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Severity of climate change and deprivation outcomes: Micro-level assessment for sub-Saharan Africa

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ABSTRACT

Poverty has been recognized as a key socioeconomic developmental issue that exacerbates peoples' vulnerability to climate change. Given that sub-Saharan Africa (SSA) has been characterized as the region with the highest poverty levels over the years, people living in the region are more susceptible to the adverse implications of climate change relative to other world regions. Based on a micro-level dataset from 33 SSA countries, we examine how climate hazards (drought and flooding) affect various forms of deprivation (food, fuel, income, and water) to offer fresh insights into the poverty-impact of climate change. Using instrumental variable ordered probit and multilevel models, we show that the severity of drought and flooding significantly increase individuals' likelihood of experiencing the various forms of deprivation. However, water deprivation appears not to be a consequence of flooding. Considering locational heterogeneity, the severity of drought and flooding on deprivation outcomes is more deleterious for rural dwellers compared to their urban counterparts. By and large, we provide evidence to argue that the individuals' experiences of food, fuel, income, and water deprivation can be attributed to the incidence and severity of hazards induced by climate change.

1. Introduction

Sub-Saharan Africa (SSA) is developing rapidly and it is a region endowed with great ecological, climatic and cultural diversity (Serdeczny et al., 2017). However, SSA is still faced with many developmental challenges, and it is widely recognized as the least developed region in the world. For instance, since the 1980 s, SSA has been the region with the highest poverty levels from both unidimensional and multidimensional perspectives compared to other regions of the world. From a unidimensional perspective–an international poverty line of US $1.90 per day, more than half of the world's extremely poor lived in SSA in 2015 (World Bank, 2018). Further, SSA accounted for 60% of the global poor at the US $2.15 poverty line in 2019 (World Bank, 2022). Taking a multidimensional view, SSA still has the highest rates of multidimensional poverty with 53–58% of its populace classified as multidimensionally poor (Oxford Poverty and Human Development Initiative, 2018; Tewolde and Weldeyohannes, 2018), and these estimates are associated with the pre-COVID-19 era. Given that the COVID-19 pandemic has created multi-layered vulnerabilities to poverty, SSA's progress toward achieving SDGs will drawback by five extra years (Montes et al., 2020).

The Intergovernmental Panel on Climate Change (IPCC) has identified climate change as the prominent cause of poverty in SSA (IPCC, 2015, 2022). Climate change extremely affects poorer countries, and poorer individuals living in these countries (Jafino et al., 2020).[2] IPCC (2015), from a poverty stance, contends that climate change is expected to limit the effectiveness of poverty alleviation strategies, foster food insecurity, and protract present and create new poverty traps in most developing countries. Jafino et al. (2020) argue that, under low and high climate change scenarios, it is respectively predicted that 14.2 million and 39.7 million people in SSA would face extreme poverty by 2030 if climate change mitigation actions are not taken seriously. Thus, it is of utmost importance that climate change mitigation is pursued aggressively to reduce existing and future levels of poverty in SSA.

Climate change is largely driven by greenhouse gas (GHG) emissions, and SSA's contribution to global GHG emissions is little. Over the years,

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[2] SSA is the world's poorest region, with majority of its countries identified as low-income countries.

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the region's contribution to the global GHG emissions is usually less than 5% annually.[3] This suggests that the role of SSA in driving climate change may be inconsequential compared to other world regions. Despite this, the vulnerability of the region to climate change and its consequences is high. Of grave concern is that many countries in SSA are highly vulnerable to climate change (Edmonds et al., 2020; Feindouno et al., 2020), due to the prevalence of poverty (Hope, 2009; Jafino et al., 2020).[4] Poverty is generally considered as a factor that increases the vulnerability of people and households to climate change (Leichenko and Silva, 2014; Castells-Quintana et al., 2018). Sinha et al. (2022) argues that the vulnerability to climate change tends to be higher among households facing higher multidimensional poverty. The foregoing suggests that poor people are more susceptible to climate change and given that SSA is the world's poorest region, the overarching questions are: What are the consequences if individuals in this region become exposed to climate change? Does the severity of climate change matter in deprivation outcomes? We offer answers to these questions empirically.

The severity of climate change has become alarming. According to estimates (see United Nations, 2021; Arias, et al., 2021), between 2017 and 2021, for example, the world recorded one of its highest average surface temperatures of 1.06 °C–1.26 °C. Further, it is expected that, by 2100, the globe would become 1.1–5.4 °C warmer than now (Herring, 2012). As the globe becomes warmer, the frequency of climate hazards or extreme weather events (such as heat waves, wildfires, droughts, and flooding) tends to increase. The negative impacts are expected to be widespread and severe between 1.5 °C and 2 °C of global warming above pre-industrial era levels, among which include increased inequality and poverty (IPCC, 2022). Human life and activities are already negatively impacted by climate change and these negative impacts are more pronounced in SSA (Surminski et al., 2022). Unfortunately, virtually all SSA countries lack adequate capacity and resources to deal with these potential negative impacts. Baarsch et al. (2020) note that many African countries have recorded substantial losses from climate-related disasters, thereby weakening their ability to achieve sustainable development. The aforesaid motivated this paper.

We make a contribution to the climate change-poverty literature with particular reference to SSA. This paper is of much relevance to SSA for two reasons. First, Adenle et al. (2017) project that Africa would face adverse consequences from climate change. Also, climate change is expected to make more people poor between now and 2100, and most of its severe impacts are expected to be felt more in both urban and rural communities in SSA (IPCC, 2022). Second, in addition to hosting more than half of the world's poor, SSA is experiencing rising levels of income inequality due to population growth and increasing rates of unemployment (Gimba et al., 2021). IPCC (2015, p.796) notes that "climate change will create new poverty pockets in countries with increasing inequality". An interesting and recent study by Azzarri, Signorelli (2020) argues that climate change aggravates poverty in SSA. In this study, we take a novel perspective to understanding the climate change–poverty relationship in SSA by conducting a micro-level econometric assessment of how climate change affects various forms of deprivations (food, fuel, income, and water deprivations) that lead to poverty. This assessment allows us to offer insights into whether and how climate change potentially causes deprivations among individuals in SSA.

Employing instrumental variable ordered probit and multilevel models, we find that the severity of climate change heightens deprivation outcomes (food, fuel, income, and water). In terms of food deprivation, we find that for individuals that have experienced much more severe drought in the areas where they live, their probable risk of experiencing food deprivation once/twice, many times and always increases by 0.6% point, 6.8% points, and 0.8% point, respectively compared to those that faced much less severe drought. Similarly, for flooding, those that have experienced much more severe flooding, their probability of experiencing food deprivation once/twice, many times and always goes up by 0.5% point, 3.0% points, and 0.4% point respectively, relative to their counterparts that have faced much less severe flooding. Regarding fuel deprivation, we find that for individuals that have experienced much more severe droughts in their areas, their likelihood of suffering fuel deprivation rise by 0.9–4.5% points compared to those that have faced much less severe drought. In the same vein, fuel deprivation increases by 0.7–2.7% points for those that have faced much more severe flooding compared to their counterparts who experienced much less severe flooding. In terms of income deprivation, we find that people that have experienced much more severe droughts and flooding, their probable risk of being income deprived increases by 2.0–3.4% points for drought and 2.0–2.4% points for flooding. Finally, we observe that the propensity to experience water deprivation increases by 0.7–6.9% points for individuals that have faced much more severe droughts compared to individuals that have experience much less severe drought. Interestingly, we find that flooding does not lead to water deprivation among individuals.

The rest of this paper is set as follows. The next section presents the literature review and develops hypotheses. Section 3 discusses the methodology. Section 4 discusses the empirical results. In the last section, we provide the conclusion and offer policy implications.

2. Literature review and hypotheses development

2.1. Climate change and food deprivation

Many people across the world experience food insecurity on a daily basis (Webb et al., 2006). According to the American Society for Nutritional Sciences, "food insecurity exists whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain". Drawing from this definition, the propensity of people to become food deprived rises in the face of food insecurity. People experience food deprivation not because of the unavailability of safe and nutritional foods in the market but due to constraints to accessing these foods (Sen, 1981). Thus, food deprivation is the lack of accessibility to safe and nutritional foods to promote a good dietary lifestyle and enjoy a healthy life. Hunger, undernutrition, and malnutrition are potential but not necessary outcomes of food deprivation (Hendriks, 2015).

The 2015 United Nations (UN) Sustainable Development Goal 2 (SDG2–Zero Hunger) emphasizes the need to tackle food deprivation by curbing hunger and increasing access to safe and nutritious food as part of efforts to be taken by countries to achieve sustainable development by 2030. However, the Food and Agriculture Organization (FAO) has raised concerns that climate change would weaken the fight against food deprivation (FAO, 2015). FAO warns that climate change has the tendency to exacerbate food deprivation outcomes (FAO, 2022). The IPCC Fourth Assessment Report suggests that people lack access to food as a result of the hazards induced by climate change which adversely affect crop production and livestock farming (IPCC, 2007).

Under the IPCC Special Report on Emissions Scenario (SRES) A1B scenario, it is projected that climate change would increase the number of people in the world vulnerable to food deprivation–undernourishment prevalence– by an additional 1.7 billion, 1.3 billion and 1.1 billion in the year 2050, 2085 and 2100, respectively (Dawson et al., 2016). Baldos and Hertel (2014) predict that more than 500 million people would avoid chronic hunger by 2050 because of improvements in agricultural productivity; however, climate change puts this prediction in doubt. The hazards caused by climate change result in a fall in agricultural productivity, loss of food in the supply chains, weak resilience

[3] Statistic based on computation by authors from WDI, relying on data from 1990 to 2019.

[4] The poorer the country, the more vulnerable it is to climate change (IPCC, 2022).

of the poor in rural areas and undernourishment prevalence and child malnutrition (Esham et al., 2018). The access of households to food tends to be hindered by climate hazards (Randell et al., 2021). Bandara and Cai (2014) argue that climate change limits food productivity and causes prices of food to increase. Further, Kahsay and Hansen (2016) observe that variations in climate change significantly influence agricultural productivity in Eastern Africa. Gentle and Maraseni (2012) argue that the ability of communities to support themselves has been severely hampered by climate change, which has led to food shortages, a lack of essential services, and a rise in social inequality. We therefore hypothesize that:

H_1: Severity of climate change (drought and flooding) causes food deprivation.

2.2. Climate change and fuel deprivation

Fuel is regarded as a critical source of energy for people in rural and urban communities. However, people living in rural communities tend to experience higher fuel deprivation compared to those in the urban communities (Adusah-Poku and Takeuchi, 2019; Karakara et al., 2021). Fuel deprivation exists when people lack access to clean and modern energy sources (such as electricity and liquefied petroleum gas) but rely on biomass fuel (such as firewood, animal dung, wood, and charcoal among others) for cooking and lighting. Fuel poverty is a severe case of deprivation in which households are unable to access fuel not only for heating and cooling but also for hot water, light and other essential household needs (Thomson and Snell, 2013). It is "a condition in which a household is unable to guarantee a certain level of consumption of domestic energy services (especially heating) or suffers disproportionate expenditure burdens to meet these needs" (IPCC, 2015, p.123).

Climate hazards have significant adverse implications for the extraction, both onshore and offshore, and refining of fuels such as petroleum, gas, oil, and biomass (IPCC, 2022). For instance, Schaeffer et al. (2012) argue that the availability of biomass fuels is affected by climate change. Heatwaves and droughts potentially limit the availability of biofuels (Moiseyev et al., 2011; IPCC, 2022). The global warming caused by climate change has made fuels to dry out (Running, 2006; IPCC, 2007). Climate hazards, especially heat waves, can cause damage to thermal power plants and their connected infrastructures such as pipes (Sieber, 2013), and this can affect the supply and access to electricity and may cause people to resort to biomass fuel to meet domestic energy needs. On the back of the aforementioned, we conjecture that:

H_2: Severity of climate change (drought and flooding) causes fuel deprivation.

2.3. Climate change and income deprivation

Income deprivation is a phenomenon which exists when a person is unable to generate earnings to enjoy a good quality of life. A person deprived of income is at the risk of not enjoying the basic needs of life (such as food, water, clothing, and shelter). The poor population are often and severely deprived of income because they have limited access to income to use to meet these basic needs.

The IPCC Fifth Assessment Report asserts that people, especially those living in rural communities, are at risk of losing their income and livelihoods due to climate change (IPCC, 2015). Pittman et al. (2011) argue that the livelihoods of rural dwellers are adversely impacted considerably by the incidence of climate hazards in the future. Rural communities are mostly agrarian in nature and their dwellers largely depend on subsistence agriculture as their source of livelihood. Rural dwellers in developing economies rely on crops, forest extraction, and other sources of income for their livelihoods; however, the income generated from these livelihoods is climate change-sensitive (Wunder et al., 2018). Rural dwellers struggle to deal with the hazards caused by climate change because of changing socio-economic and environmental conditions (Pittman et al., 2011); hence, they have limited or no ability to generate income from their source of livelihood. Rural communities are more likely to be vulnerable to climate change compared to urban centres owing to demographical, economic, and social factors (Lal et al., 2011; Dumenu and Obeng, 2016).

While climate change increases the number of people that would fall into the income poverty trap, it makes those already poor even poorer (Leichenko and Silva, 2014). It can make strategies designed to alleviate income poverty ineffective (Hallegatte, 2014; Hallegatte and Rozenberg, 2017). Agriculture is the mainstay for a significant number of people in developing countries and these countries are not well-equipped to adapt to changing climatic conditions (Seaman et al., 2014). Climate hazards limit agricultural productivity (Adams et al., 1990; Esham et al., 2018). Berhe et al. (2017) argue that loss of livestock and crop failure are the direct outcomes of climate change, and these outcomes threaten the income-generating ability of households. Thus, we formulate the hypothesis that:

H_3: Severity of climate change (drought and flooding) causes income deprivation.

2.4. Climate change and water deprivation

Water is the basis of human life. Therefore, there would be dire consequence if human life is deprived of water. Water deprivation is a situation whereby clean water is not available for use by people. The UN SDG6–Clean water and sanitation– targets ensuring the availability of clean water for all by 2030. However, climate change creates major uncertainties in the availability of clean water in the future especially in rural communities that are already challenged with water insecurity (Kisakye and Van der Bruggen, 2018). The IPCC Sixth Assessment Report highlights that climate change poses risk to water security–the availability of water of adequate quality and quantity for the benefits of people, and this risk is considered to be potentially severe because climate change could affect the hydrologic cycle in ways that would cause significant negative implications for livelihoods, property, health and culture of majority of the people (IPCC, 2022). Tandon (2007, p.4) argues that "climate change compounds the cost and complexity of ensuring water security…".

Climate change has been projected to increase water resources deficits (Denton, 2002). Naqvi et al. (2017) note that the total water resources available for consumption across the world is less than 1% and this level of availability would be lessened by climate change. Climate change leads to changes in the amount and spatial distribution of available water resources by speeding up the atmospheric circulation and the hydrological cycle and this would cause more climate hazards such as droughts and flooding (Jianyun et al., 2009). These hazards reduce the availability of clean water (IPCC, 2007). Climate change is predicted to reduce the average water availability in the future as well as increase the frequency of drought events (Sanders et al., 2010; Mushtaq et al., 2013). It also increases the duration and severity of droughts (Allen et al., 2015; Goodwin et al., 2021). Thus, we hypothesize that:

H_4: Severity of climate change (drought and flooding) causes water deprivation.

3. Methods

3.1. Data

We obtain data for this research from the Afrobarometer survey– a cross-sectional survey. This nationally representative survey was initiated in 1990 and it covers only countries in Africa. It has become a popular source for researchers to obtain micro-level data on Africa (Isaksson, 2015; Olabiyi, 2021). As at the time of conducting this research, seven waves of the Afrobarometer survey were available but we rely on only the survey from the latest wave– seventh wave (wave 7). The main reason for using only wave 7, which was conducted between 2016 and 2018, is that it contains rich information on individuals' lived experiences of the severity of climate hazards (drought and flooding) and various forms of deprivations (food, fuel, income, and water). The uniqueness of Wave 7 lies in its emphasis on the lived experiences of respondents on the severity of climate hazards and deprivations not on the individuals' perceptions which are reported in the previous waves. In this study, we are neither interested in people's perceptions of climate change nor their perceptions of deprivations. Rather, we seek to offer insights into whether and how experiences of hazards associated with climate change influence actual deprivations.

Wave 7 covers 34 countries in SSA which each country consisting of a sample of at least 1200 adult's respondents (18 years and above). We observe that in all the 34 countries, the questions on individuals' experiences of the severity of climate hazards (drought and flooding) in the areas where they live were solicited in the Afrobarometer survey with the exemption of Kenya; thus, we drop Kenya from the sample. After merging the data files of individual countries, we arrive at a sample size of 45,753 individuals across 33 SSA countries.

3.2. Measures of deprivation outcomes

Our dependent variable is deprivation outcome. In this study, four key deprivation outcomes have been considered namely food, fuel (considered as cooking fuel), income, and water deprivation. To ascertain the respondents' lived experiences of deprivations, they were quizzed how often (if ever) they have gone without basic necds of life in four key dimensions–food, fuel, income, and water– over the past 12 months preceding the survey period. Precisely, respondents were quizzed: how often (if ever) have you or anyone in your family gone without:

a. Enough food to eat
b. Enough fuel to cook your food
c. Cash income
d. Enough clean water for home use

For each of these four questions, there are five response categories– 'never', 'once/twice', 'several times', 'many times', and 'always'. For each question, we generated an ordinal response variable as follows: '0 =Never', '1 =once/twice', '2 =several/many times', and '3 =always'. We merged responses on 'several times' and 'many times' as 'many times' because these responses have similar meanings; hence, respondents may have selected either of the responses to indicate the same lived experience. Thus, each of our dependent variables (food deprivation, fuel deprivation, income deprivation and water deprivation) has four categories ranging from 0 to 3 where 0 stand for no deprivation and 3 reflects severe deprivation–extreme case of deprivation. Table 1 shows the distribution of respondents' lived experiences of various forms of deprivation. From Table 1, three key observations arose. First, about 46.85%, 37.27%, 78.77% and 48.67% of the people had experienced food, fuel, income, and water deprivation at varying degrees, respectively. Secondly, individuals that had faced income deprivation (78.77%) and water deprivation (48.67%) are higher compared to those that had faced food deprivation and fuel deprivation. Finally, across all four deprivation outcomes, those that had been deprived many times (29.53% for food, 21.5% for fuel, and 51.29% for water) are higher compared to those that had been deprived once/twice and always.

Table 1
Experiences of various forms of deprivation.

Deprivation outcome	Never deprived	Deprived once/twice	Deprived many times	Deprived Always	*N*
Food deprivation	53.15	14.69	29.53	2.63	45,753
Fuel deprivation	62.73	12.97	21.5	2.8	45,685
Income deprivation	21.23	13.69	51.29	13.79	45,678
Water deprivation	51.33	11.38	28.01	9.29	45,750

3.3. Measures of climate change

The key independent variable of interest is climate change. We capture climate change using two main climate hazards, namely drought and flooding. In various reports of the IPCC, climate hazards (also known as extreme weather events) such as drought, flooding and heat waves are often cited as key indicators of climate change. Heat waves is not considered in our study due to data constraints. Our micro-level dataset does not contain information on heat waves. The reason for this is not farfetched. Heatwaves rarely occur in Africa owing to the region's tropic climate. The macro-level datasets available on heat waves are limited and have serious spatial and temporal coverage concerns (Miller, Chua, Coggins, and Mohtadi, 2021). To assess climate change at the micro-level, respondents were asked about their lived experiences of the severity of climate hazards (drought and flooding) in areas where they live. The typical question asked in the survey was: *In your experience, over the past 10 years, has there been any change in the severity of the following events in the area where you live? Have they become more severe, less severe or stayed about the same?*

a. Drought
b. Flooding

For each of these two questions, the respondent must answer from six response categories as follows: 'much more severe', 'somewhat more severe', 'stayed the same', 'somewhat less severe' and 'much less severe' and 'don't know'. Thus, we excluded the 'don't know' group and recoded the remaining five responses as follows: '5 =much more severe', '4 =somewhat more severe', '3 =stayed the same', '2 =somewhat less severe' and '1 =much less severe'. After recoding, we derived ordinal data for drought and flooding ranked from 1 to 5 with 1 stand for much less severe drought/flooding and 5 reflects much more severe drought/flooding–extreme case of drought/flooding.

Fig. 1 shows the distribution of respondents' lived experiences of the severity of drought and flooding in their localities over the past ten years preceding the survey. Regarding drought, more than half (80.49%) of the people in the sample have experienced severe drought although the level of severity differs across the sample. For instance, those that experienced much more severe drought (30.17%) in their localities were higher compared to those that experienced much less severe drought (13.13%). With respect to flooding, majority of the respondents (77.57%) had experienced severe flooding at varying degrees. However, individuals who faced much more severe flooding (17.69%) are relatively lower compared to those that faced less severe flooding (27.15%) in their localities. By implication, albeit most of the people have faced varied degrees of severe climate hazards, the proportion of those that faced much more severe drought were higher than flooding.

3.4. Controls

We select the control variables guided by their practical and theoretical relevance. Thus, in the food, fuel, income, and water deprivation models, we controlled for the respondent's age and its squared term, gender, household size, employment status, education attainments and rural-urban residence. It is important to underscore that we first carried out some key preliminary analyses before engaging with the main hypotheses testing. First, we test whether there is a statistically association between peoples' experiences of the severity of drought and flooding and their exposure to various forms of deprivation outcomes. In our view, these first step empirical examinations are crucial mainly on two grounds. First, it enables us to fully understand the issue under investigation and pathway for the development of our main hypotheses.

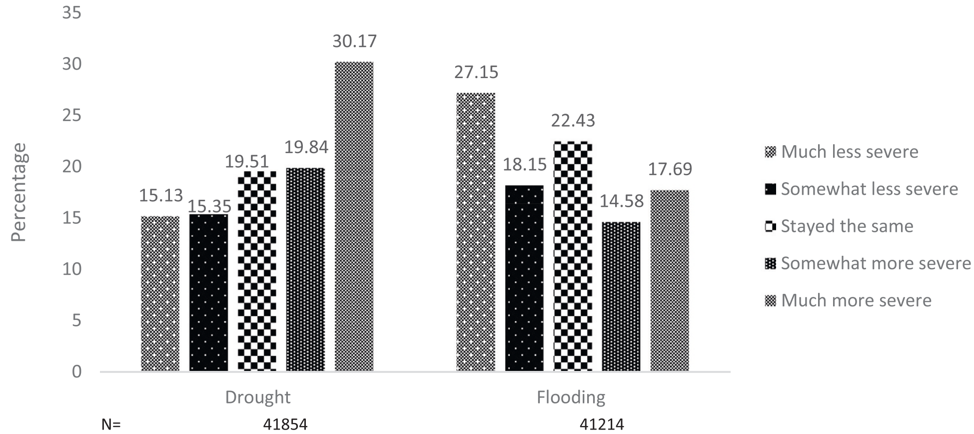

Fig. 1. Experiences of the severity of climate hazards.

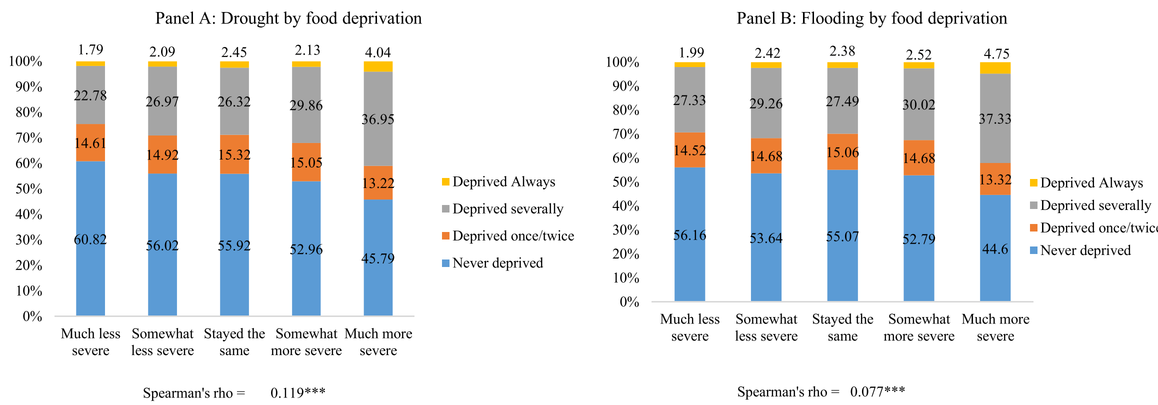

Fig. 2. Associations between the severity of drought and flooding and individuals' exposure to food deprivation. * ** p < 0.01.

Fig. 2–5 present results from those empirical examinations.

Fig. 2 shows the statistical associations between the severity of drought and flooding and individuals' exposure to food deprivation. For food deprivation, we can deduce that among people that have experienced much more severe drought (see Panel A), over half (54.21%) of them have faced food deprivation compared to those that experienced much less severe drought (39.13%). Similarly, among those that experienced much severe flooding (see Panel B), more than half of them (55.4%) have experienced food deprivation relative to those that experienced much less severe flooding (43.84%). Crucially, the Spearman rank correlation for both drought (rho=0.119 ***) and flooding (rho=0.077 ***) are statistically significant at 1% alpha level. The implication is that food deprivation is not independent of both drought and flooding.

In Fig. 3, we examine the statistical associations between the severity of drought and flooding and fuel deprivation. We also find supporting evidence that there is a statistically significant association between severity of these climate hazards and fuel deprivation. Precisely, while 41.57% of those that have experienced much more severe drought (see Panel C) in their localities have experienced fuel deprivation, only 30.96% of those that experienced much less severe drought have experienced food deprivation. Similar patterns hold in the case of flooding (see Panel D). 55.4% of the people who faced much more severe flooding have experienced fuel deprivation compared to their counterparts who experienced much less severe flooding where 43.84% experienced fuel deprivation.

In terms of income deprivation (see Fig. 4), we observe that among individuals that have faced much more severe drought (see Panel E),

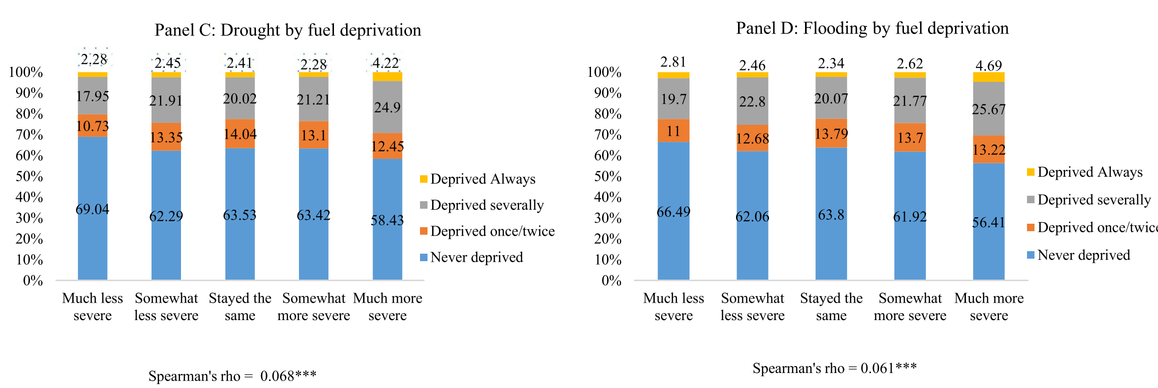

Fig. 3. Associations between the severity of drought and flooding and individuals' exposure to fuel deprivation. * ** p < 0.01.

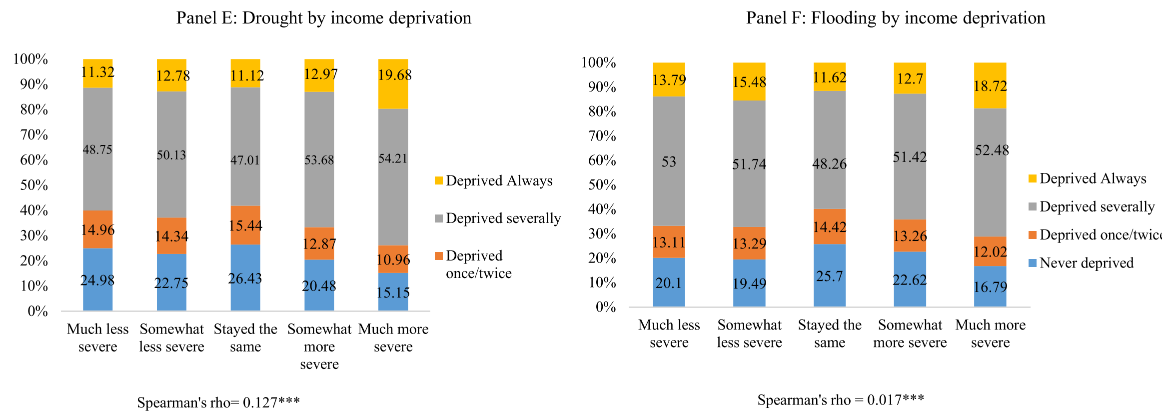

Fig. 4. Association between the severity of drought and flooding and individuals' exposure to income deprivation. * ** p < 0.01.

84.85% have experienced income deprivation compared to 75.02% among those that have faced much less severe drought. What this suggests is that income deprivation is relatively high among both groups. By implication, regardless of the level of severity, drought generally worsens income deprivation. For flooding (see Panel F), while 83.21% of those that experienced much more severe flooding were income deprived, 79.9% of those that experienced much less severe flooding also experience income deprivation.

With regards to water deprivation (see Fig. 5), we see that among those that experienced drought (see Panel G), 55.34% faced water deprivation compared to 39.66% for the case of those that experienced much less severe drought. Along the same line, among people that experienced much more severe flooding (see Panel H), 53.38% of them experienced water deprivation compared to 46.99% for the case of those that experienced much less severe flooding. The Spearman rank correlations are statistically significant and thus, indicate that water deprivation is not independent of both drought and flooding. Overall, given the caveat that correlation is not causation, the pieces of evidence from the foregoing preliminary analyses warrant further investigation into the effects of climate hazards on deprivations outcomes.

3.5. Estimation strategy

To examine the effect of climate change on deprivation outcomes, we estimate our baseline ordered probit model in Eq. 1:

$$W_{ij} = \begin{cases} 0 & \text{If} \quad \delta H_{ijt} + \lambda Z_{ij} + \varepsilon_{ij} \le \alpha_1 \\ 1 & \text{If}\alpha_1 < \quad \delta H_{ijt} + \lambda Z_{ij} + \varepsilon_{ij} \le \alpha_2 \\ 2 & \text{If}\alpha_2 < \quad \delta H_{ijt} + \lambda Z_{ij} + \varepsilon_{ij} \le \alpha_3 \\ 3 & \text{if}\alpha_3 < \quad \delta H_{ijt} + \lambda Z_{ij} + \varepsilon_{ij} \le \alpha_4 \end{cases} \quad (1)$$

where W_{ij} is the response variable which alternatively captures the four deprivation outcomes (food, fuel, income, and water deprivation) of an individual i in country j. Each of these four dependent variables are ranked into four categories–never deprived, deprived once/twice, deprived many times, and deprived always. Recall that $W \in \{0, 1, 2, 3\}$ while $\alpha_1 < \alpha_2 < \alpha_3 < \alpha_4$.

The vectors of interest are H_{ij} and δ. Vector H_{ij} captures the two main climate hazards–drought and flooding. Both drought and flooding are ordinal variables measuring the severity of climate change ranked into five categories each–much less severe, somewhat less severe, stayed the same, somewhat more severe, and much more severe. Vector δ consists of the corresponding coefficients from vector H_{ij} and it measures the impact of the severity of climate change (drought and flooding) on deprivation outcomes. Z_{ij} is a vector of controls with λ as the vector of parameters ε_{ij} is the error term.

4. Results

4.1. Baseline estimates

4.1.1. Effect of climate change on food deprivation

Tables 2–5 report the baseline results for the effect of climate change on deprivation outcomes. In each of the Tables 2–5, from columns (1)–(4), we present coefficients from the ordered probit estimation while from columns (5)–(7) we present the marginal effects using the full model (model 4). For each of the deprivation outcome variables (food, fuel, income, and water), we estimate a series of ordered probit model estimations. Table 2 shows the regression estimates for food deprivation. In model 1, we check whether severity of drought is related to whether people's experiences of food deprivation. We find that the coefficient is

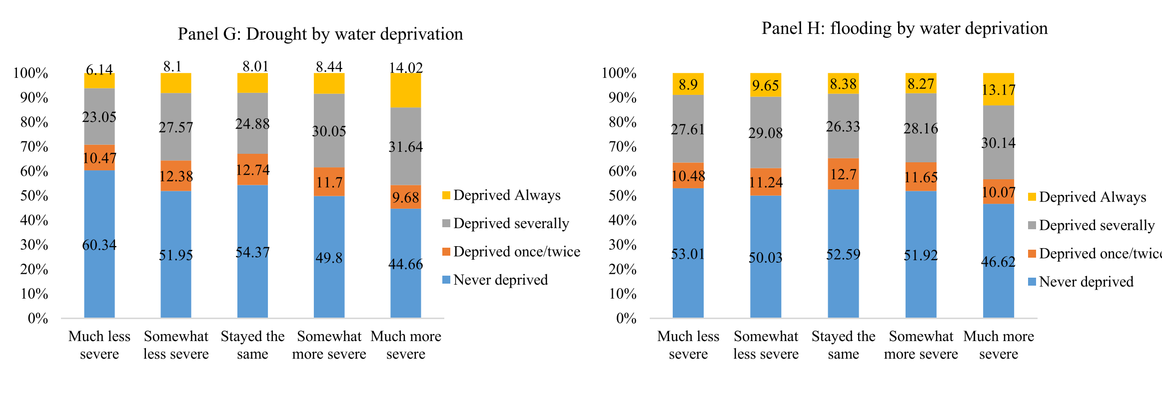

Fig. 5. Association between the severity of drought and flooding and individuals' exposure to water deprivation. * ** p < 0.01.

Table 2
Severity of climate change and food deprivation (ordered probit model baseline estimations).

	Coefficients				Marginal effects from model 4		
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Once/Twice	(6) Many times	(7) Always
Drought (ref=much less severe)							
Somewhat less severe	0.122 * **		0.106 * **	0.098 * **	0.006 * **	0.029 * **	0.003 * **
	(0.021)		(0.023)	(0.024)	(0.001)	(0.007)	(0.001)
Stayed the same	0.127 * **		0.118 * **	0.096 * **	0.006 * **	0.029 * **	0.003 * **
	(0.020)		(0.023)	(0.024)	(0.001)	(0.007)	(0.001)
Somewhat more severe	0.195 * **		0.168 * **	0.121 * **	0.007 * **	0.037 * **	0.004 * **
	(0.020)		(0.021)	(0.023)	(0.001)	(0.007)	(0.001)
Much more severe	0.408 * **		0.352 * **	0.220 * **	0.011 * **	0.068 * **	0.008 * **
	(0.018)		(0.019)	(0.021)	(0.001)	(0.006)	(0.001)
Flooding (ref=much less severe)							
Somewhat less severe		0.066 * **	0.051 * **	0.035 *	0.002 *	0.011 *	0.001 *
		(0.017)	(0.019)	(0.020)	(0.001)	(0.006)	(0.001)
Stayed the same		0.028 *	0.024	0.033	0.002 *	0.010 *	0.001
		(0.016)	(0.019)	(0.020)	(0.001)	(0.006)	(0.001)
Somewhat more severe		0.088 * **	0.064 * **	0.044 * *	0.002 * *	0.014 * *	0.002 * *
		(0.018)	(0.020)	(0.021)	(0.001)	(0.006)	(0.001)
Much more severe		0.324 * **	0.232 * **	0.096 * **	0.005 * **	0.030 * **	0.004 * **
		(0.017)	(0.018)	(0.020)	(0.001)	(0.006)	(0.001)
Controls							
Household size				-0.000	-0.000	-0.000	-0.000
				(0.002)	(0.000)	(0.001)	(0.000)
Urban (ref=rural)				-0.002 * **	-0.000 * **	-0.001 * **	-0.001 * **
				(0.000)	(0.000)	(0.000)	(0.000)
Female (ref=male)				-0.025 * *	-0.001 *	-0.007 *	-0.001 *
				(0.012)	(0.001)	(0.004)	(0.000)
Age				0.011 * **	0.000	0.000	0.000
				(0.002)	(0.000)	(0.000)	(0.000)
Age squared				-0.000 * **	-0.000	-0.000	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)
Employed (ref=unemployed)				-0.159 * **	-0.007 * **	-0.045 * **	-0.006 * **
				(0.014)	(0.001)	(0.004)	(0.001)
Education (ref=no formal education)							
Basic education				-0.160 * **	-0.002 * **	-0.050 * **	-0.010 * **
				(0.019)	(0.000)	(0.006)	(0.001)
Secondary education				-0.419 * **	-0.014 * **	-0.132 * **	-0.021 * **
				(0.020)	(0.001)	(0.006)	(0.001)
Tertiary education				-0.722 * **	-0.039 * **	-0.213 * **	-0.027 * **
				(0.025)	(0.002)	(0.007)	(0.001)
N	**41,800**	**41,161**	**40,668**	**40,390**	**40,390**	**40,390**	**40,390**

Notes: Country dummies are included in model 4. Standard errors are in parentheses. * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. Marginal effects are based on Model 4. ref. denotes reference group.

positive and significant, that is, exposure to more severe drought, the more likely people would experience food deprivation. In model 2, we replace our drought measure with our indicator of flooding. This model indicates that severity of flooding, too, has an adverse consequence on food deprivation–the more severe the flooding, the more likely for food deprivation to occur. In model 3, both drought and flooding are included and remarkably, their effects are only marginally reduced once both are controlled for in the same model. In essence, exposure to severe drought and flooding still increase people's experiences of food deprivation. In model 4, we include individual-level controls and country dummies. Here too, as can be seen, after controlling for these variables, the severity of both drought and flooding still significantly increase people's experiences of food deprivation. Recall that our response variables (food, fuel, income, and water deprivation) have four outcomes –deprived once/twice, many times, and always with 'never deprived' as the reference group. Thus, using the full model (model 4), we now predict the marginal effect for each of the outcomes.

Therefore, our interpretations and discussions are based on these marginal effects presented from Table 2–5 for the sake of brevity. From Table 2, food deprivation is higher for individuals that have experienced much more severe drought relative to groups that have experience much less severe drought. Specifically, for individuals that have experienced much more severe drought, their probability of experiencing food deprivation once/twice, many times, and always increases by 0.6% point, 6.8% points, and 0.8% point, respectively compared to those that have faced much less severe drought. The implication of this finding is that albeit drought increases individuals' probable risk of experiencing food deprivation, the level of severity matters as those that live in much more severe areas are affected intensely. Turning attention to flooding, we find evidence that while flooding increases individuals' exposure to food deprivation, the degree of exposure to severe flooding is more influential in their food deprivation experience. In more specific terms, compared to individuals that have faced much less severe flooding, the probable risk of being food deprived once/twice, many times, and always rises by 0.5% point, 3.0% points, and 0.4% point, respectively for individuals who experience much more severe flooding. Crucially, these marginal effects are all statistically significant at both one percent and five percent alpha levels; thus, indicating that the severity of flooding is crucial in explaining variations in the food deprivation of individuals.

Our finding that climate change significantly increases individuals' food deprivation outcomes offers evidence to validate H_1 as well as assertions in the climate change literature (see Randell et al., 2021); FAO (2022); Bandara and Cai, 2014). FAO (2022) emphasized that climate change has the tendency to exacerbate food deprivation and we find such evidence in this study. Besides, our study shows that the severity of climate change matters most as those who have faced much more severe drought and flooding have experienced significantly higher food deprivations relative to those that have experienced much less severe

Table 3
Severity of climate change and fuel deprivation (ordered probit model baseline estimations).

	Coefficients				Marginal effects from model 4		
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Once/Twice	(6) Many times	(7) Always
Drought (ref=much less severe)							
Somewhat less severe	0.157 * **		0.128 * **	0.068 * **	0.005 * **	0.016 * **	0.003 * **
	(0.022)		(0.023)	(0.024)	(0.002)	(0.006)	(0.001)
Stayed the same	0.118 * **		0.107 * **	0.066 * **	0.005 * **	0.016 * **	0.003 * **
	(0.021)		(0.024)	(0.024)	(0.002)	(0.006)	(0.001)
Somewhat more severe	0.128 * **		0.095 * **	0.066 * **	0.005 * **	0.016 * **	0.003 * **
	(0.021)		(0.022)	(0.023)	(0.002)	(0.006)	(0.001)
Much more severe	0.287 * **		0.237 * **	0.180 * **	0.013 * **	0.045 * **	0.009 * **
	(0.019)		(0.020)	(0.022)	(0.002)	(0.005)	(0.001)
Flooding (ref=much less severe)							
Somewhat less severe		0.093 * **	0.070 * **	0.002	0.000	0.001	0.000
		(0.018)	(0.019)	(0.020)	(0.002)	(0.005)	(0.001)
Stayed the same		0.036 * *	0.024	0.013	0.001	0.003	0.001
		(0.017)	(0.020)	(0.021)	(0.002)	(0.005)	(0.001)
Somewhat more severe		0.089 * **	0.080 * **	0.065 * **	0.005 * **	0.016 * **	0.003 * **
		(0.019)	(0.021)	(0.022)	(0.002)	(0.005)	(0.001)
Much more severe		0.258 * **	0.195 * **	0.109 * **	0.007 * **	0.027 * **	0.006 * **
		(0.018)	(0.019)	(0.021)	(0.001)	(0.005)	(0.001)
Controls							
Household size				0.007 * **	0.001 * **	0.002 * **	(0.000)
				(0.003)	(0.000)	(0.001)	
Urban (ref=rural)				-0.000	-0.002 * *	-0.008 * *	-0.002 * *
				(0.000)	(0.001)	(0.004)	(0.001)
Female (ref=male)				0.034 * **	0.003 * **	0.009 * **	0.002 * **
				(0.012)	(0.001)	(0.003)	(0.001)
Age				0.005 * *	-0.000	-0.000	-0.000
				(0.002)	(0.000)	(0.000)	(0.000)
Age squared				-0.000 * *	0.000	0.000	0.000
				(0.000)	(0.000)	(0.000)	(0.000)
Employed (ref=unemployed)				-0.090 * **	-0.006 * **	-0.021 * **	-0.004 * **
				(0.014)	(0.001)	(0.003)	(0.001)
Education (ref=no formal education)							
Basic education				-0.057 * **	-0.003 * **	-0.014 * **	-0.003 * **
				(0.020)	(0.001)	(0.005)	(0.001)
Secondary education				-0.130 * **	-0.009 * **	-0.033 * **	-0.007 * **
				(0.021)	(0.001)	(0.006)	(0.001)
Tertiary education				-0.304 * **	-0.023 * **	-0.074 * **	-0.015 * **
				(0.025)	(0.002)	(0.006)	(0.001)
N	**41,751**	**41,111**	**40,620**	**40,345**	**40,345**	**40,345**	**40,345**

Notes: Country dummies are included in model 4. Standard errors are in parentheses. * ** p < 0.01, * * p < 0.05, * p < 0.1. Marginal effects are based on Model 4. ref. denotes reference group.

drought and flooding. This finding lend support to Randell et al.'s (2021) argument that individuals' access to food tends to be hindered by climate hazards. Climate change is making it difficult for people to have enough food to eat (Bandara and Cai, 2014). Similar finding has been reported by Gentle and Maraseni (2012) for Nepal.

4.1.2. Effect of climate change on fuel deprivation

Here, we present our baseline results for the effect of climate change on fuel deprivation in Table 3. In this table, we find that fuel deprivation increases with rising severity of climate change. Take drought, for instance, for individuals that have experienced much more severe drought, the probable risk of experiencing fuel deprivation once/twice, many times, and always increases by 1.3% points, 4.5% points and 0.9% point respectively compared to those that have experienced much less severe drought. These are all statistically significant at both five percent and one percent alpha levels. By implication, drought worsens the fuel deprivation situations of its victims. Similarly, in terms of flooding, we observe that individuals that have experienced much more severe flooding have significantly higher probability of experiencing fuel deprivation. Precisely, relative to persons that have experienced much less flooding, the chances of experiencing fuel deprivation once/twice, many times, and always significantly increase by 0.7% point, 2.7% points, and 0.6% point respectively for persons who have faced much more severe flooding. Our finding that climate change increases individuals' exposure to fuel deprivation provide support for $H_{2,}$ and it is consistent with extant literature (see Moiseyev et al., 2011; Schaeffer et al., 2012; IPCC, 2022), which argues that climate hazards limit people's access to cooking fuel.

4.1.3. Effect of climate change on income deprivation

The baseline results showing the effect of climate change on income deprivation are reported in Table 4. Overall, we find that higher income deprivation is associated with rising severity of climate change. Specifically, we find that the probable risk of experiencing income deprivation once/twice, many times, and always rises by 2.0% points, 3.2% points, and 3.4% points respectively for individuals that have experienced much more severe drought compared to those that have experienced much less severe drought. These are all statistically significant at both five percent and one percent alpha levels. What this finding suggests is that drought worsens the income deprivation situations of its victims (Leichenko and Silva, 2014). Similarly, in terms of flooding, we observe that individuals that have experienced much more severe flooding have significantly greater probability of experiencing income deprivation. Precisely, relative to persons that have experienced much less flooding, the probable risk of experiencing income deprivation once/twice, many times and always significantly increase by 2.0% points, 2.4% points, and 2.1% points respectively for individuals who have faced much more severe flooding. In support of H_3 and aligning

Table 4
Severity of climate change and income deprivation (ordered probit model baseline estimations).

	Coefficients				Marginal effects from model 4		
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Once/Twice	(6) Many times	(7) Always
Drought (ref=much less severe)							
Somewhat less severe	0.073 * **		0.084 * **	0.046 * *	0.005 * *	0.009 * *	0.008 * *
	(0.019)		(0.021)	(0.022)	(0.002)	(0.004)	(0.004)
Stayed the same	0.037 * *		0.037 *	0.032	0.003	0.006	0.005
	(0.018)		(0.021)	(0.022)	(0.002)	(0.005)	(0.004)
Somewhat more severe	0.137 * **		0.174 * **	0.067 * **	0.007 * **	0.013 * **	0.011 * **
	(0.018)		(0.020)	(0.021)	(0.002)	(0.004)	(0.004)
Much more severe	0.368 * **		0.374 * **	0.186 * **	0.020 * **	0.032 * **	0.034 * **
	(0.017)		(0.018)	(0.020)	(0.002)	(0.004)	(0.004)
Flooding (ref=much less severe)							
Somewhat less severe		0.037 * *	0.028	0.021	0.002	0.004	0.004
		(0.016)	(0.017)	(0.018)	(0.002)	(0.003)	(0.003)
Stayed the same		0.158 * **	0.127 * **	0.058 * **	0.006 * **	0.010 * **	0.010 * **
		(0.015)	(0.018)	(0.019)	(0.002)	(0.003)	(0.003)
Somewhat more severe		0.068 * **	0.089 * **	0.056 * **	0.006 * **	0.010 * **	0.010 * **
		(0.017)	(0.018)	(0.020)	(0.002)	(0.004)	(0.004)
Much more severe		0.154 * **	0.052 * **	0.003	0.000	0.000	0.000
		(0.016)	(0.017)	(0.019)	(0.002)	(0.003)	(0.004)
Controls							
Household size				0.010 * **	-0.001 * **	0.002 * **	0.002 * **
				(0.002)	(0.000)	(0.000)	(0.000)
Urban (ref=rural)				-0.001 * **	0.008 * **	-0.013 * **	-0.013 * **
				(0.000)	(0.001)	(0.002)	(0.002)
Female (ref=male)				-0.028 * *	0.003 * *	-0.004 * *	-0.004 * *
				(0.012)	(0.001)	(0.002)	(0.002)
Age				0.014 * **	0.000	-0.000	-0.000
				(0.002)	(0.000)	(0.000)	(0.000)
Age squared				-0.001 * **	0.000	-0.000	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)
Employed (ref=unemployed)				-0.224 * **	0.022 * **	-0.036 * **	-0.037 * **
				(0.013)	(0.001)	(0.002)	(0.002)
Education (ref=no formal education)							
Basic education				-0.182 * **	0.020 * **	-0.014 * **	-0.042 * **
				(0.019)	(0.002)	(0.001)	(0.005)
Secondary education				-0.415 * **	0.046 * **	-0.054 * **	-0.085 * **
				(0.020)	(0.002)	(0.002)	(0.005)
Tertiary education				-0.701 * **	0.068 * **	-0.127 * **	-0.122 * **
				(0.023)	(0.002)	(0.005)	(0.005)
N	**41,738**	**41,101**	**40,610**	**40,334**	**40,334**	**40,334**	**40,334**

Notes: Country dummies are included in model 4. Standard errors are in parentheses. * ** p < 0.01, * * p < 0.05, * p < 0.1. Marginal effects are based on Model 4. ref. denotes reference group.

with Leichenko and Silva (2014), our finding suggests that climate change increases the number of people that would become trapped in income poverty and further aggravate the income poverty levels of those already in the income poverty trap.

4.1.4. *Effect of climate change on water deprivation*

In Table 5, we offer the baseline results for the effect of climate change on water deprivation. We find that, for individuals that have experienced much more severe drought, their probable risk of experiencing water deprivation once/twice, many times, and always increases by 0.7% point, 6.9% points, and 4.2% points respectively compared to those that have experienced much less severe drought. These are all statistically significant at both five percent and one percent alpha levels. What this finding connotes is that drought worsens the water deprivation situations of its victims, and this is consistent with Tandon's (2007) assertion that climate change compounds water insecurity problem. Along the same line, IPCC (2007) maintains that climate hazards reduce the availability of clean water and by extension leads to water deprivation. On the contrary, in terms of flooding, we observe that it has no statistically significant effect on water deprivation, and this suggests that flooding does not cause individuals to become water-deprived. Given the aforesaid findings, we offer partial support for H_4.

4.2. *Sensitivity to endogeneity and robustness checks*

Here, we subject our baseline results (presented on Table 2–5) to a series of robustness checks. The results are presented in Table 6–7. The first issue of concern is that our response variables (food, fuel, income, and water deprivation) are ordinal in nature. In equation one, experiences of deprivation are repetitive–once/twice, many times, and always. However, there may be concern that despite people facing varying levels of severity of climate hazards, their experiences of deprivations would not be frequent as equation one seems to indicate. For example, although some people may have faced much more severe climate change, they may not have experienced deprivation many times or always; rather such persons might have experienced deprivation only once. Under such circumstance, we question whether the effect of climate change would still be consistent with our baseline results. To check this, we generate a dichotomous response variable which takes a value of one if the respondent has been deprived only once/twice and zero otherwise. We re-estimated equation one using the dichotomous response variable by implementing the Lewbel (2012) two-stage least squares (2SLS) estimation approach. We implemented the Lewbel (2012) 2SLS approach for two main reasons. First, the Lewbel (2012) addresses any concern that may arise due to potential endogeneity in the climate change-deprivation nexus. Secondly, it has the advantage of utilising internally generated instruments and has no strict requirement

Table 5
Severity of climate change and water deprivation (ordered probit model baseline estimations).

	Coefficients				Marginal effects from model 4		
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Once/Twice	(6) Many times	(7) Always
Drought (ref=much less severe)							
Somewhat less severe	0.190 * **		0.188 * **	0.135 * **	0.004 * **	0.032 * **	0.017 * **
	(0.020)		(0.022)	(0.023)	(0.001)	(0.005)	(0.003)
Stayed the same	0.137 * **		0.152 * **	0.097 * **	0.003 * **	0.023 * **	0.012 * **
	(0.020)		(0.022)	(0.023)	(0.001)	(0.006)	(0.003)
Somewhat more severe	0.242 * **		0.249 * **	0.167 * **	0.005 * **	0.040 * **	0.022 * **
	(0.019)		(0.021)	(0.022)	(0.001)	(0.005)	(0.003)
Much more severe	0.429 * **		0.421 * **	0.296 * **	0.007 * **	0.069 * **	0.042 * **
	(0.018)		(0.019)	(0.021)	(0.001)	(0.005)	(0.003)
Flooding (ref=much less severe)							
Somewhat less severe		0.063 * **	0.027	0.017	0.000	0.004	0.002
		(0.017)	(0.018)	(0.019)	(0.000)	(0.004)	(0.003)
Stayed the same		-0.015	-0.026	-0.002	0.000	0.000	0.000
		(0.016)	(0.018)	(0.019)	(0.000)	(0.005)	(0.003)
Somewhat more severe		0.004	-0.037 *	-0.024	0.001	0.006	0.004
		(0.018)	(0.019)	(0.021)	(0.000)	(0.005)	(0.003)
Much more severe		0.184 * **	0.071 * **	0.010	0.000	0.002	0.001
		(0.017)	(0.018)	(0.020)	(0.000)	(0.005)	(0.003)
Controls							
Household size				0.010 * **	0.000 * **	0.002 * **	0.001 * **
				(0.002)	(0.000)	(0.001)	(0.000)
Urban (ref=rural)				-0.001 *	-0.001 * **	-0.011 * **	-0.007 * **
				(0.000)	(0.000)	(0.003)	(0.002)
Female (ref=male)				-0.057 * **	-0.001 * **	-0.013 * **	-0.008 * **
				(0.012)	(0.000)	(0.003)	(0.002)
Age				0.011 * **	-0.000 * *	-0.000 * *	-0.000 * *
				(0.002)	(0.000)	(0.000)	(0.000)
Age squared				-0.000 * **	0.000 * *	0.000 * *	0.000 * *
				(0.000)	(0.000)	(0.000)	(0.000)
Employed (ref=unemployed)				-0.098 * **	-0.002 * **	-0.019 * **	-0.012 * **
				(0.013)	(0.000)	(0.003)	(0.002)
Education (ref=no formal education)							
Basic education				-0.141 * **	-0.001 * **	-0.029 * **	-0.024 * **
				(0.019)	(0.000)	(0.004)	(0.003)
Secondary education				-0.287 * **	-0.004 * **	-0.064 * **	-0.046 * **
				(0.020)	(0.000)	(0.004)	(0.004)
Tertiary education				-0.466 * **	-0.011 * **	-0.106 * **	-0.066 * **
				(0.023)	(0.001)	(0.005)	(0.004)
N	**41,794**	**41,155**	**40,663**	**40,386**	**40,386**	**40,386**	**40,386**

Notes: Country dummies are included in model 4. Standard errors are in parentheses. * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. Marginal effects are based on Model 4. ref. denotes reference group.

of including external instruments. The marginal effects results from the Lewbel (2012) 2SLS approach are presented in Table 6 and they are mostly consistent with our baseline results in Tables 2–5.

Also, the nature of the data in our investigation raises concern and this motivated a robustness check to avoid making spurious conclusions. The data are collected at the individual level nested within countries and thus, exhibit some multilevel or hierarchical characteristics. Accordingly, if there are any significant differences in both the observables and unobservables across our deprivation variables and climate change variables at the country-level, then our baseline estimates are likely to be misleading. To guard against this concern, we subject our baseline models specified in Eq. (1) to a series of multilevel fixed estimations. The results from this additional empirical examination are presented in Table 7 which revealed two key outcomes. From the random part of the multilevel fixed effect models, we find that the random effect in all the models is highly insignificant, and this indicates that the normal ordered probit estimates (our baseline estimates) are superior to the multilevel fixed effect estimates. The second crucial observation from the multilevel fixed effect estimations is that such hierarchical modelling does not change our baseline estimates in both quantitative and qualitative terms as there are no significant changes in the magnitudes and directions of the coefficients. In principle, multilevel fixed effect results are consistent with our baseline estimates as climate change still has significant lethal effect on deprivation outcomes.

Furthermore, we alternatively measure climate change by generating an aggregate index of climate hazard–climate hazard index (CHI) as an additional robustness check. The CHI is constructed to obtain further insights into how climate change impacts deprivation. The index is a composition of information on drought and flooding. We deploy the factor analysis to generate CHI. As shown in the Appendix (see Table B), both drought and flooding map well onto one factor–Factor1 (only Factor1 has an Eigenvalue greater than 1) and this gives credence that both variables are measuring the same construct (climate change). The retained factor explains about 64.00% of the variance in climate hazard. We normalized the CHI to fall between 0 and 1 for ease of interpretation.

Table 8 reports the marginal effects of CHI obtained from the ordered probit model estimations. In Table 8, we find that climate hazard increases individuals' exposure to food deprivation. Precisely, a unit increase in climate hazard increases food deprivation once/twice, many times, and always by 1.4% points, 8.5% points, and 1.1% points, respectively. Also, we find that climate hazard increases fuel deprivation. Specifically, a unit increase in climate hazard increases the probable risk of experiencing fuel deprivation once/twice, many times, and always by 1.9% points, 6.6% points, and 1.4% points, respectively. In addition, we find that climate hazard causes income deprivation to increase. Specifically, a unit increase in climate hazard increases the probable risk of experiencing income deprivation once/twice, many times, and always by 1.6% points, 2.9% points, and 2.7% points,

Table 6
Severity of climate change and deprivation (Marginal effects obtained from Lewbel 2SLS estimations).

	Food deprivation	Fuel deprivation	Income deprivation	Water deprivation
Drought (ref=much less severe)				
Somewhat less severe	0.049 * **	0.033 * *	0.041 * **	0.071 * **
	(0.016)	(0.016)	(0.012)	(0.016)
Stayed the same	0.034 * *	0.006	0.015	0.039 * *
	(0.015)	(0.015)	(0.012)	(0.015)
Somewhat more severe	0.044 * **	0.019	0.017	0.063 * **
	(0.016)	(0.016)	(0.012)	(0.017)
Much more severe	0.076 * **	0.058 * **	0.047 * **	0.114 * **
	(0.012)	(0.012)	(0.009)	(0.012)
Flooding (ref=much less severe)				
Somewhat less severe	0.008	0.006	0.002	0.007
	(0.014)	(0.014)	(0.009)	(0.015)
Stayed the same	0.044 * **	0.044 * **	0.018 * **	0.023
	(0.014)	(0.014)	(0.001)	(0.015)
Somewhat more severe	0.025	0.044 * **	0.021 * *	0.005
	(0.016)	(0.016)	(0.002)	(0.017)
Much more severe	0.026 * *	0.042 * **	0.028 * **	0.010
	(0.012)	(0.013)	(0.001)	(0.014)
Controls?	Yes	Yes	Yes	Yes
R^2	0.150	0.077	0.196	0.094
N	**40,415**	**40,370**	**40,359**	**40,411**

Notes: All models include controls and country dummies. Standard errors adjusted for heteroscedasticity are in parentheses. * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. ref denotes reference group.

Table 7
Severity of climate change and deprivation (Marginal effects obtained from multilevel fixed effect estimations).

	Food deprivation	Fuel deprivation	Income deprivation	Water deprivation
Drought (ref=much less severe)				
Somewhat less severe	0.105 * **	0.123 * **	0.035	0.191 * **
	(0.023)	(0.024)	(0.022)	(0.022)
Stayed the same	0.150 * **	0.124 * **	0.010	0.182 * **
	(0.023)	(0.024)	(0.022)	(0.023)
Somewhat more severe	0.143 * **	0.096 * **	0.056 * **	0.251 * **
	(0.022)	(0.022)	(0.021)	(0.021)
Much more severe	0.250 * **	0.205 * **	0.181 * **	0.377 * **
	(0.020)	(0.020)	(0.019)	(0.019)
Flooding (ref=much less severe)				
Somewhat less severe	0.057 * **	0.060 * **	0.040 * *	0.018
	(0.019)	(0.019)	(0.018)	(0.018)
Stayed the same	0.061 * **	0.039 *	0.082 * **	0.007
	(0.019)	(0.020)	(0.018)	(0.019)
Somewhat more severe	0.134 * **	0.118 * **	0.093 * **	0.007
	(0.020)	(0.021)	(0.019)	(0.020)
Much more severe	0.262 * **	0.210 * **	0.033 *	0.091 * **
	(0.018)	(0.019)	(0.018)	(0.018)
Controls?	Yes	Yes	Yes	Yes
Random effect (Variance)	1.624	0.665	1.708	1.035
	(1.629)	(0.667)	(0.076)	(1.468)
No. of countries	**33**	**33**	**33**	**33**
N	**40,415**	**40,370**	**40,359**	**40,411**

Notes: All models include controls. Country dummies and GDP are used to account for country-fixed effects. Standard errors adjusted for heteroscedasticity are in parentheses. * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. ref denotes reference group.

respectively. Lastly, we find that climate hazard increases water deprivation. Specifically, a unit increase in climate change (CHI) increases the probable risk of experiencing water deprivation once/twice, many times, and always by 0.6% point, 5.8% points, and 3.6% points, respectively. From Table 8, we show that the adverse impact of climate hazard on the deprivation outcomes is consistent irrespective of the extent to which an individual is deprived. Thus, we argue that climate

Table 8
Ordered Probit model estimations using Climate Hazard Index (CHI) (Marginal effects).

	Food deprivation			Fuel deprivation			Income deprivation			Water deprivation		
	Once/twice	Many times	Always	Once/twice	Many times	Always	Once/twice	Many times	Always	Once/twice	Many times	Always
CHI	0.014 * **	0.085 * **	0.011 * **	0.019 * **	0.066 * **	0.014 * **	0.016 * **	0.029 * **	0.027 * **	0.006 * **	0.058 * **	0.036 * **
	(0.001)	(0.007)	(0.001)	(0.002)	(0.006)	(0.001)	(0.002)	(0.004)	(0.004)	(0.001)	(0.005)	(0.003)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	**40,415**	**40,415**	**40,415**	**40,370**	**40,370**	**40,370**	**40,359**	**40,359**	**40,359**	**40,411**	**40,411**	**40,411**

Notes: All models included country dummies. Standard errors are in parentheses. * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$.

change tends to cause food, fuel, income, and water deprivation.

In furtherance, we use the Lewbel 2SLS and multilevel fixed effect estimation methods to obtain the marginal effects of CHI reported in Table 9. Regardless of the estimation methods, we find that climate hazard increases food, fuel, income, and water deprivation. These findings are qualitatively similar and give more support to the baseline results.

4.3. Further results

4.3.1. Locational heterogeneities in the effect of climate change on deprivation outcomes

Here, we explore the effect of climate change on the four deprivation outcomes along locational dimensions (rural and urban) by estimating rural versus urban sub-samples as shown in Tables 10–13. In each table, attention should be paid to columns (7) – (9) which show the statistical differences in marginal effects between rural and urban areas on each category of deprivation (i.e., deprived once/twice, many times, and always). Specifically, Column (7) shows the differences (in terms of magnitudes) in the effect of climate change between rural and urban areas for individuals that have experienced food deprivations once/twice. Column (8) shows similar case for those that have experienced food deprivations many times between rural and urban settings while Column (9) indicates the case for those that have experienced food deprivation always between rural and urban areas.

Table 10 reports results obtained for the food deprivation. We find that the effect of climate change on food deprivation is more pronounced in rural areas relative to the urban settings. Precisely, individuals that have experienced much more severe drought in rural localities have higher likelihood of experiencing food deprivation once/twice, many times, and always with a differential magnitude of 0.5% point, 3.7% points, and 0.7% point, respectively compared to their urban counterparts who faced the same situation. These differential effects are statistically significant at both five percent and one percent alpha levels and by implication indicates the locational heterogeneities in the effect of climate change on food deprivation with rural dwellers are adversely affected intensely. Similar patterns hold for flooding as individuals that have faced much more severe flooding in rural areas face additional risk of experiencing food deprivation once/twice, many times, and always compared to those that have experienced similar exposures to flooding in urban settings. Specifically, the differential magnitude of 0.4% point, 1.8% points, and 0.4% point for exposure to food deprivation once/twice, many times, and always respectively at the disadvantage of those in rural areas that faced much more severe drought are statistically significant at both five percent and one level of significance. What this means is that although exposure to climate change increases the risk of experiencing food deprivation in both rural and urban settings, affected persons in rural areas are relatively worse off under similar scenarios. Our finding lends credence to the IPCC (2022) projection that climate change would make more people poor between now and 2100, and most of its severe impacts are expected to be felt more in rural communities in SSA.

Regarding climate change and fuel deprivation along locational heterogeneities (see Table 11), we find that climate change has a heterogeneous effect on fuel deprivation with those in rural communities severely affected compared to their urban counterparts. Individuals in rural localities that have experienced much more severe drought and flooding have comparatively higher probability of being fuel deprived once/twice, many times, and always. The differential magnitude of 0.3% point, 2.6% points, and 0.8% point for drought and 0.3% points, 1.7% points, and 0.4% point for flooding against rural folks are statistically significant at five percent and one alpha levels.

Further, in Table 12, we find that the effect of climate change on income deprivation is more pronounced in rural communities compared to urban communities. Specifically, the differential magnitude of 0.9% point, 1.4% points, and 1.3% points for exposure to income deprivation once/twice, many times, and always respectively at the disadvantage of those in rural areas that faced much more severe drought are statistically significant at both five percent and one alpha levels. Similarly, those that have experienced much more severe flooding in rural areas possess higher risk of being income deprived once/twice, many times, and always by a differential magnitude of 0.7% point, 0.5% point, and 0.8% point respectively compared to those that faced much more severe flooding in urban settings.

Finally, we find that locational heterogeneities exist regarding the effect of climate change and water deprivation (see Table 13). Precisely, those that have experienced much more severe drought in rural areas have higher probable risk of being income deprived once/twice, many times, and always by a differential magnitude of 1.0% points, 0.5% points and 1.8% points respectively compared to those that faced much more severe drought in urban settings. These are all statistically significant at both five percent and one percent alpha levels and thus, indicates the relevance of such heterogeneities. However, we find that the effect of flooding on water deprivation largely does not exhibit statistically significant difference between urban and rural areas.

5. Conclusion and policy implications

The UN via its ambitious sustainable development agenda 2030 is poised to not only end poverty and hunger, but to also end deprivation in all ramifications to ensure that all individuals can fulfil their potential in life. Regrettably, climate change is likely to mar this desire. Hence, SDGs has at its heart to protect the planet by taking urgent actions on climate change so that it can support the needs of both the present and future generations. Achieving this requires policy efforts driven by robust research to advance our knowledge and understanding of climate change. Given this and against the backdrop in literature, we examine climate change-deprivation nexus with a focus on SSA–the world's poorest region with acute income inequalities. We find that climate change increases individuals' experiences of food, fuel, income, and

Table 9
Alternative estimations using Climate Hazard Index (CHI) (Marginal effects).

	Lewbel 2SLS				**Multilevel fixed effect**			
	Food deprivation	Fuel deprivation	Income deprivation	Water deprivation	Food deprivation	Fuel deprivation	Income deprivation	Water deprivation
CHI	0.221 * **	0.100 * **	0.057 * *	0.202 * **	0.462 * **	0.353 * **	0.131 * **	0.396 * **
	(0.034)	(0.034)	(0.027)	(0.035)	(0.021)	(0.021)	(0.020)	(0.020)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.150	0.077	0.196	0.094				
Random effect					1.624	0.665	1.708	1.035
(Variance)					(1.629)	(0.667)	(0.076)	(1.468)
N	**40,415**	**40,370**	**40,359**	**40,411**	**40,415**	**40,370**	**40,359**	**40,411**
No. of countries					**33**	**33**	**33**	**33**

Notes: All models include country dummies. Standard errors adjusted for heteroscedasticity are in parentheses. In the multilevel fixed effect estimations, GDP is also included to account for country-fixed effects. * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$.

Table 10
Severity of climate change and food deprivation by rural-urban dimension.

	(1) Rural	(2)	(3)	(4) Urban	(5)	(6)	(7) Differences (rural-urban)	(8)	(9)
	Once/twice	Many times	Always	Once/twice	Many times	Always	Once/twice	Many times	Always
Drought (ref=much less severe)									
Somewhat less severe	0.006 * *	0.033 * **	0.004 * **	0.004 * *	0.021 * *	0.002 * *	0.002 * **	0.012 * **	0.002 * *
	(0.003)	(0.010)	(0.001)	(0.001)	(0.010)	(0.001)			
Stayed the same	0.005	0.039 * **	0.005 * **	0.005	0.015 *	0.001 *	0.000	0.024 * **	0.004 * **
	(0.003)	(0.011)	(0.001)	(0.003)	(0.009)	(0.001)			
Somewhat more severe	0.008 * **	0.040 * **	0.005 * **	0.005 * **	0.025 * **	0.002 * **	0.003 * *	0.015 * **	0.003 * **
	(0.003)	(0.010)	(0.001)	(0.001)	(0.009)	(0.001)			
Much more severe	0.012 * **	0.078 * **	0.011 * **	0.007 * **	0.041 * **	0.004 * **	0.005 * **	0.037 * **	0.007 * **
	(0.003)	(0.009)	(0.001)	(0.001)	(0.009)	(0.001)			
Flooding (ref=much less severe)									
Somewhat less severe	0.006 * *	0.006 * *	0.003 * *	0.001	0.005	0.002 * *	0.005 * **	0.001 * **	0.001 * **
	(0.003)	(0.009)	(0.001)	(0.001)	(0.008)	(0.001)			
Stayed the same	0.002 * *	0.022 * **	0.003 * *	0.001	0.004	0.000	0.001 *	0.017 * **	0.003 * **
	(0.001)	(0.009)	(0.001)	(0.001)	(0.008)	(0.001)			
Somewhat more severe	0.007 * *	0.026 * *	0.004 * *	0.003	0.024 * *	0.002 * *	0.006 * *	0.002 * *	0.002 * **
	(0.003)	(0.009)	(0.001)	(0.001)	(0.009)	(0.001)			
Much more severe	0.007 * **	0.041 * **	0.006 * **	0.003 * **	0.023 * **	0.002 * *	0.004 * **	0.018 * **	0.004 * **
	(0.003)	(0.009)	(0.001)	(0.001)	(0.009)	(0.001)			
Controls?	Yes	Yes	Yes	Yes	Yes	Yes			
N	22,469	22,469	22,469	17,882	17,882	17,882			

Notes: All models include country dummies. Standard errors are in parentheses. * ** p < 0.01, * * p < 0.05, * p < 0.1.

Table 11
Severity of climate change and fuel deprivation by rural-urban dimension.

	(1) Rural	(2)	(3)	(4) Urban	(5)	(6)	(7) Differences (rural-urban)	(8)	(9)
	Once/twice	Many times	Always	Once/twice	Many times	Always	Once/twice	Many times	Always
Drought (ref=much less severe)									
Somewhat less severe	0.009 * **	0.028 * **	0.006 * **	0.002	0.006	0.001	0.007 * **	0.022 * *	0.005 * **
	(0.002)	(0.008)	(0.002)	(0.003)	(0.009)	(0.001)			
Stayed the same	0.009 * **	0.028 * **	0.006 * **	0.002	0.005	0.001	0.007 * **	0.023 * **	0.005 * **
	(0.003)	(0.008)	(0.002)	(0.003)	(0.009)	(0.001)			
Somewhat more severe	0.008 * **	0.029 * **	0.006 * **	0.002	0.006	0.001	0.006	0.023 * **	0.005 * **
	(0.002)	(0.007)	(0.002)	(0.003)	(0.009)	(0.001)			
Much more severe	0.016 * **	0.035 * **	0.014 * **	0.013 * **	0.009 * **	0.006 * **	0.003	0.026 * **	0.008 * **
	(0.002)	(0.007)	(0.002)	(0.003)	(0.001)	(0.001)			
Flooding (ref=much less severe)									
Somewhat less severe	0.004 * *	0.015 * *	0.003 * *	0.005 *	0.013 *	0.002 *	0.001	0.002 * *	0.001
	(0.002)	(0.006)	(0.002)	(0.003)	(0.008)	(0.001)			
Stayed the same	0.000	0.004	0.000	0.001	0.000	0.000	0.001	0.004 * **	0.000
	(0.002)	(0.008)	(0.002)	(0.003)	(0.007)	(0.001)			
Somewhat more severe	0.003 * *	0.014 * **	0.004 * **	0.001	0.007 * **	0.001	0.002 * *	0.007 * *	0.003 * *
	(0.001)	(0.001)	(0.001)	(0.003)	(0.009)	(0.001)			
Much more severe	0.009 * **	0.026 * **	0.007 * **	0.006 * *	0.019 * *	0.003 * *	0.003 * **	0.017 * **	0.004 * **
	(0.002)	(0.007)	(0.002)	(0.003)	(0.008)	(0.001)			
Controls?	Yes	Yes	Yes	Yes	Yes	Yes			
N	22,447	22,447	22,447	17,859	17,859	17,859			

Notes: All models include country dummies. Standard errors are in parentheses. * ** p < 0.01, * * p < 0.05, * p < 0.1.

water deprivations in the region. Precisely, individuals living in areas with much more severe drought and flooding have experienced relatively higher deprivations compared to their counterparts living in localities with much less severe drought and flooding. Further, we find that the effect of climate change on deprivations is more intense in rural settings compared to urban settings and thus indicate the heterogeneous effect of climate change on deprivations. These findings have several implications policy and practice. First, this study signals that policy should not only merely aim at detecting climate change (occurrence or incidence) but seek to address severity of its hazards. We put forth that mitigating climate change requires a renewed focus on policies that tackle the intensity of climate hazards rather than its incidence.

Again, this study shows that locational heterogeneities exist regarding climate and deprivation outcomes with those in rural areas being largely disadvantaged. This bear implication that policy efforts aimed at ending climate change should be location-specific and not generic. We advocate for climate adaptation and resilience practices as mitigation strategies to climate change impact on deprivations. Specifically, climate resilience policies should be targeted toward rural settings while climate adaptation policies directed toward urban areas. The recent COP27 highlights that keeping global warming around 1.5 °C by 2030 seems not feasible; hence, it has called for urgent climate action. Our study underscores this climate action as an exigency; therefore, there is no time better than now for SSA countries to intensify their efforts in mitigating climate change to ensure that more people do not fall into or remain in the poverty trap which potentially jeopardizes their attainment of sustainable development. We offer some suggestions that can be useful for climate change mitigation in the SSA region. First, there should be reduction in the reliance on non-renewable energy sources (fossil fuels) in SSA countries and more dependence on renewable energy sources (such as solar and wind). Second, recognizing that SSA countries are in a policy dilemma of combating climate change and

Table 12
Severity of climate change and income deprivation by rural-urban dimension.

	(1) Rural	(2)	(3)	(4) Urban	(5)	(6)	(7) Differences (rural-urban)	(8)	(9)
	Once/twice	Many times	Always	Once/twice	Many times	Always	Once/twice	Many times	Always
Drought (ref=much less severe)									
Somewhat less severe	0.017 * *	0.008 * *	0.014 * *	0.010 * **	0.002	0.002	0.007 * **	0.006 * **	0.012 * **
	(0.003)	(0.004)	(0.006)	(0.003)	(0.009)	(0.004)			
Stayed the same	0.018 * *	0.011 * *	0.014 * *	0.012 * **	0.005	0.002	0.006 * **	0.007 * **	0.012 * **
	(0.003)	(0.004)	(0.007)	(0.003)	(0.009)	(0.004)			
Somewhat more severe	0.019 * *	0.018 * *	0.016 * *	0.013 * **	0.010 * **	0.005	0.006 * **	0.008 * **	0.011 * **
	(0.003)	(0.004)	(0.006)	(0.003)	(0.003)	(0.004)			
Much more severe	0.021 * **	0.028 * **	0.031 * **	0.012 * **	0.014 * **	0.018 * **	0.009 * **	0.014 * **	0.013 * **
	(0.003)	(0.003)	(0.006)	(0.003)	(0.008)	(0.004)			
Flooding (ref=much less severe)									
Somewhat less severe	0.003	0.003	0.007	0.000	0.001	0.003	0.003 * **	0.002 * **	0.004 * **
	(0.003)	(0.002)	(0.005)	(0.002)	(0.008)	(0.004)			
Stayed the same	0.007 * *	0.006 * *	0.014 * *	0.003	0.002 * *	0.009 * **	0.004 * *	0.004 * *	0.005 * *
	(0.003)	(0.002)	(0.006)	(0.002)	(0.001)	(0.002)			
Somewhat more severe	0.009 * **	0.009 * **	0.018 * **	0.004 * *	0.005 * **	0.012 * **	0.005 * **	0.005 * **	0.006 * **
	(0.003)	(0.003)	(0.006)	(0.001)	(0.001)	(0.004)			
Much more severe	0.013 * **	0.011 * **	0.023 * **	0.006 * **	0.006 * **	0.015 * **	0.007 * **	0.005 * **	0.008 * **
	(0.003)	(0.002)	(0.001)	(0.000)	(0.001)	(0.004)			
Controls?	Yes	Yes	Yes	Yes	Yes	Yes			
N	22,447	22,447	22,447	17,851	17,851	17,851			

Notes: All models include country dummies. Standard errors are in parentheses. * ** p < 0.01, * * p < 0.05, * p < 0.1.

Table 13
Severity of climate change and water deprivation by rural-urban dimension.

	(1) Rural	(2)	(3)	(4) Urban	(5)	(6)	(7) Differences (rural-urban)	(8)	(9)
	Once/twice	Many times	Always	Once/twice	Many times	Always	Once/twice	Many times	Always
Drought (ref=much less severe)									
Somewhat less severe	0.007 * **	0.027 * **	0.020 * **	0.002 * **	0.024 * **	0.009 * **	0.005 * **	0.003 * **	0.011 * **
	(0.002)	(0.007)	(0.005)	(0.001)	(0.009)	(0.003)			
Stayed the same	0.005 * *	0.027 * **	0.020 * **	0.002 * **	0.024 * *	0.006 * *	0.003 * **	0.003 * *	0.014 * **
	(0.002)	(0.007)	(0.005)	(0.001)	(0.009)	(0.003)			
Somewhat more severe	0.007 * **	0.037 * **	0.028 * **	0.003 * **	0.034 * **	0.010 * **	0.004 * *	0.005 * **	0.018 * **
	(0.002)	(0.007)	(0.005)	(0.001)	(0.008)	(0.003)			
Much more severe	0.012 * **	0.066 * **	0.033 * **	0.002 * **	0.061 * **	0.015 * **	0.010 * **	0.005 * **	0.018 * **
	(0.002)	(0.006)	(0.005)	(0.001)	(0.008)	(0.003)			
Flooding (ref=much less severe)									
Somewhat less severe	0.003 * *	0.006 * *	0.006 * *	0.000	0.002	0.001	0.003 * **	0.004 * **	0.005 * **
	(0.001)	(0.008)	(0.003)	(0.000)	(0.005)	(0.005)			
Stayed the same	0.001	0.004	0.003	0.000	0.002	0.002	0.001	0.002	0.001
	(0.002)	(0.008)	(0.003)	(0.000)	(0.005)	(0.005)			
Somewhat more severe	0.000	0.005	0.005	0.000	0.005	0.004	0.000	0.001	0.001
	(0.002)	(0.008)	(0.003)	(0.000)	(0.006)	(0.005)			
Much more severe	0.001	0.010	0.009	0.000	0.008	0.008	0.001	0.002	0.001
	(0.002)	(0.018)	(0.003)	(0.000)	(0.005)	(0.005)			
Controls?	Yes	Yes	Yes	Yes	Yes	Yes			
N	22,460	22,460	22,460	17,887	17,887	17,887			

Notes: All models include country dummies. Standard errors are in parentheses. * ** p < 0.01, * * p < 0.05, * p < 0.1.

promoting economic growth, it is important for their drive for economic growth to be environmentally sustainable. Put differently, SSA countries should pursue policies promoting green economic growth whilst dealing with climate change. Third, on the part of individuals, we encourage them to adopt greener household technologies. However, these technologies are often too expensive for individuals to afford, and this causes lack of adoption. Thus, we propose that governments in SSA countries should provide subsidies on greener household technologies.

We acknowledge that this research has limitations. The research is limited by data availability. The IPPC has frequently cited drought, flooding, and heat waves as hazards attributable to climate change. However, in our research, we are only able to direct our attention to drought and flooding while failing to consider heat waves due to the dearth of data. Also, the research focuses on 33 out of the 48 countries in the SSA region. We are optimistic that these data limitations would not in any way undermine the outcome of this research. For instance, the incidence of heat waves may not carry considerable implications for the deprivation outcomes given that heatwaves rarely occur in the SSA region. Also, the sample size of 33 countries can serve as a good representation of the SSA region. It is important to state that these data limitations are difficult to overcome because they emanate from the survey that provided the micro-level data for this research.

Declaration of Competing Interest

There is no conflict of interest or whatsoever among the authors.

Data Availability

The authors do not have permission to share data.

Appendix

Table A: Measurement of variables

Food deprivation (never deprived=0, deprived once/twice=1, deprived many times=2, deprived always=3)
Fuel deprivation (never deprived=0, deprived once/twice=1, deprived many times=2, deprived always=3)
Income deprivation (never deprived=0, deprived once/twice=1, deprived many times=2, deprived always=3)
Water deprivation (never deprived=0, deprived once/twice=1, deprived many times=2, deprived always=3)
Drought (much less severed=0, Somewhat less sever=1, Stayed the same=2, Somewhat more severe=3, Much more severe=4)
Flooding (much less severed=0, Somewhat less sever=1, Stayed the same=2, Somewhat more severe=3, Much more severe=4)
Climate Hazard Index (CHI)
Household size (continuous)
Location (urban=1, rural=0)
Female (female=1, male=0)
Age in years
Employment (employed=1, unemployed=0)
Education (no formal education=0, basic education=1, secondary education=2, tertiary education=3)
Real GDP per capita (in US dollars)

Table B. Climate Hazard Index (CHI) via Factor Analysis

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	1.27273	0.54546	0.6364	0.6364
Factor2	0.72727	.	0.3636	1.0000
Retained Factors	1			
N	40,720			

Table C. List of countries

Benin	Gabon	Malawi	Nigeria	Togo
Botswana	Gambia	Mali	São Tomé and Príncipe	Tunisia
Burkina F	Ghana	Mauritius	Senegal	Uganda
Cabo Verd	Guinea	Morocco	Sierra Leone	Zambia
Cameroon	Lesotho	Mozambique	South Africa	Zimbabwe
Côte d'Ivoire	Liberia	Namibia	Sudan	
Eswatini	Madagascar	Niger	Tanzania	

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