by reductions in the value of the crops produced by female-headed households, where results show that for every additional day of extreme temperature exposure, female-headed households lose 2.1 percent in crop value compared to male-headed households. This estimate is substantially higher than that for the effect of heat stress on total on-farm income, suggesting that female-headed households are able to compensate some of the losses in crop value through other on-farm income sources, such as the sale of livestock or forest products.

Similarly, exposure to droughts is associated with a 0.4 percent decrease in female-headed households' farm incomes compared to male-headed households, although this is compensated by off-farm earnings. The bigger loss in on-farm income of female headed households is driven by the relatively higher loss in crop value, compared to male-headed households.

Overall, flood and heat stresses reduce the total incomes of rural female-headed households in low- and middle-income countries by USD 16 billion and USD 37 billion per year, respectively, compared to male-headed households.[8] The magnitude of this loss highlights the urgent need for increased support for vulnerable female-headed households, to enable them to manage the impacts of climate stressors on their livelihoods and transition toward more climate-resilient livelihood strategies.

Our results suggest that while the total incomes of female-headed households are generally more sensitive to extreme weather events than those of male-headed households, there are important differences between the types of extreme events and across different sources of income. Female-headed households increase their crop value relative to male-headed households when exposed to floods but lose substantially in terms of their off-farm income, leading to an overall negative effect of such events on total income relative to male-headed households. Conversely, female-headed households lose farm income and crop value relative to male-headed households as a result of heat stress. While they are able to increase their off-farm incomes, this is not sufficient to compensate the losses in farm incomes. Finally, in case of droughts, female-headed households can compensate their losses in crop value with revenues from other farm and off-farm sources, leading to the absence of significant differences in total income change relative to male-headed households.

Thus, female-headed households exhibit a high degree of livelihood flexibly in the face of extreme weather events. However, the effectiveness of this flexibility is limited by a range of gender-based resource constraints and time burdens (FAO, 2023a).

[7] The robustness checks in Annex 4 show that this result is not driven by remittances, which are a component of off-farm incomes.

[8] For more information on the methodology used to calculate these estimates, see Annex 2.

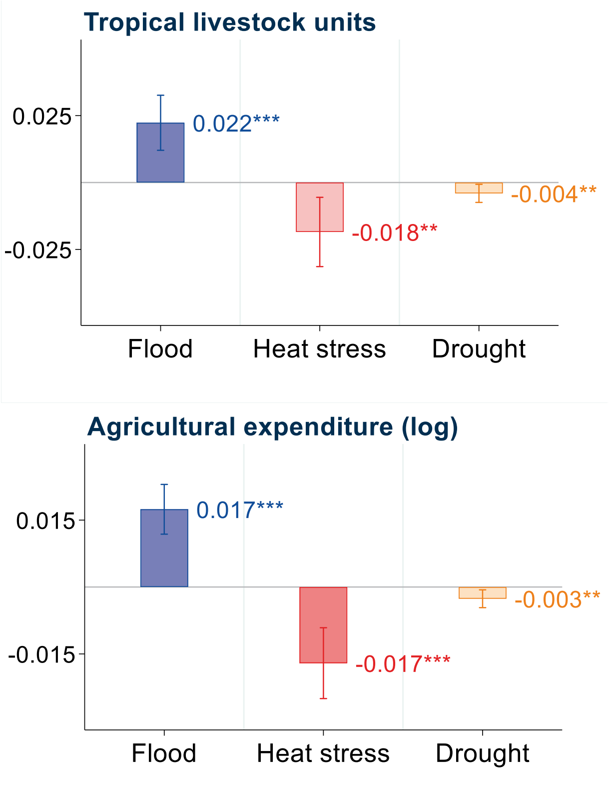
Female-headed households cope with extreme weather events in various ways

The evidence in **Figure 9** shows that when female-headed households are exposed to floods, their short-term coping response is to increase livestock ownership relative to male-headed households. This is consistent with the findings discussed above that floods tend to push female-headed households to increase their agricultural activities more than male-headed households. Conversely, exposure to heat stress and droughts is associated with a significant reduction in the livestock holdings of female-headed households relative to male-headed households. This finding indicates that female-headed households are more likely than male-headed households to either liquidate livestock to cope with these events or to experience higher overall livestock mortality rates. In either case, the loss of this asset base represents a significant loss of wealth for these households and is likely to undermine their future ability to respond to climate-related and other economic stresses.

Reducing agricultural expenditures in the face of extreme weather events is an important reactive adaptation strategy for female-headed households. The results in **Figure 9** show that female-headed households reduce their agricultural expenditures relative to male-headed households when exposed to heat stress and droughts. The relative reductions in agricultural expenditure partially explain the higher levels of agricultural income loss (only for heat stress) and crop value losses (for both droughts and heat stress) that female-headed households experience when exposed to these events. It is also indicative of an effort to shift scarce resources away from agricultural activities that are highly sensitive to these events, towards other economic activities and consumption. Meanwhile, when exposed to flood events, female-headed households increase their agricultural expenditures relative to male-headed households. Again, this is consistent with the general tendency for female-headed households to intensify their reliance on agriculture in the face of floods. The factors underlying this dynamic require further investigation.

FIGURE 9

Female-headed households' reactions to extreme weather differ depending on the type of event



Note: log = natural logarithmic transformation.

Source: authors' elaboration based on own calculations.

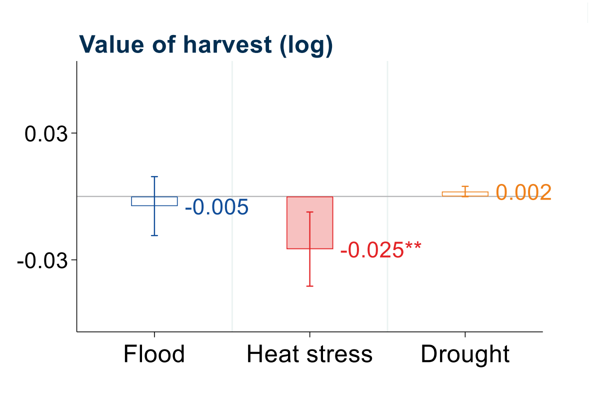
Female plot managers are as capable as male plot managers to adopt adaptive agricultural practices, but lose more as a result of extreme weather events

Using data collected at farm plot-level for seven sub-Saharan African countries, we are able to move beyond the household level and examine how exposure to extreme weather events influences the production and adaptive practices of women as compared to those of men. We focus on the value of crops harvested (total and per hectare), comparing results across a wide range of crops.[9]

[9] Our analysis focuses on male-headed households, as there are only few male-managed plots in female-headed households.

FIGURE 10

Female plot managers can increase the value of their harvest relative to male plot managers when floods occur, but they lose under heat stress

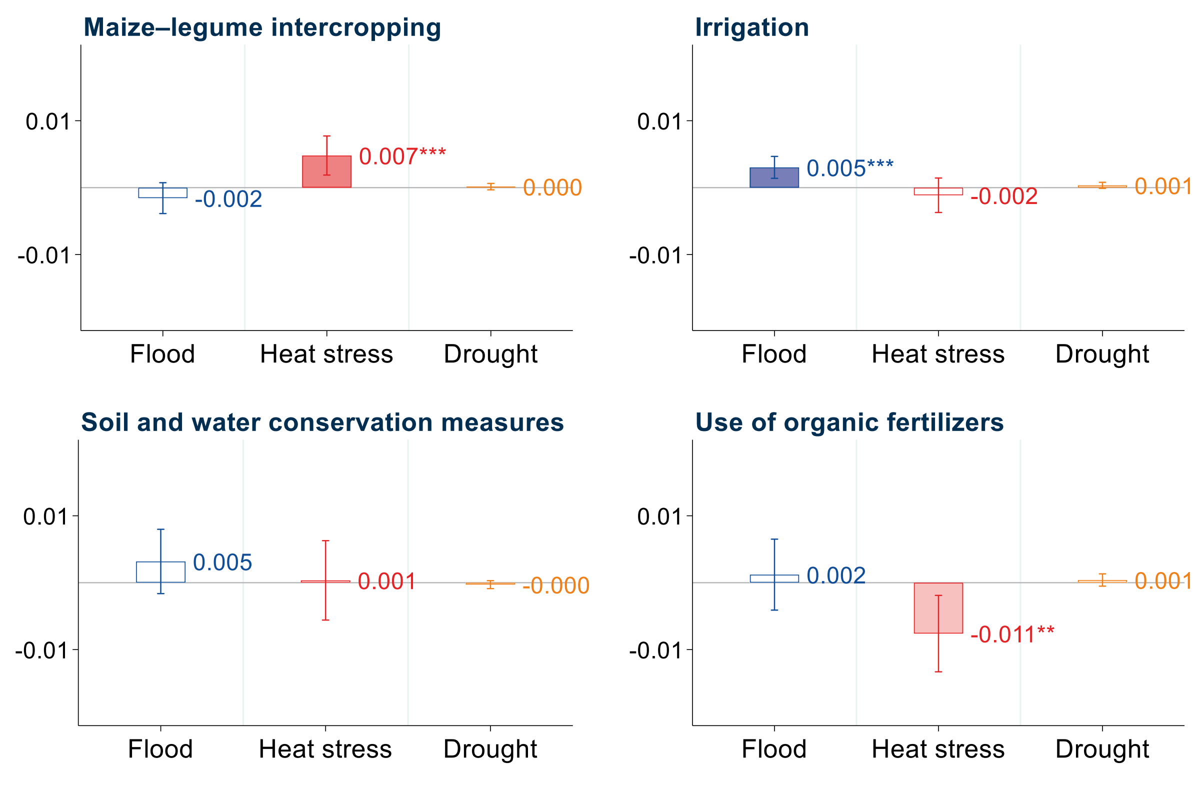


Note: log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

FIGURE 11

There are few differences between female and male plot managers in terms of the adoption of climate-adaptive practices when exposed to extreme weather events



Source: authors' elaboration, based on own calculations.

The results (see **Figure 10**) show that an additional day of high temperature exposure is associated with a 2.5 percent reduction in the total value of crops produced on women's plots compared to men's, while there is no difference in terms of sensitivity to floods or droughts. However, women's plots are on average significantly smaller than those of men (0.5 ha vs 1.5 ha in the sample analysed). To account for this, we compute the total value of crop production on a per hectare basis and find that the difference in sensitivity of crop value per hectare to high temperatures is in fact 0.5 percentage points larger than the difference in overall crop values. Meanwhile, an additional day of high precipitation increases the value of crops per hectare on women's plots by 1.6 percent relative to men. This finding further reinforces the analysis that female-headed households tend to intensify production more than men when faced with heavy precipitation.

The differences in the effects of heat and heavy precipitation on female- vs male-managed plots require further investigation. Factors such as the crop types grown on female- vs male-managed plots and the technologies required to manage different stressors are likely to be important drivers of these differences.

We also examine the differences between male and female plot managers in terms of their adoption of climate-adaptive agricultural practices. The results (see **Figure 11**) show that in most cases, the differences between women and men in terms of the adoption of such practices when exposed to extreme weather events are largely not statistically significant.

The significant differences observed are that women are more likely to intercrop maize and legumes, and less likely to use organic fertilizer when exposed to extreme temperatures than men. Intercropping is an important climate-adaptive practice that is well-suited for small land holdings, which tend to be managed by women (see the data in Annex 5). Interestingly, women are more likely than men to adopt irrigation methods when exposed to extreme precipitation. This is likely driven by the adoption of traditional irrigation techniques, such as the use of shallow wells in flood zones to irrigate garden vegetables. The adoption of simple irrigation systems in flood-exposed areas may explain why female plot managers are able to increase the value of their crops per hectare more than men when floods occur.

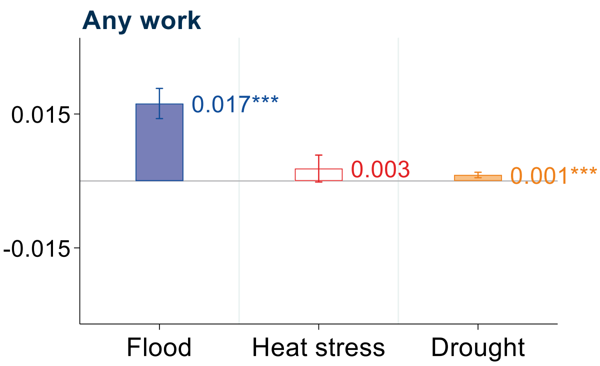
Our results suggest that despite the significant resource and time constraints faced by rural women, they tend to be as able as or even more able than men to adapt their agricultural systems to climate stressors. Yet, they are also more likely than men to experience crop value losses. Thus, it is crucial that programmes and policies help female farmers ensure that their adaptive actions translate into meaningful improvements in their agricultural systems. Gender-responsive agricultural extension services are likely to play an important role in such efforts.

Women take on an additional work burden compared to men when extreme weather events occur

Our analysis shows that when floods and droughts occur, women are more likely than men to join the labour force (for farm and off-farm work) (see **Figure 12**).

FIGURE 12

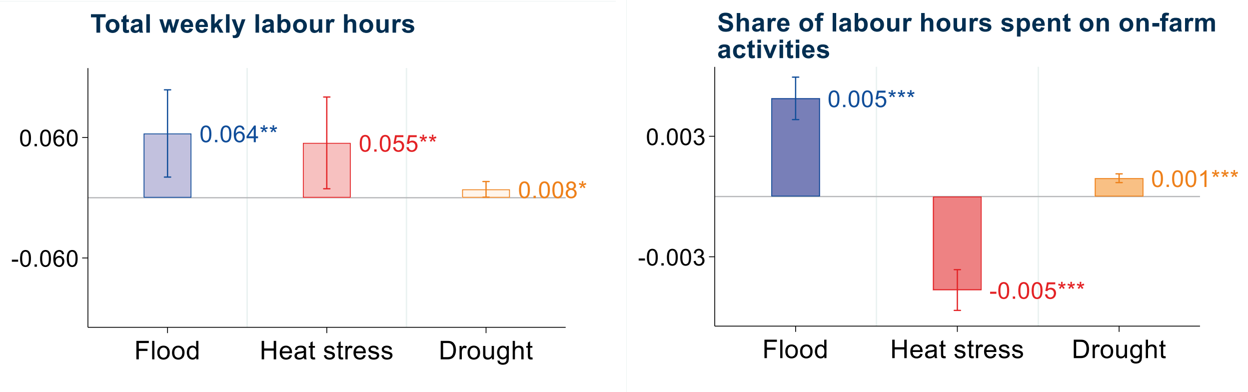
Women are more likely than men to work when facing extreme weather events



Source: authors' elaboration, based on own calculations.

FIGURE 13

Women increase their weekly labour hours relative to men when facing extreme weather events and spend relatively more time working on the household's farm when floods and droughts occur



Source: authors' elaboration, based on own calculations.

Moreover, for all extreme weather events, women increase the total number of hours they work per week relative to men (**Figure 13**). Women increase their weekly working hours by about four, three and one minutes for each additional day of extreme precipitation, temperature and dry spell, respectively, relative to men. This implies that when exposed to the average yearly number of days of extreme weather events, women increase their weekly labour hours by 55 minutes relative to men.[10]

For floods and droughts, the increase in labour time is associated with a relative increase in the share of labour dedicated to activities on the household farm, which is consistent with the results of other analyses (Nico and Azzarri, 2022). Meanwhile, exposure to heat stress is associated with a relative reduction in the share of labour hours spent on the household farm, implying a shift towards working on other people's farms or engaging in non-farm work. These results are consistent with the findings presented above, showing a gendered pattern of shifting away from farm work toward off-farm work in response to heat stress.

Long-term increases in temperature affect the farm and total incomes of female-headed households more than those of male-headed households

As shown in **Figure 14**, an increase of 1 °C in long-term average temperatures is associated with a 23.6 percent reduction in the farm incomes and a 34 percent reduction in the total incomes of female-headed households, compared to male-headed households. No differences can be observed in terms of off-farm income.

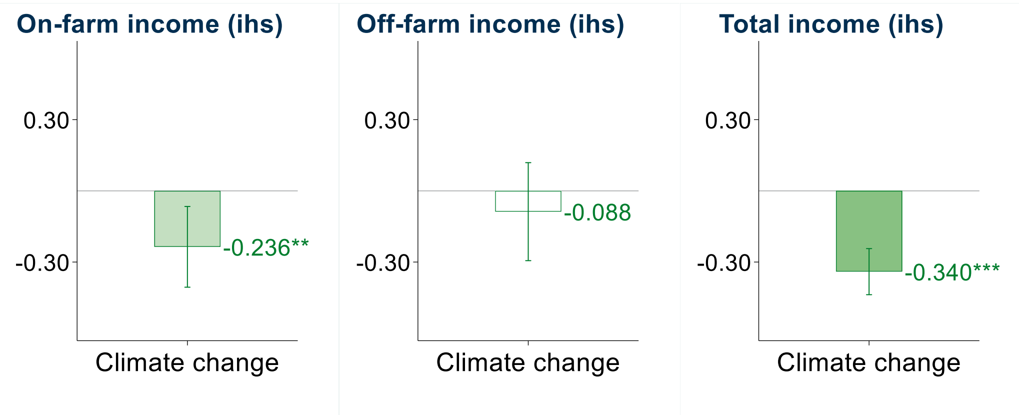
This finding demonstrates that long-term increases in temperatures are an important driver of income inequality between households headed by women and men. Thus, there is an urgent need to strengthen the resilience of the agricultural production systems of female producers to rising temperatures.

Interestingly, the loss in on-farm incomes associated with long-term temperature changes is not due to a reduction in agricultural expenditures by female-headed households. Indeed, the opposite is true: female-headed households increase their agricultural expenditures relative to male-headed households in response to long-term

[10] In the sample considered, the average yearly exposure to extreme weather events is about seven days for floods, seven days for heat stress and 12 days for drought.

FIGURE 14

Long-term climate change leads to a reduction in the on-farm and total incomes of female-headed households, relative to male-headed households

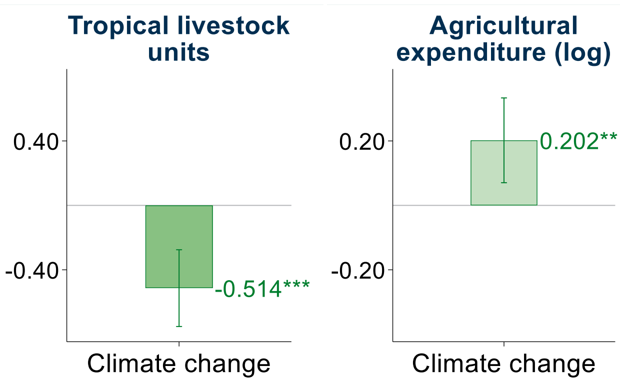


Note: ihs = inverse hyperbolic sine transformation.

Source: authors' elaboration based on own calculations .

FIGURE 15

Long-term climate change drives a relative reduction in the livestock holdings and a relative increase in agricultural expenditures of female-headed households, compared to male-headed households



Note: log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

increases in average temperatures (see **Figure 15**). At the same time, they reduce the number of livestock units they have relative to male-headed households, indicating that their agricultural production systems become less diversified as a result of long-term temperature rises.

These findings highlight the importance of climate- and gender-sensitive agricultural extension services that can help female-headed households target their agricultural investments towards practices and technologies that are better adapted to rising temperatures. Moreover, it is important to develop strategies to encourage female-headed rural households to maintain and even increase their livestock holdings as global temperatures, with a view to increasing the resilience and productivity of the livelihoods for this vulnerable population (FAO, 2023a).

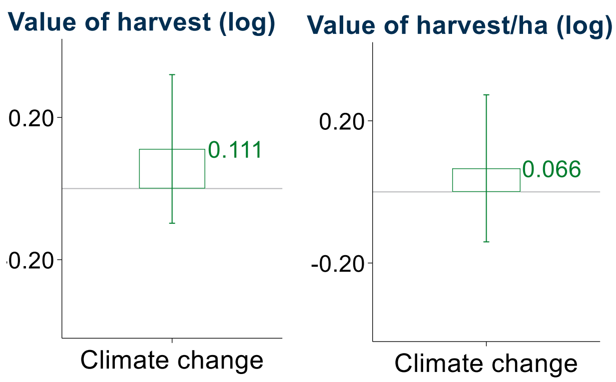
Long-term exposure to temperature rises affects plots managed by men and women in the same manner, notwithstanding differences in adaptive strategies

There are no statistically different impacts of long-term temperature rises on the crop values produced on plots managed by women and men (see **Figure 16**). This suggests that despite the structural differences faced by women in terms of access to resources and the time burden of domestic tasks, they are as able as men to adapt their agricultural practices to rising temperatures in the long run.

However, men and women adopt different adaptive strategies (see **Figure 17**). In areas where average temperatures are rising fastest, women are less likely than men to use organic fertilizers on their plots, but more likely to have infrastructure for the conservation of the soil and water. The limited use of organic fertilizers on plots managed by women may be due to constraints in terms of livestock ownership, while the higher adoption rate of soil and water conservation structures may be related to the fact that plots managed by women are more likely to be located in less desirable locations, with higher exposure to extreme precipitation (see Annex 5). Further analysis is required to understand how female plot managers adapt their farm systems to rising temperatures.

FIGURE 16

Long-term climate change does not lead to differences between female and male plot managers in terms of the value of crops produced

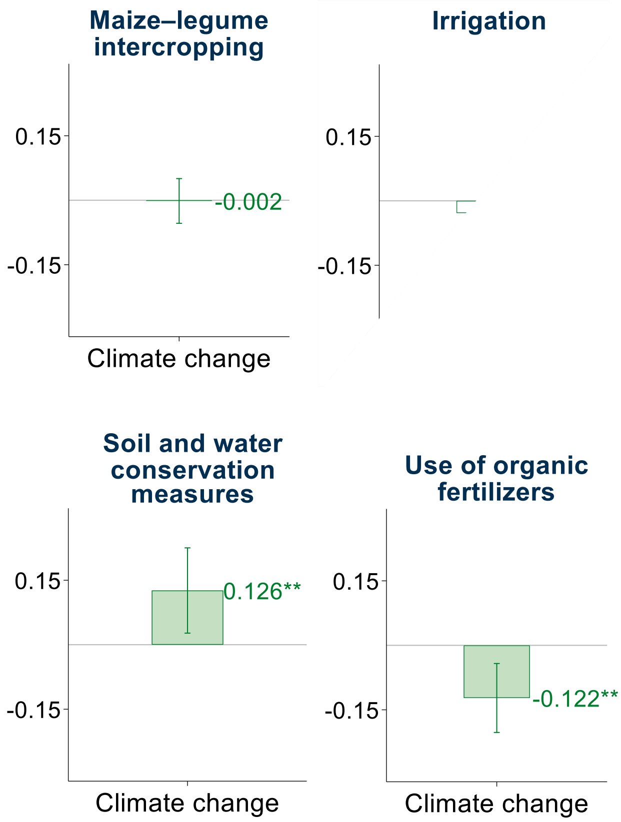


Note: log = natural logarithm.

Source: authors' elaboration, based on own calculations.

FIGURE 17

Farm-level adaptive practices differ by the gender of the plot manager in response to long-term climate change



Source: authors' elaboration, based on own calculations.

ARMENIA - A young shepherd tends to his animals in the mountains. Severe winters threaten the livelihood and food security of the most vulnerable households in Armenia.

5. Age-related disparities in climate vulnerability

KEY FACTS

- Because young households have better access to off-farm employment opportunities, their incomes are less vulnerable to the impacts of extreme weather events than those of older households.
- In an average year, households headed by young people increase their total income by 3 percent in response to floods and 6 percent in response to heat stress, relative to older households.
- Young households are able take advantage of distress livestock sales following extreme weather events and increase their livestock holdings.
- Floods push children, young people and seniors to work more on their own farms, while prime-aged adults increase the number of off-farm working hours.
- Heat stress events are an important driver of children's work in rural areas.

Age-related biological, social and economic factors are likely to affect people's climate vulnerability. However, the relationship between age and climate vulnerability, particularly in rural areas, is still not well understood. Biologically, both children and seniors are more sensitive to heat-related illness than prime-aged adults. Given that much of the work available in rural areas, and particularly in low-income countries, involves physical labour in often harsh outdoor environments, rising temperatures pose a significant risk to the labour productivity of older people (Helldén *et al.*, 2021; Orlov *et al.*, 2020).

While older people face greater physical challenges as a result of rising temperatures, they also have more experience in adapting to and coping with climate change. Multiple studies have documented a positive relationship between the number of years of farming experience and the adoption of climate-adaptive agricultural practices (Abid, Schneider and Scheffran, 2016; Aryal *et al.*, 2020; Elahi *et al.*, 2022). Moreover, older people are more likely to have experienced extreme weather events in their lifetimes, which is often an important driver of climate-adaptive actions (Dassanayake *et al.*, 2018; Gebrehiwot and van der Veen, 2013; Makate *et al.*, 2022).

Differences in the structure and composition of households headed by young versus older people may lead to disparities in climate vulnerability. Households headed by young people are generally smaller and have fewer working-aged members than those headed by older people. This may limit their capacity to invest in labour-intensive agricultural practices. Evidence suggests that, in general, older rural people are more likely than younger ones to adopt farm-level adaptive actions, such as crop diversification, agroforestry and modifications in planting dates (Kidane *et al.*, 2022; Kogo *et al.*, 2022; Ochieng, Kirimi and Mathenge, 2016; Wouterse, Andrijevic and Schaeffer, 2022).

Furthermore, households headed by younger people often have few productive assets, including land, and limited access to credit and other financial products because they are at the beginning of their economic lives and have not had time to accumulate these assets (Kosec and Mo, 2017). A lack of productive assets may limit these households' capacity to cope with climate stresses and adopt adaptive agricultural practices to mitigate their impacts.

On the other hand, younger farmers are more likely to adopt capital-intensive practices (such as the use of drought-tolerant seed varieties) or to seek non-farming employment (including by migrating to urban areas) (Faisal *et al.*, 2021; Keshavarz and Moqadas, 2021; Kogo *et al.*, 2022).

Indeed, access to off-farm employment is likely to be an important factor in reducing the climate vulnerability of younger people.

Moreover, younger generations often have higher levels of educational attainment and more familiarity with digital technologies and information than older generations (Edmunds and Turner, 2005). Differences in educational attainment may expand the range of non-farm employment options available to younger people relative to older generations. Meanwhile, familiarity with digital technologies may increase their capacity to access critical information, such as weather advisory services and online extension services, which can enable them to better adapt to climate stresses.

Thus, while rural youth likely face important vulnerabilities to climate change, particularly in terms of agricultural activities, they also may have access to human capital resources that they can leverage to reduce their overall vulnerability.

A final dimension of the nexus between age, agriculture and climate vulnerability is that of children's work. A vast body of literature identifies poverty as the main determining factor in whether and how much children work (see FAO, 2023b for a comprehensive literature review). Rising household incomes are associated with a decrease in the number of working children, as well as with a reduction in the intensity of their economic activities (Edmonds and Pavcnik, 2005). Children's work occurs predominantly in the agriculture sector and, more specifically, on their families' farms. The livelihoods derived from household agricultural activities critically determine whether parents must resort to sending their children to work. By leading to reductions in farm incomes and pushing more rural households into poverty, climate change may force many families to resort to children's work as a means of survival (FAO, 2023b).

The sections below provide novel empirical evidence on the relationship between age, climate stressors and climate vulnerability, drawing on data from 24 low- and middle-income countries. These sections focus on the key findings of the analysis, while further evidence is provided in Part II of the report and in Annex 3 and Annex 4. Most of the analysis is based on the age of household heads, but this is complemented with analyses of individual labour outcomes across age groups.

Young households leverage off-farm income sources to overcome extreme weather events

BOX 6

Age categories

At the household level:
- young households: household head younger than 35
- prime-aged households: household head between 35 and 64

At the individual level:
- children: between 10 and 14
- youth: between 15 and 24
- prime-aged adults: between 25 and 54
- seniors: between 55 and 84

The results in **Figure 18** show that households headed by young people are more likely to lose agricultural income due to extreme weather events, relative to those headed by older people. However, they are able to compensate these losses by leveraging off-farm income sources, leading to better outcomes in terms of total incomes relative to older households. Exposure to an additional day of extreme precipitation or extreme temperature is associated with a 0.6 percent and 1 percent increase, respectively, in the total incomes of young households, compared to older households. In an average year, therefore, young households increase their total income by 3 percent due to floods and 6 percent because of heat stress, compared to older households.[11] Thus, while the discussion in global fora tends to focus on young people's vulnerability to climate change, our results show

[11] In the sample considered, the average yearly exposure to these extreme weather events is about six days for floods and six days for heat stress.

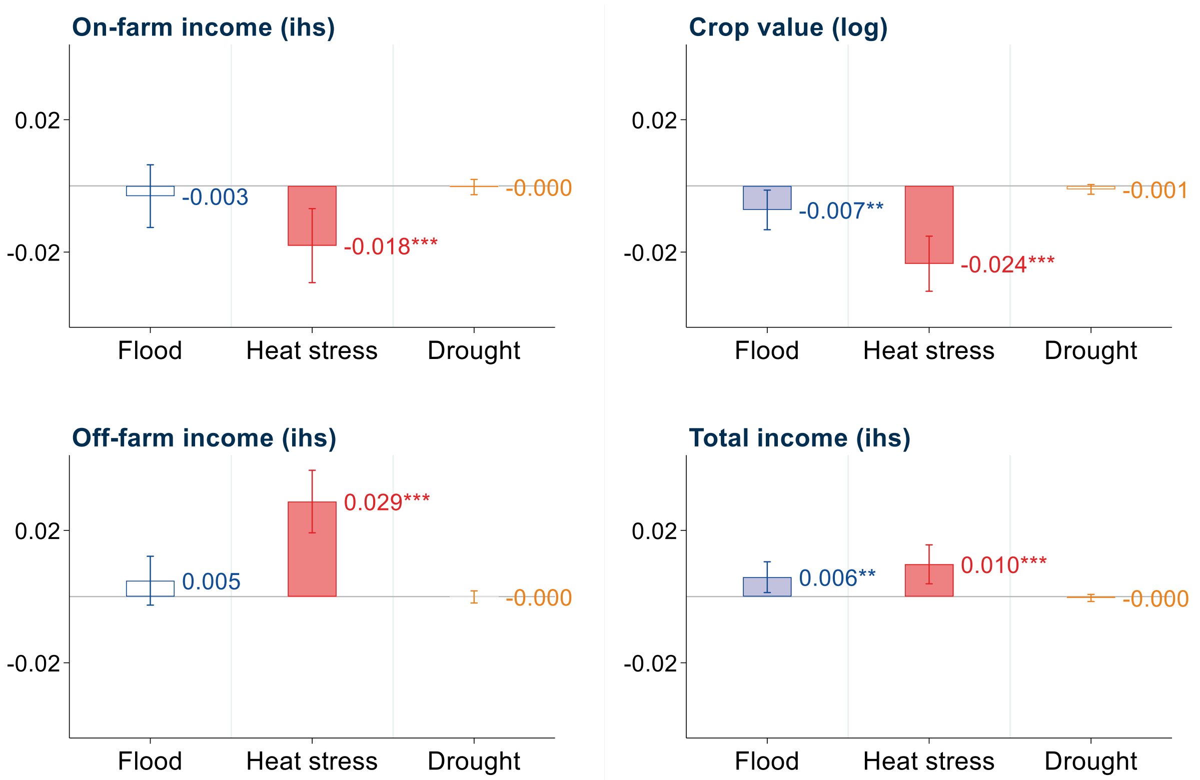
that older rural households are considerably more vulnerable.

An additional day of extreme high temperature is associated with a 1.8 percent reduction in farm income and a 2.4 percent reduction in the crop value of young households, relative to prime-aged households. However, young households compensate this loss with a relative increase in off-farm income of 2.9 percent. These dynamics may be influenced by the fact that young households have, on average, fewer agricultural resources than older households and less years of farming experience to draw on to adapt their farming systems. In other studies, these factors have been found to influence the ability of farm households to adapt their agricultural systems effectively to climate stressors (Abid, Schneider and Scheffran, 2016; Aryal *et al.*, 2020; Elahi *et al.*, 2022). Lacking these resources, young households turn to off-farm income sources to sustain their livelihoods in the face of climate stresses.

Our results show that when exposed to floods, young households experience a decline in crop value relative to prime-aged households. However, no difference is observed in terms of on-farm income (see **Figure 18**). This finding suggests that, despite their limited agricultural resources, young households can compensate losses in crop value by leveraging other agricultural income sources, such as livestock rearing, forestry and fisheries. This

FIGURE 18

Due to extreme weather events, young households lose on-farm income relative to older households, but compensate through off-farm income sources



Note: ihs = inverse hyperbolic sine transformation, log = natural logarithmic transformation.

Source: authors' elaboration, based on own calculations.

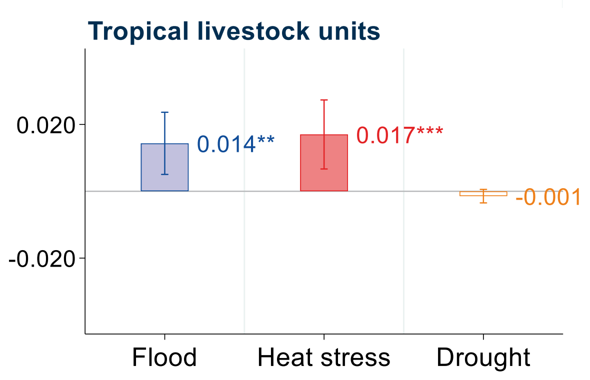
flexibility in agricultural production strategies is likely to be an important source of climate resilience for younger households.

Access to off-farm employment is an important driver of young households' climate resilience. Young rural households in low- and middle-income countries increase their off-farm income by USD 47 billion per year when exposed to heat stress relative to other households, resulting in an increase in total incomes of USD 27 billion. This finding highlights the significant contribution that young households can make to the broader rural economy as heat stresses become more frequent and intense due to climate change.

Overall, the evidence suggests that the livelihoods of young households are not more vulnerable to extreme weather events than those of older households. Indeed, young households are able to adjust their livelihoods and farm production systems in ways that help build their overall resilience to such events. These findings indicate that holistic and integrated climate programmes and actions in rural areas, including support measures for both farm and non-farm sectors, are likely to be more effective at building the climate resilience of young people than interventions with firm sectoral boundaries.

FIGURE 19

Young households increase livestock holdings relative to older households during floods and heat stress



Source: authors' elaboration, based on own calculations.

The non-farming economic dynamism in rural areas, for young and older populations alike, can be boosted by providing targeted skills training for rural entrepreneurs, improving access to financing and strengthening policies towards the formalization of rural labour markets, with due attention to gender-based constraints. Moreover, occupational safety and health training can help adolescents and young adults prevent or mitigate the negative effects of increased exposure to climate change and its related events.

Young households take advantage of extreme weather events to acquire livestock

When exposed to heat stress and flood events, young households are more likely relative to older households to increase their livestock holdings in the short term (see **Figure 19**). As shown above, the total incomes of young households are higher relative to those of prime-aged households when exposed to these events. Some of this economic gain is used to accumulate livestock, which may be available at reduced prices as vulnerable households often liquidate these assets to cope with extreme events. The accumulation of livestock by young people in response to extreme weather events is therefore a positive indication that these households may increase their future incomes and their resilience to climate stresses.

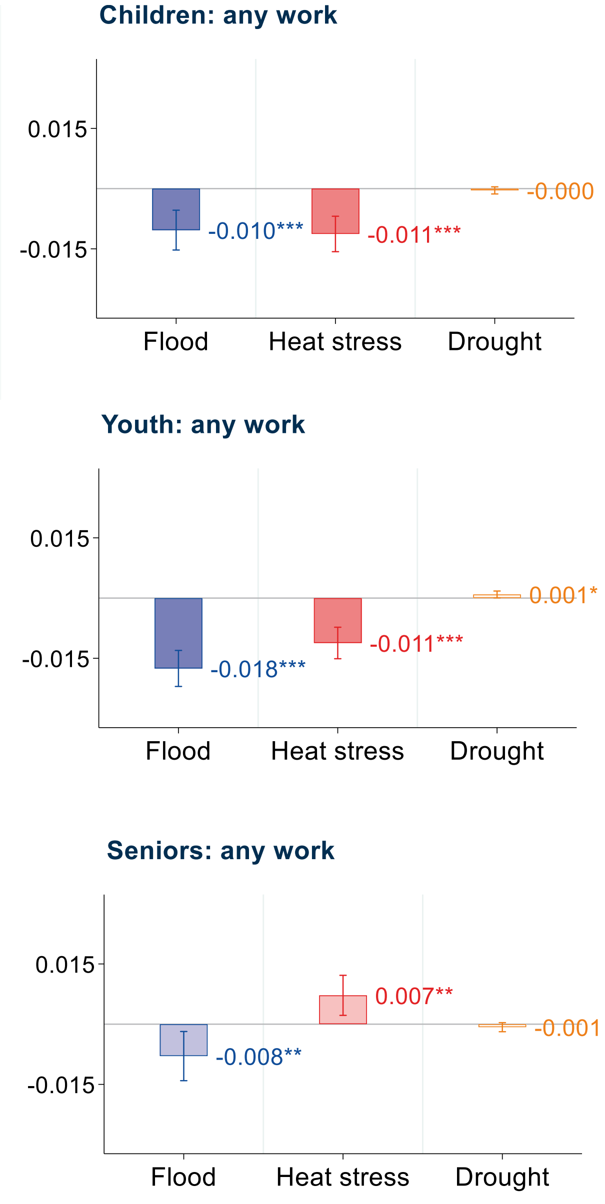
Extreme weather events alter employment opportunities and labour allocations for different age groups

Figure 20 shows that children (10 to 14), young people (15 to 24) and seniors (55 to 84) are less likely than prime-aged adults (25 to 54) to participate in the labour force when exposed to floods. For heat stress, the effect is negative for children and youth, while seniors are likelier than prime-aged adults to take up employment.

Figure 21 illustrates that when exposed to floods, children, youth and seniors reduce the total number of hours worked relative to prime-aged adults, and allocate more of their time to working on their own farms. This finding suggests that flood events create

FIGURE 20

Floods decrease the likelihood of children, youth and seniors to participate in the labour force relative to prime-aged adults, while effects are mixed for heat stress and droughts



Source: authors' elaboration, based on own calculations.

employment opportunities for prime-aged adults, but substantially limit them for others. This is not surprising, given that floods can cause substantial damage to infrastructure and that recovery efforts involve arduous work that is better suited to prime-aged people. However, it also means that non-prime-aged people must compensate for these income losses by increasing their work on farms. The implications of this trend for the welfare and well-being of children, young people and seniors require further investigation.

Worryingly, the results show that for each day of extreme temperatures, the number of weekly hours worked by children increases by seven minutes compared to prime-aged adults. Given that children experience an average 6.76 days of heat stress per year, this effect translates into a relative increase in children's weekly labour time of 50 minutes. This finding is alarming, especially when considering that children's average weekly working time in our sample amounts to about 15.5 hours – well above international legal limits, even in the absence of this climate stress.[12] Moreover, the increase in children's work coincides with a relative reduction in the share of their time dedicated to on-farm activities, and thus with a larger share of working time spent on off-farm work.

The impact of heat stress on labour outcomes is similar for children and women. This finding indicates that the way women allocate their time to different tasks has a considerable impact on children's work.

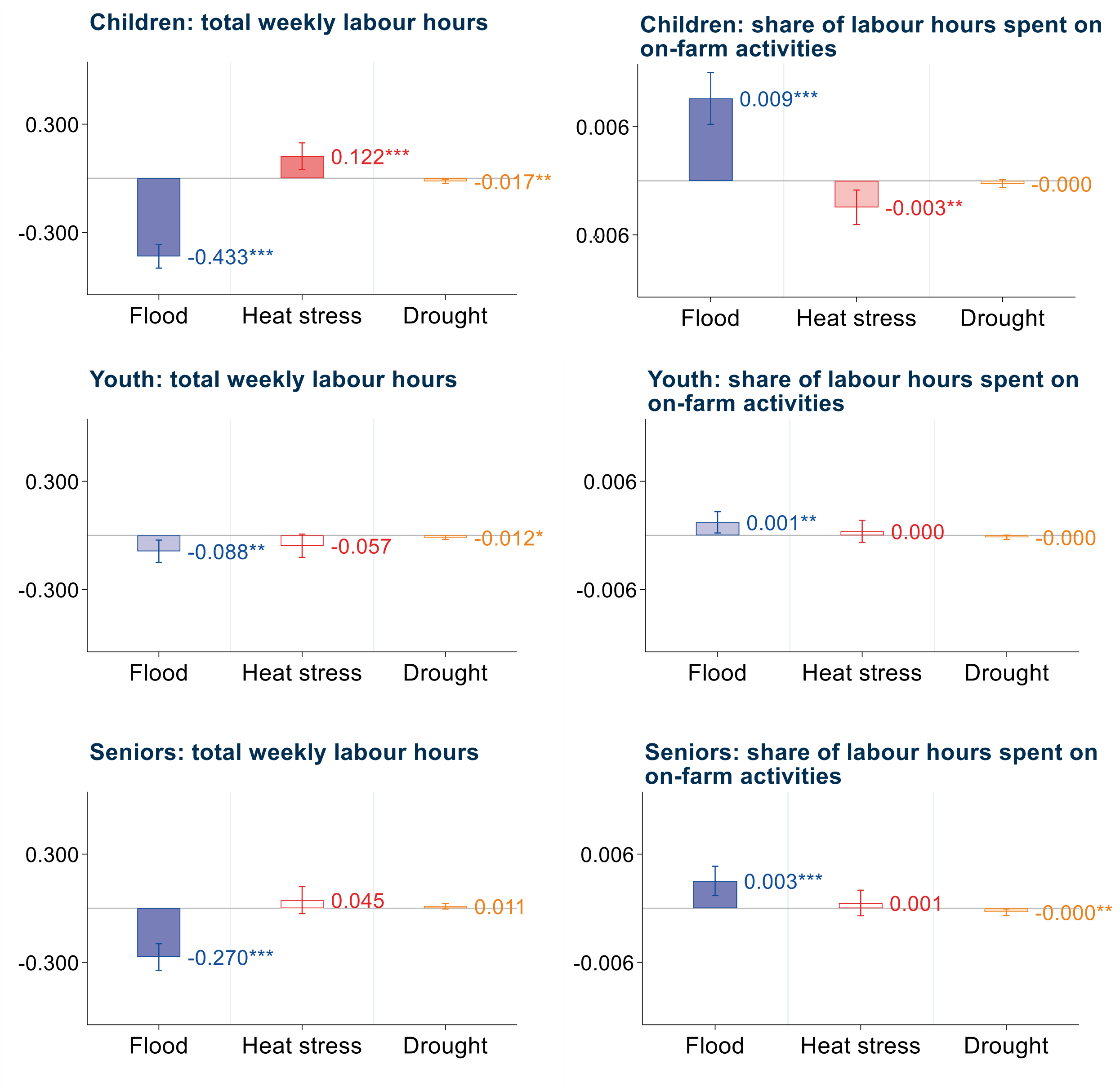
Long-term temperature rises push young households to diversify their incomes

Contrary to extreme weather shocks, long-term increases in temperatures are not associated with any observable differences between young and prime-aged households in terms of the impacts on-farm, off-farm or total incomes (see Annex 3 for more details). However, they are associated with important shifts in the livelihoods of young households.

[12] Rules set by the International Labour Organization (ILO) stipulate that children aged 12 to 14 can perform light work for a maximum of 14 hours per week, while children under 12 should not be working at all (ILO, 1973).

FIGURE 21

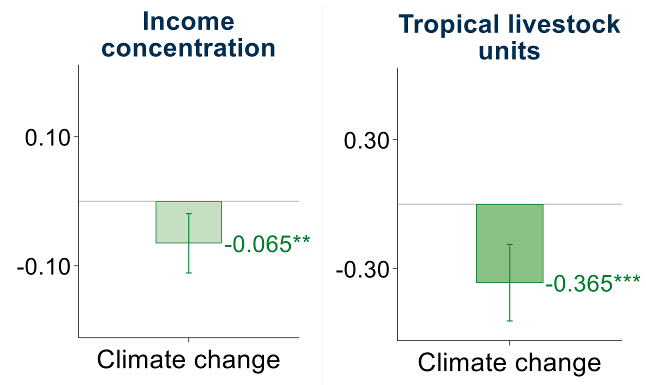
Relative to prime-age adults, children, youth and seniors work more on their own farms when floods occur. Heat stress drives a relative increase in children's work



Source: authors' elaboration, based on own calculations.

FIGURE 22

Young households diversify their incomes and reduce their livestock holdings relative to older households in response to long-term climate change



Source: authors' elaboration, based on own calculations.

Young households diversify their incomes (reduce their income concentration) when exposed to long-term increases in temperature relative to older households (**Figure 22**). This diversification is likely to be achieved through a major reliance on off-farm income sources, as increasing temperatures limit agricultural options. In addition, young households tend to reduce their livestock holdings relative to older households as temperatures rise. Taken together, these results highlight the importance of non-farm opportunities for young rural people to sustain their livelihoods in the context of climate change.

TUNISIA - In Monastir, a woman waters seeds. The country faces pressing water challenges. Sustainable water management is essential to solving climate problems.

6. Priorities and recommendations for inclusive climate

KEY FACTS

- Rural people and their climate vulnerabilities are not visible in national climate policies.
  - Only 6 percent of the climate actions in the NDCs and NAPs of the 24 countries analysed for this study mention women, while 2 percent explicitly refer to youth, less than 1 percent to poor people and about 6 percent to farmers living in rural communities.
- Current climate financing for rural people covers only a fraction of the actual needs.
- The climate vulnerabilities of rural people are multidimensional and therefore require multifaceted farm and non-farm interventions.
- Inclusive climate actions require addressing resource constraints and risks, and providing training with due attention to the needs of specific groups.

More attention and funding for vulnerable rural people

This report presents stark evidence of the unequal impacts of climate change on vulnerable people in rural areas of low- and middle-income countries, and highlights the urgency of integrating global efforts to alleviate rural poverty with equitable approaches to addressing the climate crisis. The evidence shows that extreme weather events and the rise in global temperatures deepen income disparities among rural people based on wealth, gender and age, with significant implications for the achievement of global sustainable development goals. The report highlights the profound economic repercussions of climate-related stress on vulnerable people, with potential annual income losses for female-headed households due to heat stress estimated at up to USD 37 billion, relative to male-headed households.

Despite the magnitude of the challenge, current levels of financing for the climate adaptation of rural people fall woefully short of needs of the agriculture sector, much less of those specific to vulnerable populations (Lipper *et al.*, 2022). It is estimated that redirecting agrifood systems onto a more climate-resilient and low-emissions pathway requires a sevenfold increase in climate financing by 2030 (Roe *et al.*, 2019; Thornton *et al.*, 2023). The latest *Global Landscape of Climate Finance* report (Climate Policy Initiative, 2022) suggests that reaching our global climate objectives will require USD 4.3 trillion in annual finance flows by 2030. It is estimated that in 2017/18, only 7.5 percent of total tracked climate financing went toward adaptation efforts, which are critical to reduce the vulnerability of rural people. Of this total, less than 3 percent went to AFOLU (agriculture, forests and other land use) and other agriculture-related investments, while only 1.7 percent (or roughly USD 10 billion) reached small-scale producers (Chiriac, Naran and Falconer, 2020).

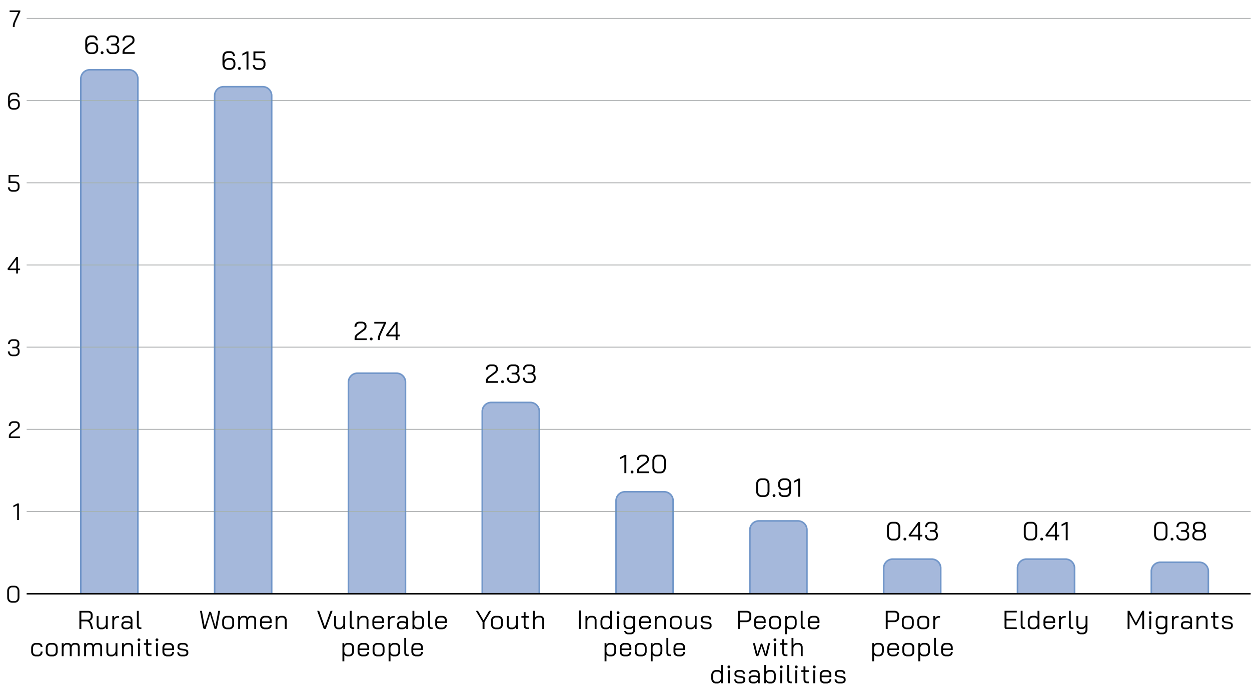
The lack of financing to address the distinct climate vulnerabilities of rural populations reflects a general neglect of the human dimension in climate change policies. This is apparent in strategic climate documents, such as NAPs and NDCs, which are pivotal for communicating a government's commitment to addressing the climate crisis to the international community.

Based on a thorough review of the NDCs and NAPs of the countries included in this report, we developed a dataset to track the specific climate actions, goals and areas of interventions foreseen for each country. This dataset enables us to examine the extent to which countries are acknowledging and addressing people and their specific vulnerabilities to climate stressors in their national climate strategies.

Our analysis paints a sobering picture of the lack of policy attention directed towards the needs of vulnerable rural populations. We find that less than 21 percent of all 4 164 actions analysed across the 24 countries make an explicit mention of people and of their livelihoods. Moreover, only about 6 percent explicitly acknowledge the needs of women, while less than 3 percent explicitly mention vulnerable people, less than 1 percent poor people and about 6 percent farmers living in rural communities. In addition, only about 2 percent explicitly mention youth, whereas very few actions explicitly target indigenous people (1.2 percent) or migrants, older people or people with disabilities (less than 1 percent). **Figure 23** reports these percentages.

FIGURE 23

Mentions of vulnerable population groups in national climate actions (NAPs and NDCs) (% of actions including a mention)



Source: authors' own elaboration.

In 2025, countries will submit revised NDCs to the IPCC. This is an important opportunity for countries and the global community to ensure that the next iteration of these critical policy documents place people at the centre of climate actions and develop interventions that address the diversity of vulnerabilities that people face because of the climate crisis.

However, acknowledging rural people in policy documents is just the first step. Policy commitments must be translated into concrete and effective actions. While this report does not provide the level of context specificity needed to guide climate interventions at the national or subnational level, it does provide indications of the types of interventions that should be prioritised for different rural populations.

Policy priorities for inclusive climate actions that address the needs of rural people

The evidence in this report suggests that different types of rural people are adversely affected by climate stressors through different channels, including through reductions in farm and non-farm incomes and reliance on maladaptive coping strategies. Policies and programmes must address these specific vulnerabilities. Furthermore, given the multidimensional nature of rural people's climate vulnerabilities, implementing multifaceted policies and interventions is critical. This section discusses potential approaches for addressing people's diverse climate vulnerabilities, both on and off-farm.

Promoting the adoption of inclusive adaptive actions in farm systems

This report shows that poor households and those headed by women and young people tend to experience higher on-farm income losses as a result of climate stressors than other rural groups. This reflects the generally lower levels of adaptive capacities among these groups and points to the urgent need for interventions that enable them to adopt climate-adaptive farming practices and technologies.

There are a wide range of farming practices and technologies that are effective at addressing the adverse effects of extreme weather events and long-run climate change, and are appropriate for different agroecological contexts.[13] However, supporting their adoption by vulnerable and resource-constrained farm households requires programmatic interventions that address key adoption barriers and constraints.

Barriers to the adoption of adaptive agricultural practices among vulnerable rural people can be grouped into three general categories. First, there are constraints to accessing and mobilizing the resources required for adoption. These may include the financial resources needed to acquire new technologies, such as improved seed varieties, irrigation equipment and technologies, as well as other factors of production, such as land and labour (Deininger *et al.*, 2023; Murage, A.W., Pittchar, J.O., Midega, C.A.O., Onyango, C.O. & Khan, Z.R., 2015; Mutenje, M.J., Farnworth, C.R., Stirling, C., Thierfelder, C., Mupangwa, W. & Nyagumbo, I., 2019; Villamayor-Tomas and García-López, 2017); Motsholapheko, Kgathi and Vanderpost, 2011; Ngigi and Muange, 2022; Ofoegbu *et al.*, 2016; Shisanya and Mafongoya, 2016; Wouterse, Andrijevic and Schaeffer, 2022). The groups considered in this report tend to be highly resource-constrained along multiple dimensions, making it difficult for them to invest in new practices and technologies, and to divert scarce production factors towards their implementation.

A second factor is access to information and human capital. This includes access to extension, technical assistance and weather advisory services to enable producers to anticipate climate stressors and identify potentially effective solutions. Vulnerable groups are often excluded from these information sources for a variety of reasons. Women, for example, face challenges in participating in agricultural extension programmes because of discriminatory norms that place a disproportionate care burden on them or limit their mobility (Ngigi, Mueller and Birner, 2017; UN Women, 2014). Meanwhile, because of the low farmer-to-extension worker ratios in many countries, extension services often target larger land holders, neglecting the poorer

13 For an inventory of such interventions, see the Agriculture Adaptation Atlas developed by the Consultative Group on International Agricultural Research (CGIAR) at https://adaptationatlas.cgiar.org/.

and land-constrained producers who are the focus of this report.

A third barrier are the risks associated with the adoption of adaptive practices. Many of these practices, particularly those focused on strengthening natural processes to build more resilient agricultural systems (e.g. agroforestry, residue retention, minimum soil disturbance, etc.), take time to generate describable benefits and may even lead to a short-term drop in productivity Alfani *et al.*, 2021; Maggio, Mastrorillo and Sitko, 2022). For vulnerable households, who often live in very precarious food security situations, the uncertainty and long-time horizons of these practices is a serious impediment to adoption. In the absence of mechanisms to manage these risks, vulnerable households often prioritize management practices that are proven and present low risks, but are also less effective at addressing climate stressors.

Managing the multiple and diverse constraints to farm-level climate adaptation by vulnerable people requires multidimensional and integrated approaches. Moreover, such approaches must take due account of the social structures that underlie peoples' vulnerabilities and address these structures directly, rather than work around them.

While the evidence on the most effective approaches for enabling and sustaining the adoption of farm-level adaptation practices remains quite limited, the literature points to several areas for prioritization, including leveraging social protection programmes, tailoring extension services to the needs of vulnerable people and integrating gender-transformative methodologies.

Leveraging social protection programmes

A recent synthesis of the evidence on social protection programmes suggests that these programmes not only help compensate people for losses in income due to climate stressors, but also overcome some of the costs and risks that prevent climate adaptation among vulnerable rural populations (Correa *et al.*, 2023). The review shows an emerging consensus in the literature that access to cash and cash-plus interventions helps increase the productive assets held by rural people, encourages the use of improved inputs and farm practices, and enables a shift away from casual wage labour arrangements. The evidence of the productive benefits of social protection programmes for rural people suggests that such programmes can be successfully integrated into broader climate adaptation and agricultural development strategies, to boost the uptake of climate-adaptive practices and minimize reliance on maladaptive practices (Correa *et al.*, 2023).

Social protection measures are particularly well-suited for supporting vulnerable groups because they are often unable to access traditional risk management mechanisms, such as credit or insurance services. In addition, social protection mechanisms can be tailored to address the specific vulnerabilities of women, children, older people and poorer people living in rural areas. For example, in Niger, the World Bank's Adaptive Safety Net project provided participants (mainly women) with cash transfers to promote investments in productive activities, with the aim of strengthening women's capacities to cope with weather shocks. The programmes can also be scaled up and scaled out in anticipation of climate shocks, thus helping to reduce reliance on maladaptive strategies. For example, in Senegal, the government's social safety net programme transferred USD 300 to the mobile accounts of over 10 000 recipients (primarly women) to help them rebuild and avoid the adoption of maladaptive strategies in the face of severe floods in 2020 (Deininger *et al.*, 2023).

To unlock the potential of social protection measures for inclusive climate actions, several issues must be taken into consideration. First, the development of climate policies is typically led by ministries for the environment, which tend to pay little attention to the important role that social policies can play towards climate objectives. Indeed, based on our analysis of the NDCs and NAPs of the 24 countries in this report, social protection is mentioned in only 1.74 percent of all actions, and these are concentrated in only two countries. A second element is the lack of public funding for social protection programmes. This challenge may be addressed by using climate financing to fund climate-focused social protection programmes, thus helping to boost the degree of social protection of vulnerable rural people.

Tailoring extension services to the needs of vulnerable people

To promote the widespread implementation of climate-adaptive actions by rural people, access to adequate advisory services is critical. How such services are delivered, and the types of support that are associated with them, determines the degree to which they include vulnerable groups. Indeed, information is not socially neutral, and specific attention must be paid to how and by whom information is delivered to specific populations to achieve sustainable and inclusive climate change adaptation.

For example, in Ethiopia and India, extension services specifically acknowledge and address the constraints that female farmers face in participating in agricultural extension events. They foresee the timing of training sessions in function of women's schedules, take account of seasonal variations in women's work burdens, organize training sessions in accessible locations and include the provision of child care during training sessions (Njuki *et al.*, 2022). As a result of this approach, women's participation in extension activities has increased, as has their uptake of improved practices.

Participatory extension methodologies, such as farmer field schools, have been shown to increase the participation of vulnerable people and promote the uptake of improved practices. These methodologies enable farmers to experiment with different approaches to address shared challenges in farm systems, while limiting the individual risks associated with trying new practices. While the evidence remains thin, participatory methods for addressing climate impacts have proven effective in increasing the awareness of climate risks and promoting the adoption of climate-adaptive practices among poor and vulnerable producers in Bangladesh and Malawi (Hasan and Kumar, 2019; Deininger *et al.*, 2023).

The inclusiveness of climate actions is also determined by who delivers the extension services. Increasing the number of female extension agents, for example, was found to boost the adoption rate of sustainable land management practices by women farmers in Mozambique (Kondylis *et al.*, 2016). Meanwhile, peer-to-peer mentorship programmes have been shown to help young farmers develop social networks to share information on best practices and strategies to improve farm incomes (Curry and Reid, 2020). Leveraging these types of approaches in the context of climate actions is likely to be more beneficial than using traditional extension approaches.

Integrating gender-transformative methodologies

Of course, people's ability to act on information depends on their economic agency and decision-making power. Women often face discriminatory norms that limit their ability to exercise agency over economic decisions that are relevant to their lives. Incorporating gender-transformative methodologies, which employ social behavioural change approaches to directly challenge discriminatory gender norms, is crucial to tackle entrenched discrimination that prevents women from exercising full agency over their economic lives. Such methodologies typically involve both women and men, and use participatory methods for social change that can be integrated into agricultural advisory systems and value chain interventions (Deininger *et al.*, 2023; FAO, 2023a).

Enabling inclusive off-farm opportunities

This report highlights that access to off-farm income opportunities is critical for building the resilience to climate change of vulnerable populations. Losses of off-farm income sources are an important driver of climate vulnerability for poor and female-headed households, while young households are found to leverage off-farm opportunities to effectively reduce their vulnerability. Thus, inclusive climate actions in rural areas must go beyond the farm level.

Tackling the challenge of sustaining and increasing off-farm income opportunities for vulnerable groups in a context of climate change requires interventions that tackle both the macro- and micro-level factors that limit people's access to decent off-farm income opportunities.

At the macro-level, issues related to education, disparate time burdens and mobility all influence the types and quality of off-farm income opportunities that people can access. Social and economic factors that limit children's access to education, particularly for those living in economically marginalized rural households, must be identified and addressed. Low education levels limit people's options for off-farm employment and restrict their capacity to build and grow off-farm enterprises, thereby pushing many marginalized people into work that is precarious, informal and badly paid.

The impacts of climate change may be exacerbating educational inequalities, as exposure to extreme weather events can push economically marginalized households to withdraw their children from school. This effect is particularly worrisome for girls (Randell and Gray, 2016). Public policies must therefore strive to prevent the gender gap in educational attainment from growing as a result of climate change. In Malawi, school feeding programmes have been shown to reduce the probability that girls are withdrawn from school when droughts occur (Staffieri, 2022).

The so-called "green economy" is often promoted as a solution to create decent employment opportunities, while simultaneously tackling local and global environmental challenges. However, research suggests that many green jobs favour men over women, given that they tend to focus on science, technology, engineering and mathematics (STEM), fields in which women are generally underrepresented (Deininger *et al.*, 2023). Thus, measures to improve access to education must go hand in hand with efforts to tailor curricula to emerging employment needs. This includes focusing on improving the participation of girls in STEM curricula.

Addressing gender disparities in the burdens of domestic work and care responsibilities is critical to improve the access to and participation in remunerative off-farm work opportunities in rural areas. The provision of child care, for example, has been shown to have a considerable positive effect on women's off-farm employment (Clark *et al.*, 2019; Hojman and López Bóo, 2019).

Supporting the development of markets for climate-adaptation services can create important opportunities in the non-farm sector, while at the same time addressing farm-level constraints to adaptation. For example, in Burkina Faso, the use of planting pits that collect water and compost, known as *zai* pits, was limited because their construction is extremely labour intensive. To address this constraint, young people formed groups to dig these pits for local farmers for a fee. This strategy had the dual benefit of providing wage opportunities for young people, while simultaneously enabling the widespread adoption of this effective climate adaptation and land restoration practice (Pretty and Bharucha, 2014).

In rural areas, the creation of employment and the formation of enterprises in agrifood systems are particularly important, particularly for women and young people. Agrifood enterprises enable rural youth and other people to diversify their income sources and reduce their dependency on climate-sensitive primary agricultural production.

The provision of complementary services is essential to maximize the positive impact of off-farm opportunities. There is increasing evidence of the importance of strengthening people's non-cognitive skills, in addition to providing technical and vocational education. For example, personal initiative training, which focuses on building participants' socioemotional skills, was found to have a greater impact on both male and female entrepreneurs' profits than traditional business training in Togo (Campos *et al.*, 2017). However, sustaining the benefits of these programmes requires continuous support (Ubfal *et al.*, 2022). Evidence from Viet Nam shows that combining business training with gender-oriented contents, such as how to enter male-dominated sectors and deal with gender stereotypes, was effective at increasing profits and encouraging the adoption of recommended practices (Bulte, Lensink and Vu, 2017).

Finally, expanding access to financial services such as loans for agrifood enterprises and small-scale producers is crucial to create and boost off-farm income opportunities in rural areas. Enabling young people, women and people living in poverty to access these services requires innovative strategies to reduce lenders' requirements for collateral and offset the risks of loan repayment failure.

Building evidence on inclusive climate adaptation actions

The rapid increase in climate projects and programmes in recent years provides a unique opportunity to build evidence to guide future and current climate actions. There is a need to invest in the analysis of climate actions to better understand which interventions are most effective at supporting climate adaptation in rural areas, particularly among vulnerable populations who are at risk of being left behind. Without actionable evidence, the scarce resources available for climate actions may be wasted on ineffective approaches.

While data granularity has progressed over the past decade, the lack of data that can be disaggregated at the level of individuals hampers efforts to identify critical social vulnerabilities and target these with effective actions. For the analysis in this report, for example, individual sex- and gender-disaggregated data were only available for six and seven countries, respectively, out of a total of 24 countries. Other vulnerable groups, such as indigenous communities or individuals with disabilities, could not be analysed due to the lack of relevant data. Furthermore, individuals often belong to multiple vulnerable groups simultaneously, resulting in an intricacy of different types and intensities of vulnerabilities. Intersectionality is therefore a crucial aspect that deserves further research to gain a more holistic understanding of the complex dynamics of climate-related vulnerabilities.

Moving forward

This report clearly demonstrates that climate change is dramatically constraining opportunities to leverage agrifood systems to reduce poverty and hunger. The disparities in climate vulnerabilities within rural areas are considerable, and current funding to support climate actions in rural areas falls woefully short of the needs of vulnerable people. This report shows that the challenges and opportunities to reduce climate vulnerability among rural women, youth and the poor vary considerably, both between these groups and for the different types of climate stressors. We hope that the evidence presented here can motivate actions that translate this evidence into policies, investments and programmes that leave no one behind.

The availability of socially disaggregated data is still limited, and investments made still remain largely untracked. We hope that this analysis will trigger efforts to build a large body of evidence focusing on climate adaptation, but also on people and their needs, and particularly the most vulnerable. Ultimately, climate interventions and financing should target not only environmental and climatic outcomes, but also people, with their unique characteristics and vulnerabilities.

Part II

Understanding the data, variables and methods

The second part of this report provides detailed information on the data, variables and methods used in our analysis. In addition, it provides descriptive evidence to help the reader understand the spatial differences in exposure to the various climate stressors analysed, as well as the socioeconomic differences between poor and non-poor households, female- and male-headed households, and young and older households. It also provides insights into the key limitations of the analysis and how these were addressed. The aim of this second part of the report is to help readers understand what is being measured, how it is being measured, and why.

SOMALIA - In post-drought Somalia, Dhore, a local farmer in Jamao Mubaarak, Bulaburte, stands tall. Drought recovery remains an urgent concern for rural families in the region.

7. Understanding the data sources

The report combines household survey data from 24 low- and middle-income countries with georeferenced climatic and spatial data to explore inequalities in climate vulnerability. The bulk of the analysis is conducted at the level of the household. However, for a subset of countries more granular survey data were available, allowing deep dive analyses at the individual and farm plot level. This chapter describes the data sources in detail.

Main household-level analysis

The primary source of the survey data used in this report is the Rural Livelihoods Information System (RuLIS) initiative. RuLIS is the result of a collaboration between FAO, the World Bank and the International Fund for Agricultural Development (IFAD) aimed at facilitating access to harmonized and comparable data and information on the incomes and livelihoods of rural people across different countries, as well as on their evolution at the subnational level. RuLIS currently provides information on 116 ready-made indicators computed from 81 household-level surveys in 44 countries around the world. The indicators in RuLIS are organized in ten clusters: 1. Income and productivity; 2. Poverty and inequality; 3. Employment and education; 4. Social protection; 5. Land; 6. Livestock; 7. Inputs, credits and technology; 8. Infrastructure and services; 9. Shocks and migration; and 10. Sample characteristics.

This report uses RuLIS household surveys for 24 of the 44 countries. Of these, 13 are in Africa, nine in Asia and two in Latin America (see **Table 1**). The surveys were selected based on several criteria. First, for better comparability across the countries, we only considered surveys conducted between 2010 and 2019. Surveys conducted after 2019 were excluded because these data are influenced by the COVID-19 pandemic. Second, we only used surveys that provide the geographical information required to merge the data with relevant geospatial and climate information. Third, surveys without dates for the interviews were also excluded, as these dates are crucial to link the socioeconomic data to weather events. Finally, the surveys conducted in 2019 in the countries belonging to the West African Economic and Monetary Union do not provide information regarding the values of crop production and were, therefore, excluded from the analysis.[14]

The 24 surveys included in the study have a total sample size of approximately 380 000 households. However, the analysis for this report focused on rural households that were engaged in agricultural activities only. Furthermore, the absence of data for key variables led to reductions in the sample sizes. The final sample size for the main household-level analysis ranges from 69 870 to 109 803 households, depending on the outcome variable. Details on the surveys included can be found in Annex 6.

Deep-dive analysis into individual labour outcomes

The main RuLIS analysis is complemented with a deep-dive analysis into labour outcomes at the level of individuals. As such detailed information is only available for a handful of the selected countries, the deep-dive analysis is limited to surveys from six African countries (all part of the World Bank's Living Standards Measurement Study–Integrated Surveys on Agriculture [LSMS–ISA]): Ethiopia, Malawi, Niger, Nigeria, the United Republic of Tanzania and Uganda. The sample comprises individuals aged between 10 and 84 years.[15] Depending on the outcome variable, the sample size ranges between 41 186 and 70 797 observations.

[14] Whenever possible, the latest available survey of each country was used. The only exception is the United Republic of Tanzania, where the 2013 survey was used instead of the 2015 survey because of misspecifications of the urban–rural classification in the 2015 data.

[15] We include individuals aged below and above the standard working age of 15 to 64 years to study the labour dynamics of children and senior workers. See Box 6 for the definition of the different age categories.

TABLE 1

Countries included in the report, with date of survey

Country	Year	Deep-dive analysis
Armenia	2013	No
Bangladesh	2010	No
Burkina Faso	2014	Yes
Cameroon	2014	No
Ecuador	2014	No
Ethiopia	2019	Yes
Georgia	2015	No
Ghana	2017	No
India	2012	No
Iraq	2012	No
Malawi	2017	Yes
Mali	2017	Yes
Mongolia	2019	No
Nepal	2011	No
Niger	2014	Yes
Nigeria	2019	Yes
Pakistan	2014	No
Peru	2019	No
Rwanda	2014	No
Senegal	2011	No
Sierra Leone	2018	No
United Republic of Tanzania	2013	Yes
Uganda	2016	Yes
Viet Nam	2010	No

Source: authors' own elaboration.

Deep-dive analysis at the level of farm plots

For seven African countries for which detailed agricultural and sex-disaggregated information is available, a plot-level analysis was conducted into differences in crop values and in the adoption of adaptive farm-level practices between male and female plot managers. This analysis covers the same countries as the deep dive into labour, plus Mali. The total sample size ranges from 18 793 to 56 916 plot-level observations. To avoid interference with the gender of the household head, the analysis considers male-headed households only.[16]

Climate data

KEY FACTS

- We use reanalysis climatic data to ensure consistent observations across the world at high spatial resolution.
- The climatic data we use span several decades, which allows us to evaluate long-term climate changes.
- The daily frequency of the climatic data enables us to better capture extreme weather events.

This report relies on reanalysis-based datasets to analyse climate trends and extreme weather events. Reanalysis-based climate data are simulations of the atmosphere obtained by blending model forecasts with satellite and weather gauge observations. The resulting product offers several advantages compared to other climate data types, which is why reanalysis-based data are widely used in impact analyses of climate stresses (Cucchi *et al.*, 2020), in assessments by the World Meteorological Organization (WMO) and IPCC (Hersbach *et al.*, 2020), as well as in the analysis of extreme weather events (Hu and Franzke, 2020; Lei *et al.*, 2022; Sheridan, Lee and Smith, 2020). These datasets cover most of the world at a high spatial resolution, allowing for the measurement of local extreme events even in regions where the gauge station network is thin. Their time span usually extends across multiple decades, which is crucial for measuring the long-run characteristics of climate and its changes. Moreover, the observations are provided at a high temporal frequency, which is essential to capture certain extreme weather events such as floods or heat stress (Schmitt *et al.*, 2022; Tank, Zwiers and Zhang, 2009; Zhang *et al.*, 2011).

The most recent and therefore most up-to-date reanalysis source is the ECMWF Reanalysis 5 (ERA5) dataset, developed by the European Centre for Medium-Range Weather Forecasts (ECMWF) as part of the Copernicus Climate Change Service, which is financed by the European Union (Hersbach *et al.*, 2020). ERA5's ability to represent weather extreme events has been subjected to validation and comparison in various studies (Sheridan, Lee and Smith, 2020; Xu *et al.*, 2022). It has been recognized that ERA5 has some limitations, which are corrected in the WATCH Forcing Data

[16] Seventy-six percent of all female-managed crop-plot combinations belong to female-headed households.

methodology applied to ERA5 reanalysis data (WFDE5) (Cucchi *et al.*, 2020).[17]

The improvement in the accuracy of ERA5 by WFDE5 makes it our preferred choice for the analysis for this report. However, the shorter time scale of the WFDE5 limits its utility to measure long-run precipitation and temperature trends, which we use to measure long-run changes in temperature and as control variables in our analysis. For long-run analyses we therefore use the ERA5-Land dataset, produced by the Copernicus Climate Change Service.[18] **Table 2** provides an overview of the different sources of the data on climatic variables.

Spatial control data

In addition to climate information, this report uses various georeferenced datasets in the empirical analysis to account for factors that may influence the degree of climate vulnerability of a household.

TABLE 2

Climatic data sources

Data source	Spatial resolution	Temporal resolution	Time span	Variables
WFDE5	0.5° x 0.5°	daily	1979–2019	precipitation rate (kg/m²/s) maximum temperature (K)
ERA5-Land	0.1° x 0.1°	hourly monthly	1950–2021	total precipitation (m) total evaporation (m) Temperature (K)

Source: authors' own elaboration.

BOX 7

Spatial control variables

Population density
Population estimates are used to account for the level of remoteness (WorldPop, 2018).

Night-time light
Night-time light provided by Visible Infrared Imaging Radiometer Suite (VIIRS) (Elvidge *et al.*, 2021) is used to account for the level of development of infrastructure.

Urban–rural catchment areas
Travel time distance categories are used to account for the level of access to services (Cattaneo, Nelson and McMenomy, 2021).

Koeppen–Geiger climate zone classification
The climate classification provided by FAO's Global Agroecological Zone Portal v4 Data Portal is used to account for prevailing climate characteristics (Fischer *et al.*, 2021).

Sources:

Cattaneo, A., Nelson, A. & McMenomy, T. 2021. Global mapping of urban-rural catchment areas reveals unequal access to services. *Proceedings of the National Academy of Sciences*, 118(2): e2011990118. https://doi.org/10.1073/pnas.2011990118

Elvidge, C.D., Zhizhin, M., Ghosh, T., Hsu, F.-C. & Taneja, J. 2021. Annual time series of global VIIRS nighttime lights derived from monthly averages: 2012 to 2019. *Remote Sensing*, 13(5): 922. https://doi.org/10.3390/rs13050922

Fischer, G., Nachtergaele, F.O., van Velthuizen, H.T., Chiozza, F., Franceschini, G., Henry, M., Muchoney, D. & Tramberend, S. 2021. *Global Agro-Ecological Zones v4. Model documentation*. Rome, FAO. https://doi.org/10.4060/cb4744en

WorldPop. 2018. Population counts. In: *Geodata*. Southampton, UK, University of Southampton. [Cited 10 July 2023]. https://www.worldpop.org/doi/10.5258/SOTON/WP00647

[17] Building on the WATCH Forcing Data (WFD) methodology, WFDE5 incorporates elevation corrections and integrates new surface observations from CRU TS 4.03 and the Global Precipitation Climatology Centre (GPCCv2018) (Cucchi *et al.*, 2020). WFDE5 has a slightly coarser spatial resolution than ERA5, with a resolution of 0.5° x 0.5°, and offers daily temporal frequency, albeit with data going back only to 1971.

[18] This dataset is also an enhanced version of ERA5, with elevation correction and improved spatial resolution at 0.1° x 0.1°, while maintaining the hourly frequency and the time span of 1950 to present (Muñoz-Sabater *et al.*, 2021).

BOLIVIA - A woman in the fields during the seed and flower production cycle. Sustainable practices are essential to meet the challenges imposed by climate change.

8. What is measured and how is it measured in this report?

This chapter provides a detailed description of the variables used to identify different rural subpopulations based on wealth, gender and age, and to measure the three dimensions of climate vulnerability (exposure, sensitivity and adaptation). The chapter helps understand what is being measured in the report, how it is measured, and what the strengths and limitations of the variables that underpin the analysis are.

Vulnerable groups

Wealth

The recognition of poverty as a multidimensional problem has given rise to the development of various methodologies to capture the multiple deprivations (beyond monetary deprivation) that simultaneously contribute to the experience of poverty.

For this report, we constructed a household-level multidimensional poverty index following the Alkire–Foster methodology as closely as the data availability in the RuLIS database allows. Households are considered "poor" if they fall within the lowest quartile of each country's poverty index distribution.[19]

IN BRIEF

A poor household is a household that belongs to the bottom 25th percentile of a multidimensional poverty index distribution.

Our multidimensional poverty measure has seven dimensions: communication, assets, dwelling characteristics, access to water, electricity, sanitation and education (see **Table 3**). Each dimension enters the poverty index with an equal weight of 1/7. Within each dimension, we identify a set of variables that mark the specific deprivations of each household. For example, a household is deprived in education if no household member has six years of education or more. Within each dimension, each deprivation is given the same weight. Therefore, a deprivation has a higher weight in the final poverty index when fewer variables are used to construct the dimension. For example, each of the three variables defining the dwelling dimension get a weight of 1/21 in the final score, while ownership of a home, the only variable defining the asset dimension, enters with a weight of 1/7. The multidimensional poverty index ranges from 0 (household deprived in all variables in all dimensions) to 1 (household without any deprivations).

Gender

Depending on the outcome variable under consideration, as well as on the level of analysis (household or individual), we use different variables to explore disparities in climate vulnerability between females and males.

IN BRIEF

Definition of gender measures:

- Female headship of household (household- level analysis)
- Being female (individual-level analysis)
- Plot managed exclusively by females (plot-level analysis)

Gender variable in the household-level analysis

In the main household analysis, we differentiate between female and male headship to investigate gender differences in climate vulnerability between households.

We recognize that the use of the household headship variable to understand gendered

[19] This is an important divergence from the official Multidimensional Poverty Index developed by the United Nations Development Programme (UNDP) and Oxford University, which applies the same cut-off to each country and thereby measures poverty in absolute terms at a global scale.

TABLE 3

Composition of the relative wealth index

Dimension	Deprivation indicator	Deprived if:	Weight
Communication	Cell phone	The household does not have a cellphone.	1/21
	Telephone	The household does not have a telephone.	1/21
	Internet	The main dwelling of the household has no internet connection.	1/21
Asset	Own house	The dwelling is rented or the legal deed of the dwelling does not belong to a member of the household.	1/7
Dwelling	Brick walls	The dwelling does not have brick walls.	1/21
	Non-dirt floor	The dwelling does not have a dirt floor.	1/21
	Solid roof	The dwelling does not have a solid roof.	1/21
Access to water	Access to safe water	The household does not have access to safe drinking water, or safe drinking water is at a 30- minute walk or more (roundtrip) from the dwelling.	1/14
	Running water	The household does not have access to running water on the premises.	1/14
Electricity	Access to electricity	The household does not have a formal electricity connection.	1/7
Sanitation	Access to a toilet	The household does not have access to a toilet on the premises.	1/7
Education	Years of schooling	No household member has completed six years of schooling.	1/7

Source: authors' elaboration.

differences in climate vulnerability comes with a range of important limitations. First, it is impossible to determine who is the real decision-maker in the household, or whether decisions are taken jointly by males and females. Moreover, given the absence of complete information on household heads' marital status, it is unclear whether female headship signals more decision-making power for female household members than for male members, or whether it is the result of divorce, death or migration of the husband. This implies that we cannot determine whether the differences in climate vulnerability are rooted in structural differences between male- and female-headed households, or in the actual sex of the household head. We still select this variable because the RuLIS datasets do not contain more nuanced gender-related data for all countries.

Gender variable in the individual-level labour analysis
When examining differences in terms of labour allocation at the individual level, we directly differentiate between women and men, girls and boys.

Gender variable in the plot-level analysis
We measure gendered differences in the climate vulnerability of crop production and adaptation based on the gender of the managers of the different agricultural plots cultivated by the household. More specifically, we distinguish between plots that are managed by women only, men only or jointly by male and female household members.

Age

We use different age categorizations depending on whether the outcome variable is measured at the household or at the individual level.

Age categorization at the household level
We classify households as young if the household head is 34 years old or younger, while prime-aged households are those headed by people who are 35 to 64 years old. Households with a head

older than 64 years are coded as «senior-headed households».[20] This classification is applied to all the analyses conducted at the household level.

Age categorization at the individual level
Since the larger sample size allows us to explore differences between a larger number of age categories, the individual-level analysis of labour allocation follows the International Labour Organization's (ILO) age categories. We use the following classification: children (between 10 and 14 years), youth (between 15 and 24 years), prime-aged adults (between 25 and 54 years) and seniors (between 55 and 84 years). This last category includes both the ILO's category of older workers (i.e. those aged between 55 and 64), as well as people who exceed the working age (i.e. those aged 65 and older). We believe that this categorization of seniors reflects the reality of rural livelihoods in sub-Saharan Africa, where our deep dive analysis is focused and where rural people tend to work beyond the standard retirement age of 65 years.[21]

IN BRIEF

Definition of young vs prime-aged at the household level:

- Young household: household head < 35 years old
- Prime-aged household: household head 35 to 64 years old

Age categorization at the individual level:

- Children: between 10 and 14 years
- Youth: between 15 and 24 years
- Prime-age adults: between 25 and 54 years
- Seniors: between 55 and 84 years

Measuring sensitivity to climate shocks

Climate stressors can affect the well-being of rural households across multiple dimensions. To explore the diverse sensitivities of rural households to climate and weather events, we use income-related variables at the household level, labour variables at the individual level and variables measuring agricultural productivity at the plot level.

BOX 8

Child labour vs children's work

The term child labour refers to work undertaken by children below the legal minimum working age of 15 years (14 years in exceptional cases). Excluded from this definition are provisions made by national laws for light work undertaken by children aged 13 to 15 (12 to 14 years in exceptional cases). Light work entails activities that do not pose a threat to children's health, safety or school attendance and achievement. Children can be involved light work for up to 14 hours a week if they are aged between 12 and 14 years, and for up to 43 hours a week if they are aged between 15 and 17 years. In this report, we apply a broader concept than that of child labour. We use the term "children's work" to refer to all activities carried out by children aged 10 to 14 years, either on or off the household's own farm. This term does not carry any implications as to the nature of this work or its repercussions on children's well-being and development.

Source: Convention C138 - Minimum Age Convention. International Labour Organization, Geneva, Switzerland, 6 June 1973.

Household-level income variables

We use four different income variables to assess the sensitivity of rural households to extreme weather events and climate change. The first is the **total crop value** produced by the household. This variable represents the total value of crops produced by a household over the past 12 months, calculated based on harvested crop quantities and corresponding local prices.[22]

[20] We extended the standard International Labour Organization (ILO) age category of "youth" to include young adults, in view of the limited number of households with heads below the age of 25.

[21] To ensure consistency, we excluded data for children under 10 years of age, as some of the surveys pose the labour-related questions only for household members aged 10 or older.

[22] The prices were obtained by calculating the median of all crop-specific prices reported by households at the lowest sampling or administrative level possible.

Second, we measure the total **on-farm income** generated by the household. This variable captures the total net household income derived from on-farm activities, such as crop cultivation, livestock rearing, forestry activities and fisheries over the past 12 months. The costs of inputs, labour and land and machinery rental are subtracted.

Third, we measure **off-farm income**, which includes any income derived from agricultural and non-agricultural wage employment, self-employment, public and private transfers, as well as income from financial and real estate assets.[23] Due to differences in data collection methods across countries, it is impossible to analyse off-farm income in a more disaggregated manner.[24]

Finally, we estimate the association between the climate stressor and **total household income**, which encompasses the sum of on-farm income and off-farm income.[25]

IN BRIEF

Household-level sensitivity outcomes:
- ✔ value of crop production
- ✔ on-farm income
- ✔ off-farm income
- ✔ total income

Individual-level labour outcomes

To investigate the consequences of climate stressors on labour dynamics, we construct the following individual-level outcome variables: (1) an indicator determining whether or not the respondent has a job; (2) the sum of all hours worked in the main and secondary jobs per week; and (3) the share of these hours that is dedicated to work on the household's own farm.

IN BRIEF

Individual-level labour sensitivity outcomes:
- ✔ labour market participation
- ✔ hours worked per week
- ✔ labour on household farm

Plot-level productivity outcomes

We measure the productivity of individual plots based on the value of the crops produced, following the same methodology as for total crop value. In addition, we analyse climate vulnerabilities of the crop value per hectare, taking into account differences in plot sizes.

Measuring adaptation

We use three adaptation variables that are collected consistently in the RuLIS surveys, and that are relevant to both short and long-term adaptation actions in rural settings: agricultural expenditure, livestock numbers and income diversification.

IN BRIEF

Plot-level adaptation outcomes:
- ✔ agricultural expenditure
- ✔ tropical livestock units (TLUs)
- ✔ income concentration

In addition, for a subset of countries, we analyse four plot-level adaptive practices: intercropping, irrigation, the use of soil and water conservation infrastructure, and the use of organic fertilizers.

Agricultural expenditure

Agricultural expenditure is considered a proxy for households' willingness and ability to invest in agricultural intensification and capital-intensive adaptive strategies. When exposed to contemporaneous or long-term climate stressors, households may choose to increase investments in agriculture in order to boost production and increase farm resilience, or reduce expenditures and redirect available resources towards consumption or investments in other economic activities.

[23] Contrary to non-farm income, which excludes income from any agricultural activity, off-farm income includes agricultural wage income from work on non-household farms (Barrett, Reardon and Webb, 2001). The farm in "off-farm" hence refers specifically to the household farm, and not to farming activities in general.

[24] Moreover, a multi-country study is not an optimal framework to study different sources of off-farm income, as the prevalence of these income sources, as well as their importance to people's livelihoods, is very context-specific.

[25] Note that all income variables are computed as per adult equivalent and adjusted for purchasing power parity to 2011 USD. More details of the RuLIS variable construction can be found in the technical note of the RuLIS database (FAO, 2018).

Agricultural expenditure is calculated as the sum of a household's expenditures related to crop production over the past 12 months. This includes total expenses on chemicals, seeds (including improved seeds), inorganic fertilizers and labour inputs. Note that when analysing the effects of climate stressors on this variable, we focus only on crop-producing households.

Livestock ownership

Livestock tends to serve multiple functions in many rural areas. In addition to their productive value, livestock serve as a store of value and an important asset that can be liquidated in times of economic hardship. In terms of climate adaptation, vulnerable households may liquidate livestock as a reactive adaptation strategy in order to smooth consumption when climate stressors occur . Whether or not households liquidate livestock as an *ex post* adaptive strategy is likely conditioned by the household's resource endowments and the availability of alternative adaptation strategies (Rojas-Downing *et al.*, 2017; Thornton *et al.*, 2014; Wouterse, Andrijevic and Schaeffer, 2022). While the liquidation of livestock may be effective at smoothing short-term consumption, it may also reduce a household's future resilience to climate stressors. Alternatively, moving in and out of livestock production can be an important anticipatory adaptation strategy. For example, households may shift from crop to livestock production to reduce vulnerability to climate risks, as livestock are typically less sensitive to weather shocks than crops (IFAD, 2010; Thornton and Gerber, 2010; Thornton and Herrero, 2015).

We measure this adaptive action through household-level TLUs. To obtain herd/flock size, RuLIS provides the average TLUs owned by livestock-keeping farms at the time of the interview. One TLU corresponds to 250 kg of live weight. This is the metabolic weight equivalent of one head of cattle in North America; the standardization of the TLUs is obtained by multiplying the number of effective livestock units by species- and region-specific conversion factors.[26]

Income diversification

To assess the inclination of rural individuals to broaden or narrow their sources of income and livelihoods in reaction to climate-related pressures (as described in Winters *et al.*, 2009), we include the widely used Herfindahl–Hirschman Index (HHI) as a metric for gauging income concentration. The HHI ranges from zero to one and is computed by summing the squares of the shares of income from different sources (crop production, livestock rearing, fishery, forestry, agricultural wages, non-agricultural wages, self-employment, transfers, other income) in total income. A higher index value signifies a higher level of income concentration, while a lower value indicates more income diversification.

Plot-level adaptive practices

At the plot-level, we examine the ways in which exposure to different climate stressors influences the adoption of climate-adaptive farming practices. The practices considered are:

- soil and water conservation: any infrastructure preventing soil erosion or enabling water harvesting (e.g terraces, stone/earth bunds, dams);
- any type of irrigation (in contrast to rain fed cultivation);
- use of organic fertilizers, including crop residues, compost and animal manure; and
- intercropping (and crop rotation): plots on which cereals and legumes are grown in parallel, in mixed stands or intercropping cultivation systems. Hence, plots without legumes or cereals are automatically coded as not intercropped.

These four practices were selected based on their potential to strengthen the resilience of crop systems to climate stressor exposures and their consistent availability across surveys (Bell *et al.*, 2018; CGIAR, undated; FAO, 2017; World Agroforestry, 2023).

[26] The conversion factors can be found in the FAO's *Guidelines for the preparation of livestock sector reviews* (FAO, 2011).

Measuring climate stressors

KEY FACTS

- We use daily precipitation and temperature data to identify the following types of climate stressors:
  - flood: days of extreme precipitation;
  - heat stress: days of extreme temperature;
  - drought: the duration of consecutive days with extremely low precipitation; and
  - climate change: long-term changes in average temperature.
- Extreme precipitation and temperature events are identified based on the rarity of occurrence in a specific location and month of the year.
- The identification of extreme weather events takes into account geographic and seasonal characteristics, as well as the adaptive strategies implemented by local populations.

To determine how exposure to weather extreme events and climate change affects the livelihoods, well-being and adaptive responses of rural populations, we rely on the IPCC's definitions of climate, climate change and extreme weather (IPCC, 2022b). Broadly speaking, *climate* is defined as the average weather over a certain period of time, typically a 30-year period in the context of climate change (World Meteorological Organization-WMO, 2017). More rigorously, it refers to the statistical distribution of a climate variable (temperature, precipitation, wind) and its characteristics. Based on this definition, *climate change* indicates a prolonged alteration in the state of climate (identified through statistical tests) that affects its mean and/or variability over a decade or more. *Extreme weather events* occur when the climate variable surpasses a threshold value near the upper or lower bounds of the observed range for that variable (IPCC, 2022b). This report focuses on three specific weather extreme events: droughts, floods and heat stresses. Building on IPCC, 2022b, these three extreme events are defined in this report as:

- Drought: a period of abnormally dry weather long enough to cause a serious hydrological imbalance and water shortage for human populations and ecosystems.
- Flood: the overabundance of water on river streams or water bodies, or over areas that are not regularly inundated.
- Heat stress: a range of conditions in terrestrial organisms whereby the body absorbs excess heat during overexposure to high air temperatures or thermal radiation.

The determination of what qualifies as an extreme event is inherently tied to the selection of a threshold. This threshold may vary depending on factors such as time, location, historical and economic perspective of the society, and the specific purpose of the analysis (Dalezios, Dunkel and Eslamian, 2017). One method to define an extreme event is by assessing its rarity. For instance, IPCC suggests that an extreme event should be as rare as or even less frequent than the 10th or 90th percentile of a probability density function, which might vary at the local level (IPCC, 2022b).

The use of percentile threshold values for a multicountry study is useful for two reasons. First, thresholds are not fixed but vary across locations, and take into account local characteristics. The use of relative thresholds recognizes the fact that human systems have adapted over time in reaction to localized weather patterns. Therefore, percentile thresholds ensure that spatial comparisons are meaningful, as they measure anomalies with the same probability of occurrence across space (Tank, Zwiers and Zhang, 2009; Zhang *et al.*, 2011). Second, due to the diversity of production systems and livelihoods included in this report, it is extremely difficult to identify an absolute rainfall or temperature threshold that is universally relevant.

Following this approach, we define the indicators for the three extreme events as follows (details on these variables are provided in **Annex 1**):

- A drought is identified as the number of consecutive dry days (less than 1 mm of precipitation) in the longest dry spell for a given period that exceeds the 95th percentile of the historical dry spell distribution.[27] It is measured as the number of dry days that exceeds this threshold.

[27] A dry spell refers to a prolonged period of consecutive dry days, defined as five or more days with precipitation of less than 1 mm.

- A flood is detected as a wet day (greater than 1 mm) where precipitation exceeded the 95th percentile of the historical distribution and is measured in terms of the number of days that precipitation exceeded this threshold.
- A heat stress occurs when the maximum daily temperature exceeds the 99th percentile of the historical distribution. As with floods, it is measured in terms of the number of days that temperature exceeds this threshold.

Box 9 summarizes the construction of these weather extreme indicators; further details are available in **Annex 1**.

This report also considers the effects of climate change on rural people's climate vulnerability. Climate change refers to an alteration of long-run climatic conditions and it is usually associated with an increase in the frequency of extreme events. We proceed by computing the average temperature between two separate periods of observation. Each period lasts 30 years, without overlaps. We then compute the difference between the two average temperatures to measure the magnitude of change. More details on the construction of the climate change indicator are provided in Box 10 and in **Annex 1**.

BOX 9

Construction of extreme weather indicators

1. Compute the empirical distributions over 30 years of historical weather observations (1979–2009):
   - local specific distribution, to account for the spatial heterogeneities of climate; and
   - monthly specific distribution, to account for intra-annual climate seasons.
2. Select the adequate percentile from the historical distribution to be the extreme thresholds:
   - for floods, the 95th percentile of daily precipitation;
   - for heat stress, the 99th percentile of daily maximum temperature; and
   - for droughts, the 95th percentile of the length of dry spell.
3. Compare the weather experienced by the household over the past 12 months with the thresholds.

BOX 10

Measuring climate change indicators

1. Select two distinct windows of temperature observations. The windows last 30 years and do not overlap:
   - window 1 spans from 1951 to 1980; and
   - window 2 spans the 30 years before each survey.
2. Compute the average temperature for each window.
3. Compute the difference between the average temperature in window 2 and the average temperature in window 1.

Matching climate data to surveys in space and time

To spatially associate the climate data with the households, we extract the values based on the smallest available administrative divisions in each household survey. We take the average of all the cell values that overlap with the administrative division, weighted by the proportion of the cell falling within the division (see Box 11) (Flatø, Muttarak and Pelser, 2017; Letta, Montalbano and Pierre, 2022).

This approach results in a single average value per administrative division. Consequently, all households within the same division share a common average value. In essence, spatial control and climatic variables are generalized to the administrative division level, rather than being specific to individual households.[28] To match the exposure to weather events with the survey data, we use the interview dates as a reference point and match climatic observations with the reference period of the survey, which is the 12 months preceding the interview.

BOX 11

Georeferencing and data extraction

To spatially associate external data with the households, we extract the values based on the lowest administrative divisions of the survey.

- We extract all the values that overlap with the administrative division.
- We take the average of all the extracted values weighted by their proportion within the division.

[28] We acknowledge that the averaging may reduce the accuracy in climatic variables (Michler *et al.*, 2022), as certain extreme weather events may cover a smaller geographical area than administrative divisions. By averaging them with non-extreme values, the values associated with a household might be diluted. However, this approach is necessitated by the availability of spatial data in our surveys.

PAKISTAN - Locals had to swim for an hour to obtain emergency food rations after floods. Nearly 20 million people have been affected by the flood, fleeing their homes.

9. The empirical strategy: estimating the effects of climate stressors on sensitivity and adaptation

Our methodology aims to measure the different effects of climate stressors on sensitivity and adaptation outcomes based on wealth, gender and age. Given the nature of the available data, this analysis is cross-sectional and non-experimental, meaning that we cannot make strong causal claims about the effects.

For the empirical analysis, we run three separate linear regression models of the same form for each type of climate stressor (heavy precipitation, heat and drought), interacting these variables with the subgroup indicator for wealth, gender or age. All models include socioeconomic and spatial covariates.

The use of interaction effects between climate stress measures and subgroup indicators allows us to quantify the differences in outcomes within different populations (eg. poor vs non-poor) and determine whether they are statistically significant. This empirical approach is common in studies on the heterogenous effects of weather shocks and climate change. Several papers use this approach to study outcomes such as household expenditure (Azzarri and Signorelli, 2020), food consumption (Letta, Montalbano and Pierre, 2022; Mesfin and Ahmed, 2023) and agricultural adaptation (Makate *et al.*, 2022). Moreover, a number of papers use interaction terms between climate variables and different indicators of gender. For example, Carpena (2019) and Nico and Azzarri (2022) interact weather shock measures with the sex of the household head to study the gender-specific effects of these shocks on household food consumption and labour outcomes, respectively. Other studies use interaction terms with the sex of the plot manager to study gender-specific climate impacts on household consumption (Asfaw and Maggio, 2018) or on the marketing of farm outputs (Agamile, Dimova and Golan, 2021). Azzarri and Nico (2022) study agricultural incomes and the value of production by interacting climate shocks with the gender of the recipients of extension services. Lastly, studies that use interaction terms between climate variables and age indicators also exist, but they are limited to the analysis of migration (e.g Baez *et al.*, 2017) and health outcomes (e.g. Akresh, Verwimp and Bundervoet, 2011). A description of the formal equations, the covariates and the specific empirical considerations made for the analysis is found in Annex 2.

BOX 12

Sources of bias and how this study addresses them

The non-experimental nature of our approach does not allow us to make rigorous causal inference of the impact of climatic stress on the livelihoods of rural households. Yet, several features of our estimation model provide strong evidence of the robustness of the identified relationships.

First, the climatic stress indicators are not based on self-reported household weather information but are constructed from an external and independent data source. Hence, our explanatory variables are strictly exogenous to the outcomes measured. Further, there is no risk of reverse causality, as the individual farming household is unable to influence the weather and climate to a significant degree. Second, we use a wide range of covariates to reduce the risk of omitted variable bias. While climate stressors are exogenous to the incomes and agricultural production of farmers, weather events might correlate with other ecological and socioeconomic features that affect the household income, agricultural productivity and labour and farming decisions.

One essential concern for bias is the self-selection of households into climatically more stable areas (Cai *et al.*, 2016; Marchiori, Maystadt and Schumacher, 2012; McLeman and Hunter, 2010). Wealthier households and those with better off-farm labour opportunities are able to migrate out of regions facing severe climate stress. This behaviour creates a positive relationship between vulnerability and climate stressors, even when a direct impact of climate stressors on incomes and other livelihood-related outcomes is absent. Unfortunately, the RuLIS dataset does not provide sufficient information on migration to control for this effect in our estimation model. Yet, the inclusion of the stand-alone wealth-subgroup indicator *Wi* in all our regressions captures differences in household wealth levels proxied by education, dwelling characteristics, access to water, electricity, sanitation, means of communication and asset ownership, and therefore eliminates wealth-related sources of bias. Furthermore, we control for household size and age of the household head as proxies of socioeconomic status.

Another factor affecting both the exposure to climate stressors and the sensitivity and adaptation behaviour of households is the geographical location. Certain areas have historically been harder hit by heavy precipitation, temperature peaks and droughts than others, given their orographic and environmental characteristics. Such long-standing climate disadvantages affect the capacities of rural families to generate income and are associated with exposure to more recent extreme weather events (Angelsen and Dokken, 2018; IPCC, 2019, 2022c; Thornton *et al.*, 2009). To disentangle the impact of historic climatic conditions from those induced by more recent weather and climatic changes, we control for the mean values and the coefficients of variation of temperature and precipitation, and the Koeppen–Geiger climatic zones, measured at the smallest administrative level possible in all our regressions. Moreover, the thresholds for extreme weather events are tailored to specific locations to account for local climatic heterogeneity and for the fact that human systems have adapted over time to local climates.

Other structural differences across the sample are captured by the cluster-level variables: night-time light, population density and global urban–rural catchment areas (URCA). These variables are included to control for the role of economic infrastructure and proximity to urban markets in mediating the effects of climate stressors on well-being.

Notwithstanding these features of our model, potentially important unobservable or unmeasured factors that might bias our findings remain. Access to weather forecast information and information on new, weather-adapted farming methods requires infrastructure and technology. While we do account for population density and remoteness in our geospatial controls, we are not able to capture household-level access to and use of information from mass media or extension services.

In addition, the impact of climate stressors on the value of harvested crops materializes through two distinct channels: changes in output quantity and changes in prices. A significant reduction of agricultural output in case of a weather shock can be expected to increase the market price, which positively affects the income of net sellers but puts substantial constraints on the purchasing power of net buyers. However, we are not able to disentangle this price effect from the effect of changes in output quantity when estimating the climate impact on crop value and on-farm income. As a consequence, the results for these variables (and to some degree also the result of total income) need to be interpreted with caution.

Sources:

Angelsen, A. & Dokken, T. 2018. Climate exposure, vulnerability and environmental reliance: a cross-section analysis of structural and stochastic poverty. *Environment and Development Economics*, 23(3): 257–278.

Cai, R., Feng, S., Oppenheimer, M. & Pytlikova, M. 2016. Climate variability and international migration. The importance of the agricultural linkage. *Journal of Environmental Economics and Management*, 79(C): 135–151.

IPCC. 2019. *Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for policymakers*. Geneva, Switzerland. https://www.ipcc.ch/site/assets/uploads/sites/4/2022/11/SRCCL_SPM.pdf

IPCC. 2022c. Impacts of 1.5°C global warming on natural and human systems. In: IPCC. *Global warming of 1.5°C. IPCC special report on impacts of global warming of 1.5°c above pre-industrial levels in context of strengthening response to climate change, sustainable development, and efforts to eradicate poverty*, pp. 175–312. Cambridge, UK and New York, USA, Cambridge University Press.

Marchiori, L., Maystadt, J.-F. & Schumacher, I. 2012. The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management*, 63(3): 355–374.

McLeman, R.A. & Hunter, L.M. 2010. Migration in the context of vulnerability and adaptation to climate change: insights from analogues. *WIREs Climate Change*, 1(3): 450–461. https://doi.org/10.1002/wcc.51

Thornton, P.K., van de Steeg, J., Notenbaert, A. & Herrero, M. 2009. The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. *Agricultural Systems*, 101(3): 113–127. https://doi.org/10.1016/j.agsy.2009.05.002

The Tadic family managed to rebuild their greenhouse after a flood thanks to emergency aid. Floods destroy crops and undermine future productivity by damaging productive infrastructure, leaching key nutrients and reducing water quality.

10. Exploring the context: a descriptive analysis of the data

This section provides descriptive evidence on the different climate stressors and how these vary across the countries included in the study, as well as on some of the key socioeconomic differences observed in the data between the wealth, gender and age groups. These data enable the reader to contextualize the empirical findings presented in Part I and understand the different sources of vulnerability and constraints to adaptation the groups face.

Mapping exposure to climate stressors

The countries included in this study differ greatly in terms of their exposure to different types of extreme weather events and of the pace at which temperatures have been rising over time (our proxy for climate change). Based on our definition of floods, **Figure 24** shows that the observed range of flooding days between 2010 and 2019 varied between zero and 257 days. Much of sub-Saharan Africa experienced more than 79 days of extreme precipitation, with the highest values observed in areas of Cameroon, Nigeria, Rwanda, the United Republic of Tanzania and Uganda. Moreover, large parts of the two South American countries in the sample, Peru and Ecuador, experienced more than 90 days of floods over the 10-year period. These two countries exhibited the most significant within-country variations in precipitation: their coastal areas were barely affected by floods, while the number of extreme precipitation days steadily increased inland.[29] Lastly, Viet Nam, as the sole representative country in southeast Asia, is found in the highest category, with 154 to 257 days of extreme precipitation.

Extreme heat days is equally variable across countries. **Figure 25** shows that the number of days of extreme heat between 2010 and 2019 ranges from zero to 217 days. The regions with the highest exposure to extreme heat are in the sub-Saharan countries of western Africa, in Ethiopia, and in central and south Asia. The highest within-country variation was recorded in India. Meanwhile, south America and large parts of central and southern Africa experienced relatively few extremely hot days.

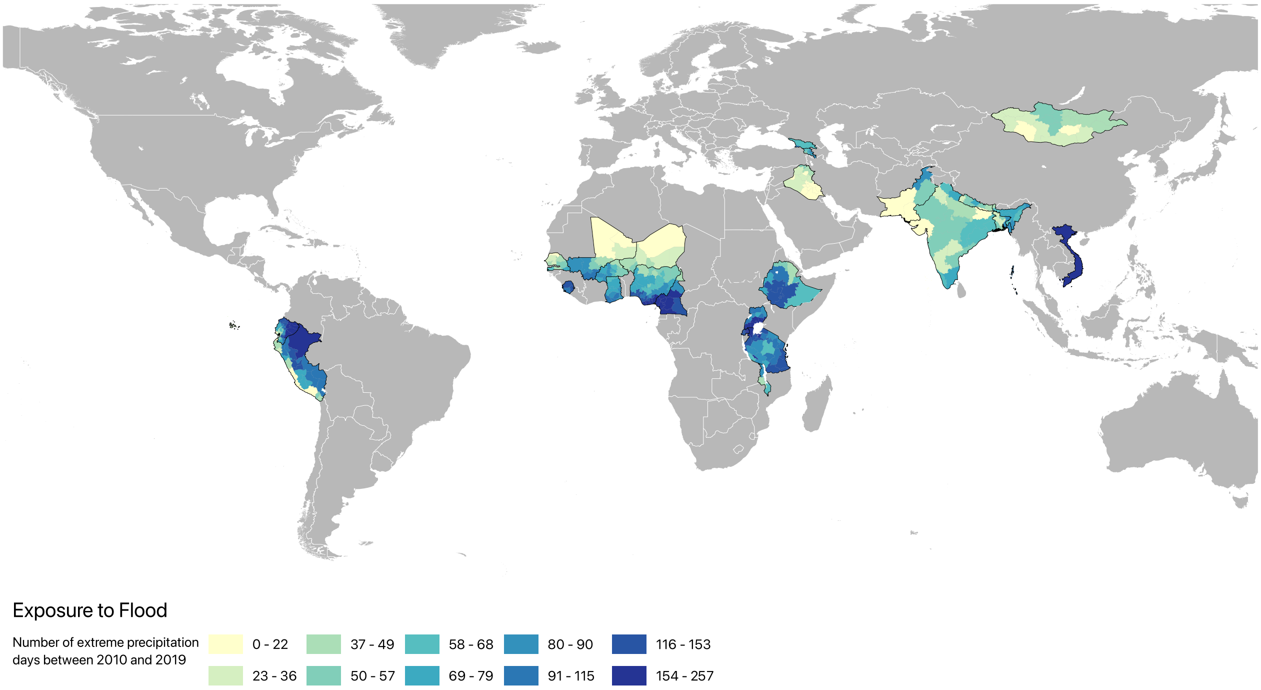
Exposure to droughts exhibits the highest degree of variability among the three measures of extreme weather used in this report, with values ranging from zero to 934 days over a ten-year period (see **Figure 26**). The regions that are most exposed to droughts are western Africa, as well as central and southern Asia (mainly Mongolia and India), where the cumulative duration of consecutive dry days between 2010 and 2019 exceeded 111 days. Burkina Faso, Mongolia, Nigeria and Peru experienced the highest within-country variation.

Figure 27 shows the distribution of long-term temperature change, which is used as a proxy for climate change in this report. Changes in temperature in the countries included in this report vary from a decrease of 0.325 °C to an increase of 1.962 °C since 1950. The largest temperature increases were recorded in western Africa, parts of eastern Africa, Iraq and Mongolia. Interestingly, most of these regions were also severely affected by droughts, while there is no evident correlation with exposure to heat waves.

[29] For some countries, weather data were available only at the national level. Therefore, it is possible that within-country variation was high in other countries as well, even though this is not depicted on the map.

FIGURE 24

Exposure to floods (number of extreme precipitation days between 2010 and 2019)



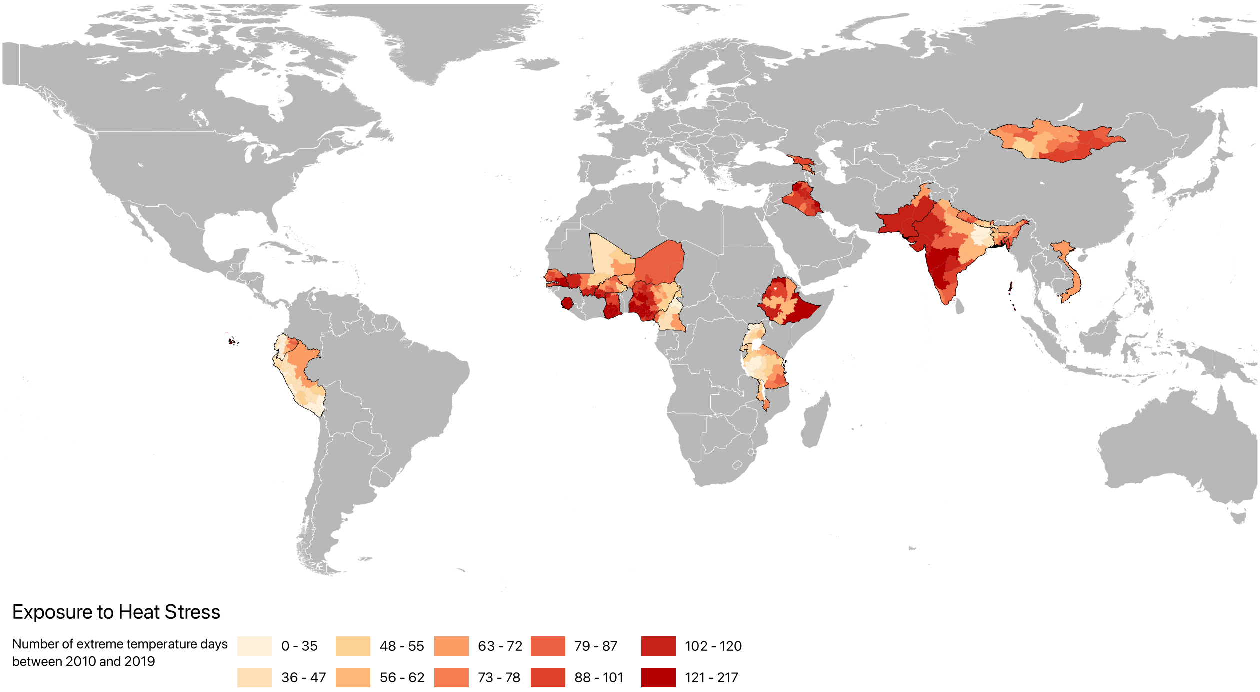
Notes:

- Extreme precipitation days are defined as days with an amount of precipitation above the 95th percentile of the wet days precipitation distribution. The number of heavy precipitation days is calculated over ten years, from 2010 to 2019.
- Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Source: Author's own elaboration based on can you replace the highlight part by: Author's own elaboration based on **Cucchi, M., Weedon, G.P., Amici, A., Bellouin, N., Lange, S., Müller Schmied, H., Hersbach, H. & Buontempo, C**. 2020. WFDE5: bias-adjusted ERA5 reanalysis data for impact studies. *Earth System Science Data*, 12(3): 2097–2120. https://doi.org/10.48364/ISIMIP.342217 **United Nations Geospatial**. 2020. Map geodata UNmap0_shp. New York, USA, United Nations.

FIGURE 25

Exposure to heat stress (number of extreme temperature days between 2010 and 2019)



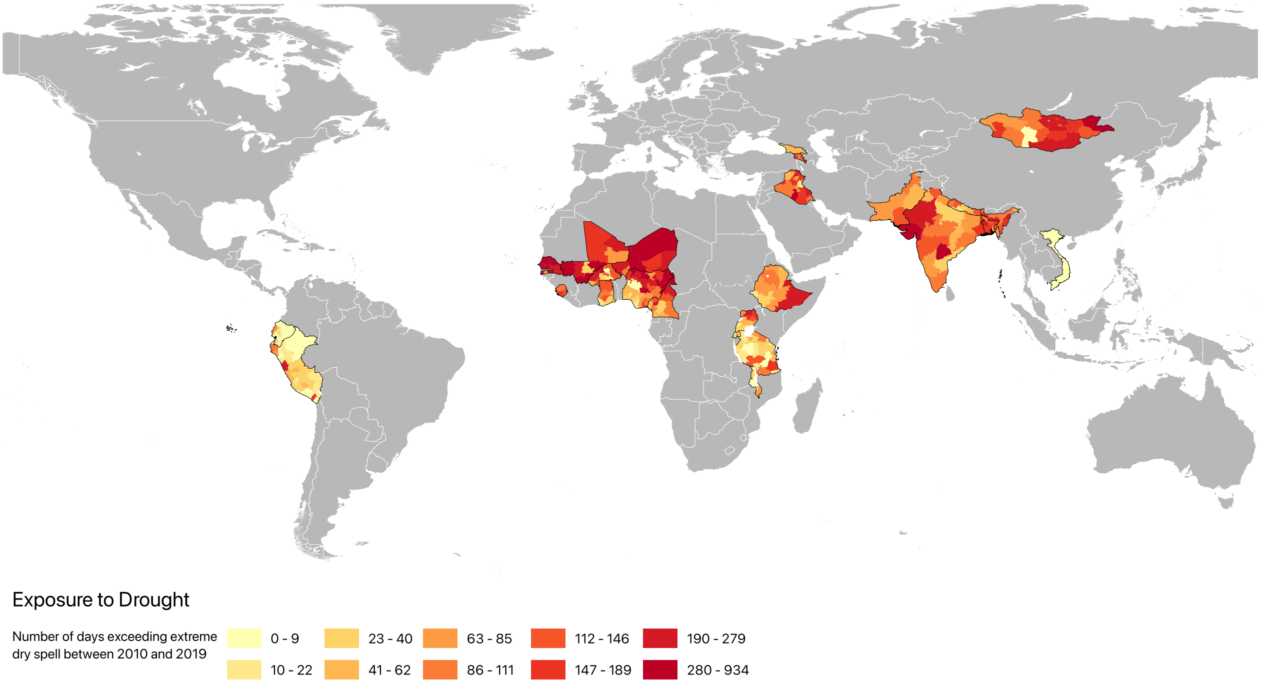
Notes:

- Extreme temperature days are defined as days with maximum temperature above the 99th percentile of the maximum temperature distribution. The number of hot days is calculated over ten years, from 2010 to 2019.
- Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Source: Author's own elaboration based on **Cucchi, M., Weedon, G.P., Amici, A., Bellouin, N., Lange, S., Müller Schmied, H., Hersbach, H. & Buontempo, C**. 2020. WFDE5: bias-adjusted ERA5 reanalysis data for impact studies. *Earth System Science Data*, 12(3): 2097–2120. https://doi.org/10.48364/ISIMIP.342217 **United Nations Geospatial.** 2020. Map geodata UNmap0_shp. New York, USA, United Nations.

FIGURE 26

Exposure to drought (number of days exceeding an extreme dry spell between 2010 and 2019)



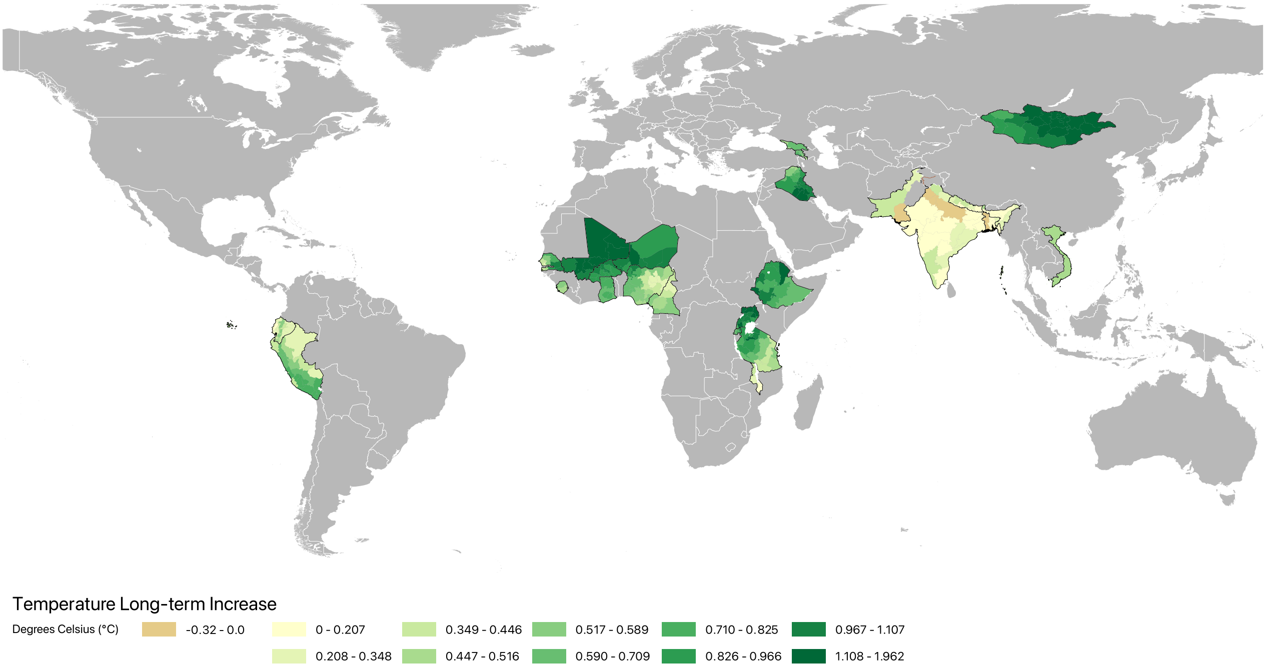
Notes:

- Extreme dry spells are defined as consecutive dry days exceeding the 95th percentile of the dry spell length distribution. The number of days is computed over ten years, from 2010 to 2019.
- The final boundary between the Sudan and South Sudan has not yet been determined. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Source: Author's own elaboration based on **Cucchi, M., Weedon, G.P., Amici, A., Bellouin, N., Lange, S., Müller Schmied, H., Hersbach, H. & Buontempo, C**. 2020. WFDE5: bias-adjusted ERA5 reanalysis data for impact studies. *Earth System Science Data*, 12(3): 2097–2120. https://doi.org/10.48364/ISIMIP.342217 **United Nations Geospatial.** 2020. Map geodata UNmap0_shp. New York, USA, United Nations.

FIGURE 27

Long-term temperature increase (°C)



Notes:

- The increse in annual temperature is the difference of the average temperature in two different time window. The first window ranges from 1951 to 1980 and the second from 1991 to 2020.
- Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Source: Author's own elaboration based on **Muñoz-Sabater, J., Dutra, E., Agustí-Panareda, A., Albergel, C., Arduini, G., Balsamo, G., Boussetta, S. *et al.*** 2021. ERA5-Land: a state-of-the-art global reanalysis dataset for land applications. *Earth System Science Data*, 13(9): 4349–4383. DOI:10.24381/cds.e2161bac **United Nations Geospatial.** 2020. Map geodata UNmap0_shp. New York, USA, United Nations.

Socioeconomic characteristics and differences based on wealth, gender and age

Climate vulnerability and adaptive capacities are influenced by the socioeconomic resources available to a person or household, as well as by their level of exposure to different climate stressors. In the sections below, we examine variations in key socioeconomic factors and in exposure to climate events, based on differences in wealth, gender and age. This contextual understanding is crucial to identify and target potential sources of climate vulnerability for different population groups. The full descriptive analysis is found in Annex 5.

Socioeconomic differences between poor and non-poor rural people

A number of key socioeconomic differences between poor and non-poor households make poor households considerably more sensitive to climate change and less able to adapt than non-poor rural households. On average, poor rural households have older heads, are more likely to be female-headed, have less formal education, cultivate less land and spend less per hectare under cultivation than non-poor households.

Despite owning less land and investing less in agriculture, poor households derive a significantly larger share of their total income from agriculture than non-poor households. This heavy reliance on agriculture for their livelihoods is an important source of their vulnerability. Adaptation investments in agriculture to reduce the climate vulnerability of the rural poor are therefore of crucial importance.

The data also show that poor households are less likely to access extension services, own agricultural machinery or have documented ownership of their land, which all act as important barriers to the adoption of climate-adaptive agricultural practices. Indeed, this constraint is reflected in the data, which show that poor households are significantly less likely than non-poor households to adopt most of the adaptive practices considered in this report.

Our data show that poor households earn significantly less income from off-farm sources than non-poor households. This reflects the challenges they face in terms of accessing such income sources, as well the low wages they earn. The data on labour allocations confirm that poor households are less likely to have employed household members and that they dedicate more of their labour time to own-farm activities.

At the same time, poor households are more likely to access social protection programmes and own slightly more livestock units. These are likely to be important mechanisms that poor households use to cope with the adverse effects of climate change on their well-being.

In terms of exposure to extreme weather events, there are small but statically significant differences between poor and non-poor households in terms of drought, heat stress and flood exposure, as well as long-term temperature rises.

BOX 13

Agricultural profile of poor households, as compared to that of non-poor households

Constraints to adaptive capacity:
- lower levels of education;
- fewer household members;
- less cultivated land;
- less investments in agriculture;
- highly dependent on agriculture, with limited access to off-farm income sources;
- less access to extension services;
- less documented ownership of plots;
- less likely to own agricultural machinery;

Enhancers of adaptive capacity:
- more livestock;
- more social protection;

Exposure to climate stressors:
- less exposed to floods, heat stress and droughts; and
- more exposed to temperature rises.

Socioeconomic differences between male- and female-headed households

Similarly to poor households, female-headed households have, on average, older heads, lower levels of education and fewer household members; in addition, they cultivate less land and invest less in agricultural activities than male-headed households. They also own significantly fewer livestock units than male-headed households. The lack of productive resources and human capital acts as a significant barrier to climate adaptation and economic inclusion for these households.

These constraints are reflected in differences in the adoption of climate-adaptive agricultural practices. The data show that plots managed by women are less likely to be irrigated or receive soil amendments, such as organic fertilizers. Female farmers are also less likely to have formal documentation for their land and to own agricultural machinery, suggesting that they are more dependent on manual labour for agricultural production.

As a result of these numerous constraints, female-headed households tend to earn significantly less than male-headed households from agricultural sources and to generate less total crop value. For this reason, they have a lower total household income than male-headed households.

The per adult equivalent amount earned by female-headed households from off-farm income sources is similar to that for male-headed households. This result is likely tied to female employment in the agrifood system, which is a major employer of women and constitutes a more important source of livelihood for women than for men (FAO, 2023a). However, employment in the agrifood system tends to be highly sensitive to climate variability. Off-farm income is therefore a potential source of vulnerability for female-headed households – although it also offers opportunities to strengthen their climate resilience.

Looking at gender-specific labour allocations, the data show that women are less likely to be employed and tend to work fewer hours than men. This suggests that despite the importance of off-farm employment in the incomes of female-headed households, their access to such employment is more constrained than that of men, and their work tends to be more informal and sporadic.

As far as exposure to climate stressors is concerned, the data show that female-headed households are more likely than male-headed households to reside in areas where temperatures are rising quickly and where floods occur frequently. This is likely due to the fact that increased exposure to climate stressors is a driver of male outmigration, leaving more women behind as household heads in these areas. Female-headed household are marginally less likely than male-headed households to reside in areas that have been exposed to droughts and heat stress.

Interestingly, the data reflect the progress that is being made in extending agricultural extension services to female farmers: on average, households with agricultural plots managed by women are more likely to receive extension advice than households with only male plot managers. They are also more likely to access social protection programmes.

BOX 14

Agricultural profile of female-headed headed households, as compared to that of male-headed households

Constraints to adaptive capacity:
- lower levels of education;
- fewer household members;
- less cultivated land and fewer livestock;
- less investments in agriculture;
- fewer plots with documented ownership;
- less likely to own agricultural machinery;

Enhancers of adaptive capacity:
- more social protection;
- more access to extension services;

Exposure to climate stressors:
- more exposed to floods and temperature rises;
- less exposed to droughts and heat stress.

Socioeconomic differences between young and older households

Young households face many of the same challenges as poor and female-headed households in terms of access to productive resources. They are, on average, less educated, have fewer household members, cultivate less land, invest less in agriculture and own fewer livestock units than households headed by an older person. They are also less likely to access social protection programmes, have titles to their land or own agricultural machinery. These factors are important contributors to the climate vulnerability of young households.

At the level of agricultural plots, the data show that young farmers are more likely than older farmers to adopt labour-intensive adaptive practices, such as using soil and water conservation structures, but also to have less diverse cropping systems and use less organic fertilizer.

BOX 15

Agricultural profile of young households, as compared to that of prime-aged households

Constraints to adaptive capacity:
- lower levels of education;
- fewer household members;
- less cultivated land and fewer livestock;
- less investments in agriculture;
- less social protection;
- less likely to have documented ownership of plots;
- less likely to own agricultural machinery;

Enhancers of adaptive capacity:
- higher share of income from off-farm activities;
- more access to extension services;

Exposure to climate stressors:
- more exposed to floods and temperature rises;
- less exposed to droughts.

Importantly, the data also show that young households have, on average, less diverse income portfolios than older households. This difference could be linked to the fact that off-farm income makes up a greater share of young households' total income than of that of older households. This is confirmed in labour statistics, which show that young people dedicate a relatively higher share of their labour hours to work off their farms. As has been shown in the section on empirical results in Part I, young households are able to shift towards off-farm income sources when exposed to climate stressors and thus reduce their total income losses more than older households.

Despite their ability to access off-farm employment, young households tend to earn less income per capita from both farm and off-farm sources than older households.

Working children

The descriptive evidence reveals that 41 percent of the children in the sample worked at least one hour in the week preceding the interview. Of those who work, 91 percent are employed on their households' farms. Their average weekly working time amounts to about 15.5 hours, or more than 50 percent of the average weekly working time of prime-aged adults. This finding points to a violation of the ILO regulations for child labour, which stipulate that children aged 12 to 14 can perform light work for a maximum of 14 hours per week, while children under 12 should not be working at all.

When comparing households with working children to households without working children, we observe several differences that are indicative of increased levels of vulnerability. Most importantly, 25 percent of the households with working children are classified as poor, compared to only 16 percent of the households without working children. Households with working children are also significantly larger and have lower average levels of education. Moreover, these households' livelihoods are more reliant on farm work, as indicated by a larger share of members, and particularly women, working on the household farm.

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Glossary

Adaptation: the process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities.

Agricultural expenditure: the sum of a households' expenditures related to crop production over the past 12 months. This includes total expenses on chemicals, seeds (including improved seeds), inorganic fertilizers and labour inputs. Note that this variable is only defined for crop-producing households.

Children's work: all labour activities carried out by children aged 10 to 14 years, either on or off the household's own farm, regardless of the nature of this work or its repercussions on children's wellbeing and development.

Climate change: climate change refers to an alteration of long-run climatic conditions and it is usually associated with an increase in the frequency of extreme events.

Climate stressors: the term climate stressors summarizes extreme weather events and climate change. Short-term climate stressors are rapid-onset extreme weather events, e.g. floods, heat waves and droughts, while long-term climate stressors are slow-onset climatic changes, e.g. rising average temperatures.

Climate vulnerability: the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2022a).

Coping capacity: the ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short to medium term (IPCC, 2022a).

Crop diversification: crop diversification is the cultivation of a larger variety of crops and is measured using the Gini-Simpson Index (GSI). The GSI is constructed as follows:

$$GSI_i = 1 - \sum_{c=1}^{n} \alpha_c^2$$

where *i* denotes the household, α_c is the share of total crop-plot area that is cultivated with crop c. The index ranges from 0 to 1. It takes the value of 0 if only one crop is cultivated across all plots. The higher the GSI, the higher the level of crop diversification.

Crop value: the total value of crop production within the household over the past 12 months, calculated based on harvested crop quantities and corresponding prices. The prices are obtained by taking the median of all crop-specific prices reported by the households at the lowest sampling level possible. Those parts of the harvest that are used as seeds, animal food, lost post-harvest or given away for free are subtracted from the total quantity. Crop value is only calculated for crop-producing households, and not for households who focus entirely on fisheries, forestry or livestock production.

Deep dive: additional analysis on a smaller subset of countries for which data at the individual and plot level are available.

Drought: a drought is a period of abnormally dry weather long enough to cause a serious hydrological imbalance and water shortage for the human population and the ecosystems.

Exposure: exposure refers to the type, frequency and intensity of climate variations, or climate stressors, that a person is affected by.

Extreme weather: the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable.

Female-headed household: female-headed households are households where either no adult men are present, or where men are present but do not contribute to the household income (because of an incapacity such as illness, disability, old age or alcoholism, but not because of unemployment).

(Female) plot manager: an agricultural plot is an area of land with particular land use characteristics. The plot manager is the person who is mainly responsible for taking decisions regarding the use of the plot. A female-managed plot is a plot that is managed by female household members alone. A jointly managed plot is a plot that is managed by female and male household members together.

Flood: a flood is the overabundance of water on river streams or water bodies, or over areas that are not regularly inundated.

Heat stress: heat stress is a range of conditions in terrestrial organisms when the body absorbs excess heat during overexposure to high air temperatures or thermal radiation.

Household headed by a youth: a household whose head is 34 years old or less; prime-aged households are those headed by people who are 35 to 64 years old.[30]

Income concentration: income concentration is the reliance on a smaller variety of income sources and is measured using the Herfindahl-Hirschman Index (HHI). The HHI, typically employed to evaluate market concentration, is calculated as follows:

$$HHI_i = \sum_{j=1}^{n} s_j^2$$

where HHI_i represents the Herfindahl-Hirschman index of household *I*, and s_j is the share of a given income from activity *j* in the household's total income. The Herfindahl-Hirschman Index (HHI) for income is determined by adding together the squares of the proportions of income derived from crop-related activities, income from livestock, other forms of income from agriculture, earnings from agricultural labour, earnings from non-agricultural employment, income from self-employment, transfers and any additional sources of income. The index takes a value between 0 and 1. The closer HHI_i is to 0, the more diversified the household income is.

Intergovernmental Panel on Climate Change (IPCC): the United Nations body that assesses science related to climate change.

Labour force participation: indicates whether an individual worked at least one hour in the past seven days.

National adaptation plan (NAP): NAPs identify medium- and long-term adaptation needs, informed by the latest climate science. Once major vulnerabilities to climate change have been identified, the NAP process develops strategies to address them.

Nationally determined contributions (NDC): NDCs embody efforts by countries to reduce their emissions and adapt to the impacts of climate change.

Off-farm income: total household income derived from activities other than the household farm, livestock or fishery activities during the past 12 months. It includes agricultural and non-agricultural wage employment, self-employment, public and private transfers, as well as income from financial and real estate assets.

On-farm income: total net household income derived from a household's own farming activities, such as crop cultivation, livestock rearing, forestry activities and fisheries over the past 12 months. Costs for inputs, labour, land and machinery rental are subtracted.

Poor household: a household belonging to the bottom 25 percentile of a multidimensional wealth index.

[30] We extended the standard International Labour Organization (ILO) age category of "youth" to include young adults too, in view of the limited number of households with heads below the age of 25.

Rural Livelihoods Information System (RuLIS): RuLIS is the result of a collaboration between the Food and Agriculture Organization of the United Nations, the World Bank and the International Fund for Agricultural Development, aimed at facilitating access to cross-country harmonized and comparable data and information on the incomes and livelihoods of rural people, as well as their evolution at the subnational level. In total, RuLIS provides information on 116 ready-made indicators computed from 81 household-level surveys from 44 countries around the world.

Sensitivity: sensitivity denotes the degree to which a person is susceptible to harm due to exposure to climate stressors.

Share of labour hours on farm activities: share of the total weekly labour hours that are dedicated to work on a household's farm.

Social protection: social protection comprises a set of policies and programmes that addresses economic, environmental and social vulnerabilities to food insecurity and poverty by protecting and promoting livelihoods (FAO, 2017).

Total weekly labour hours: sum of the weekly hours worked in main and secondary jobs.

Tropical livestock unit (TLU): the total number of livestock; one TLU corresponds to 250 kg of live weight.

BANGLADESH – Woman prepares for a possible disaster as severe floodings were forecast in the region. In Bangladesh, floods have inflicted a multifaceted impact on vulnerable communities, affecting health, hygiene, livestock, and food security.

ISBN 978-92-5-138590-6

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CC9680EN/1/03.24