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Households' coping mechanisms with droughts and floods using finance, non-finance and the social safety net measures: evidence from Kenya

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Abstract
This study analysed households' use of formal and informal finance, non-finance livelihood diversification and the social safety net measures in coping with droughts and floods. It employed a cross-sectional survey of 1370 households across 27 counties in Kenya that are prone to droughts and floods. Bivariate probit regressions reveal that households employ multiple coping measures related to finance, the social safety net and non-finance choices. The use of coping measures vary by household income, household dependency ratio, geographic and agro-climatic contexts, as well as the household head's age and educational attainment. Further, the findings reveal that the use of the social safety net and non-finance coping mechanisms demonstrate complementarities in coping with droughts, suggesting that opportunities to benefit from the social safety net do not dampen livelihood diversification initiatives by the households. Additionally, households in arid and semi-arid lands (ASALs) depend to a large extent on the social safety net and non-finance livelihood diversification coping mechanisms, signalling the need to explore ways that encourage private sector development in promoting market-oriented coping strategies.

Keywords Climate change · Households · Adaptation · Finance · Social safety net · Resilience · Developing countries

1 Introduction

Over the next six to eight decades, the global surface temperature is projected to rise by up to 1.8 ℃ under low greenhouse gas emissions and 5.7 ℃ under severe greenhouse gas emissions, which will escalate the frequency and severity of climate change-induced hazards (Intergovernmental Panel on Climate Change (IPCC), 2021). Households are adversely impacted by climate change-induced hazards through asset depletion and losses, income disruptions, poor health outcomes and loss of lives (Castells-Quintana et al., 2018). In sub-Saharan Africa (SSA), 70% of economic losses resulting from natural hazards are

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attributed to droughts and floods (Bhavnani et al., 2008). Further, within the last decade, 98 and 92% of the households in countries across SSA report being adversely affected by droughts and floods, respectively (Rahut et al., 2021).

When faced with climate change-induced hazards, households employ various coping mechanisms, including finance, non-finance livelihood diversification choices and the social safety net measures that, in the long term, are expected to strengthen adaptations (Agrawal & Perrin, 2009). However, the use of these coping mechanisms by households, including possibilities of complementary and substitution roles are yet to be adequately investigated in the previous studies (Crick et al., 2018; Rana et al., 2022). Access to finance is important as it may support long-term adaptations through consumption smoothing, which decreases destructive adaptations like distress selling of productive assets, but rather encourages investments in such assets (Abid et al., 2020). Developing countries are characterised by the coexistence of formal and informal finance (Essuman et al., 2020; Johnson, 2004; Nguyen & Canh, 2020). Formal finance is regulated or falls under some form of oversight by the government, for instance savings and borrowings from banks, microfinance institutions, Savings and Credit Cooperatives (SACCOs) and use of insurance, while informal finance operates outside supervisory or regulatory frameworks (Finaccess, 2021; Nguyen & Canh, 2020). Informal finance includes intra- and inter-households' borrowings and savings or borrowings from informal sources such as Rotating Savings and Credit Associations (RoSCAs). Theoretical literature suggests that formal and informal finance can be substitutes or complements depending on the institutional contexts (Madestam, 2014). For instance, weak legal institutions would encourage more usage of informal finance, while in contexts with strong legal institutions, consumer choices tend to be based on other factors such as the costs of accessing and using financial services (Madestam, 2014). While the traditional view of financial dualism assumes discrete or little interaction between formal and informal financial markets, contemporary views suggest more complementary roles to cater for deficiencies in the two segments of the market (Ghate, 1992; Madestam, 2014). Previous studies on households' coping mechanisms with climate change-induced hazards look at formal and informal finance in isolation, or simply do not discern formal and informal finance (Abid et al., 2020; Rahut et al., 2021), thus masking the possibilities of complementary or substitution roles. This is of interest to policymakers and development practitioners considering the impacts of droughts and floods tend to be covariate (Jensen et al., 2017), making sole reliance on informal finance that heavily depends on social networks ineffective (Agrawal & Perrin, 2009; Rana et al., 2022; Silchenko & Murray, 2023).

The cushioning of households against climate change-induced and other shocks through the social safety net measures is also common in developing countries as part of public policy interventions (Beegle et al., 2018; Ndlovu & Ndlovu, 2019; World Bank, 2001, 2018). Developing and transitional economies spend on average 1.5% of GDP on the social safety net interventions to cushion vulnerable households from income and consumption shocks (World Bank, 2018). The social safety nets are non-contributory policy measures to support households cope with vulnerabilities and comprise cash and in-kind transfers, targeted subsidies, public works and social pensions (World Bank, 2018). The social safety net interventions are, however, argued by some scholars and development agencies to create dependency by dampening households' incentives to use market-related mechanisms such as financial instruments, investments in productive assets and labour supply in coping with shocks and poverty alleviation, though these arguments are yet to be adequately supported by empirical evidence (Vera-Cossio, 2022; Weldegebriel & Prowse, 2013; World Food Programme, 2019). Despite these concerns,

use of the social safety net interventions continue to be an important policy instrument in SSA for cushioning households against adverse climate change-induced shocks (Asfaw et al., 2017; Beegle et al., 2018). The lacuna in empirical evidence as to whether households benefiting from the social safety nets are disincentivised to undertake other coping mechanisms including the use of finance and non-finance livelihood diversification measures requires further investigation. Recent literature posits that while the social safety net is seen to be an important policy instrument to mitigate households' vulnerabilities to climate change-induced hazards, supporting literature is still at a nascent stage (Rana et al., 2022).

Beyond finance and the social safety net measures, other avenues for households' coping with climate change-induced hazards include income diversification, stocking food reserves, irrigation, rainwater harvesting and participation in community joint initiatives such as construction of dykes and water pans (Abid et al., 2020; Agrawal & Perrin, 2009; Rahut et al., 2021). These measures are considered sustainable non-finance or livelihood diversification coping mechanisms as opposed to, for example, distress sale of assets, reduced human and health capital investments (e.g. skipping meals, withdrawing children from schooling), or environmental degradation activities such as charcoal burning, which are associated with long-term negative developmental outcomes (Crick et al., 2018; Jensen et al., 2017). In addition to finance and the social safety net coping mechanisms, this article explores the use of sustainable non-finance coping mechanisms. This would help in understanding whether, for example, the social safety net coping mechanisms serve as a complement or substitute role to other forms of sustainable coping measures. For conciseness, the term *non-finance coping mechanism* as used in this article refers to the *sustainable non-finance coping mechanism*.

The novelty of this study is anchored in considering various forms of coping mechanisms with droughts and floods: formal finance, informal finance, the social safety net and non-finance coping mechanisms. Moreover, previous studies mostly investigated households' coping with climate change-induced shocks in the context of farming communities (Abid et al., 2020; Adeagbo et al., 2021; Rahut et al., 2021). In contrast, arid and semi-arid lands (ASALs), one of the key focus areas of this study, is mostly inhabited by nomadic pastoralist communities, characterised by varied traditional practices and economic activities. This institutional context could shape households' adaptations to climate change-induced hazards (Agrawal & Perrin, 2009; Jensen et al., 2017). The disaggregation of households coping mechanisms with climate change-induced hazards is applied to the case of droughts and floods by addressing three research questions: *What are the factors influencing households' use of formal and informal finance in coping with droughts and floods? What are the factors influencing households' use of the social safety net in coping with droughts and floods? Does the use of various coping mechanisms (the social safety net, finance and non-finance) serve complementary or substitute roles in coping with droughts and floods?* Droughts and floods, as referred to in this study, are those related to precipitation levels as discussed in prior studies (Mujumdar et al., 2021; Shibia, 2023). Due to possibilities of using multiple coping strategies by the households (Mulwa et al., 2017), this study employed bivariate probit regressions in answering these research questions. The use of bivariate probit regression is also useful in generating insights on whether the use of various coping mechanisms are complementary or substitute. In particular, it helps in generating insights on whether households benefiting from the social safety net support also undertake finance and non-finance coping mechanisms. Similarly, it is helpful in understanding whether the use of formal and informal finance in coping with droughts and floods is complementary or substitutes by considering correlation among these choices.

2 Data, country context and econometric analysis approach

2.1 Data sources

This study employed a cross-sectional survey of 1370 households in 27 drought- and flood-prone counties (sub-national devolved units) in Kenya. The sample distribution across the 27 counties is shown in Table 1. The selection of the 27 counties was based on the frequency of droughts and floods as reported in the Emergency Events Database (EM-DAT), a widely used disaster information database globally ((UCL)-CRED (2019)). Among the 27 counties, 82% are classified as ASALs, with high exposure to droughts that are often

Table 1 Survey response rates across the sampled counties

(a) County	(b) Aridity level (%)	(c) Number of households	(d) % of sampled households
1. Baringo	30–84	50	3.7
2. Elgeyo Marakwet	10–29	49	3.6
3. West Pokot	30–84	50	3.7
4. Kajiado	30–84	44	3.1
5. Machakos	30–84	69	5.0
6. Isiolo	85–100	40	2.9
7. Marsabit	85–100	50	3.7
8. Samburu	85–100	40	2.9
9. Embu	30–84	50	3.7
10. Tharaka Nithi	30–84	50	3.7
11. Laikipia	30–84	46	3.4
12. Kitui	30–84	60	4.4
13. Garissa	85–100	40	2.9
14. Tana River	85–100	40	2.9
15. Kilifi	30–84	59	4.3
16. Kwale	30–84	49	3.6
17. Mandera	85–100	48	3.5
18. Turkana	85–100	50	3.7
19. Narok	10–29	58	4.2
20. Makueni	30–84	54	3.9
21. Taita Taveta	30–84	37	2.7
22. Homa Bay	10–29	58	4.2
23. Mombasa	< 10	40	2.9
24. Busia	< 10	58	4.2
25. Siaya	< 10	53	3.9
26. Kisumu	< 10	59	4.3
27. Nairobi	< 10	69	5.0
Total		1370	100.0

Source: Column (b) is from the author's compilations based on the Ministry of Devolution and ASAL (2022) classification of ASAL counties. Columns (c) and (d) reflect the distribution of the sampled households

followed by floods (Ministry of Devolution & ASAL, 2022). The predominantly ASAL counties are shown in Fig. 1. The other 18% of the counties are prone to floods, but they also face increasing incidences of droughts.

The households within the covered counties were randomly selected and questionnaires were administered during a survey undertaken in the months of February and March of 2018. The survey was undertaken by the Kenya Institute for Public Policy Research and Analysis (KIPPRA) to explore households' resilience and coping mechanisms with the impacts of droughts and floods. The questionnaire was designed with various modules,

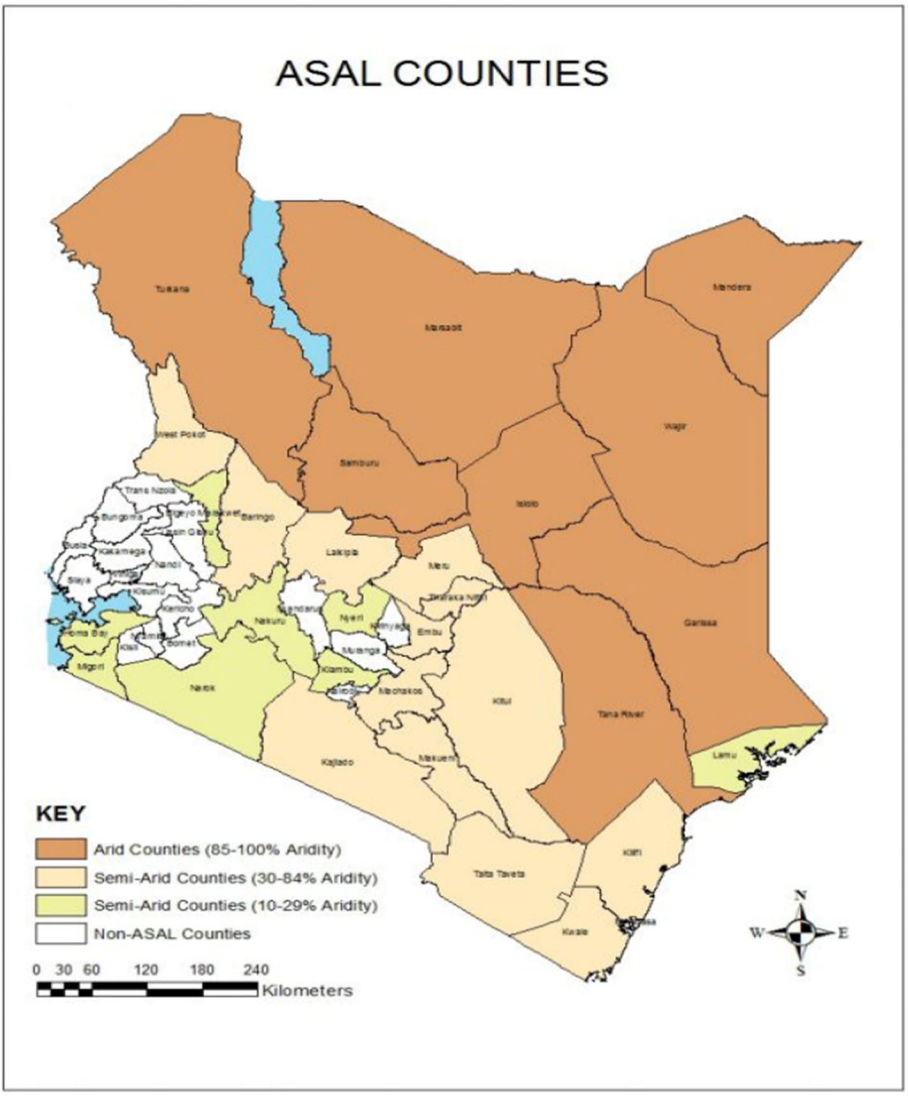

Fig. 1 Map illustrating the distribution of ASALs in Kenya. *Source*: Illustration based on Ministry of Devolution and ASAL (2022)

including coping measures used by households to manage the adverse impacts of droughts and floods. These included finance, non-finance and the social safety net measures. Further, the questionnaire covered household characteristics like age, gender, educational attainment and main economic activities. Other characteristics on which data were collected included access to weather information and the impacts of droughts and floods on livelihoods and infrastructure. Moreover, given that ASAL counties in Kenya are prone to perennial conflicts among the pastoral communities, the implications of droughts and floods on conflict were also considered, as this could be linked to resource scarcity. The focus of this study was, however, on variables related to coping mechanisms, including finance, non-finance and the social safety net.

2.2 Country context

Kenya is one of the economies within SSA, located in the East African region. It operates a devolved governance structure comprising the national government, together with 47 subnational county governments spread across varied agro-climatic zones. Kenya's economy is categorised as a lower middle-income country with a GDP per capita of US$2007 in 2021 (World Bank, 2022). The structure of the economy comprises the agriculture (22%), industrial (17%), trade (8%) and service (45%) sectors (Kenya National Bureau of Statistics, 2022). Food and beverage activities account for 55% of manufacturing GDP, signalling strong linkages to agriculture. Further, agricultural produce accounts for two-thirds of the country's exports and 60% of jobs among rural households is in the agriculture sector (Kenya National Bureau of Statistics, 2016), suggesting that shocks to this sector have severe implications for the households' livelihoods. A notable feature is also that agriculture activities are mainly rain-fed and comprise the growing of crops and animal production at 88% (Kenya National Bureau of Statistics, 2022). The Kenyan economy is, therefore, highly vulnerable to climate change-induced shocks, losing on average 6–8% of its national income every seven years due to losses inflicted by droughts and floods (Government of Kenya, 2017). Moreover, 27% of the country's households are negatively affected by droughts and floods (Kenya National Bureau of Statistics, 2018). Among these households, 43% reported income losses, and 13% reported asset losses, with one in every 10 households reporting they suffered both income and asset losses (Kenya National Bureau of Statistics, 2018). Figures 2 and 3 show trends in the impacts of these climate change-induced hazards since 1960 in terms of incidences and the number of people affected. Evidently, the recurrence of these hazards and the number of households affected have been increasing, especially since the 1990s.

Households' access to financial services in Kenya has improved substantially within the last decade. In 2006, the proportions of the adult population using formal and informal financial services were 27 and 41%, respectively, and 32% were excluded from any form of financial service (Finaccess, 2021). As of 2021, the use of formal finance has increased to 84%, while the use of informal finance and those who are financially excluded stood at 5 and 11%, respectively (Finaccess, 2021). These increased usages of financial services are mainly on account of payment services, owing to the growth of mobile money payment services, while the use of insurance and credit markets remain depressed. The national government operates a social safety net programme in the form of cash transfers to poor and vulnerable households, co-financed by development partners. During shocks such as droughts, the number of households benefiting from the social safety nets is scaled up,

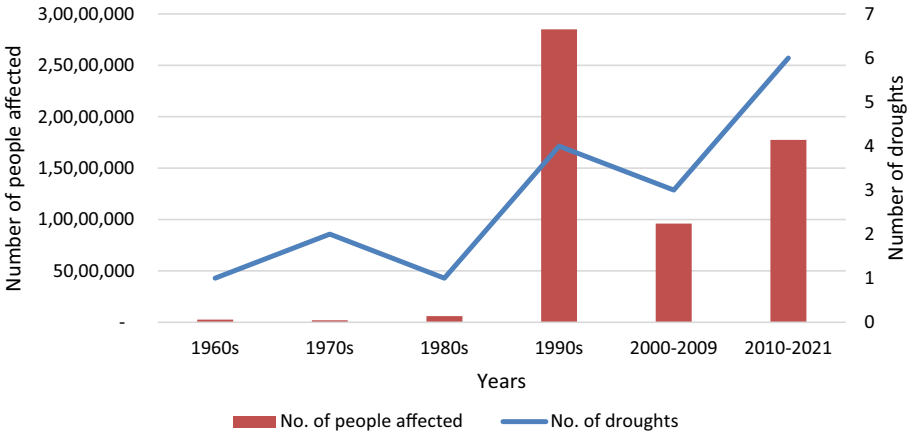

Fig. 2 Incidences of droughts and people affected, 1960–2021 (Kenya) (UCL)-CRED (2021) *Source*: Author's illustration from Université Catholique de Louvain

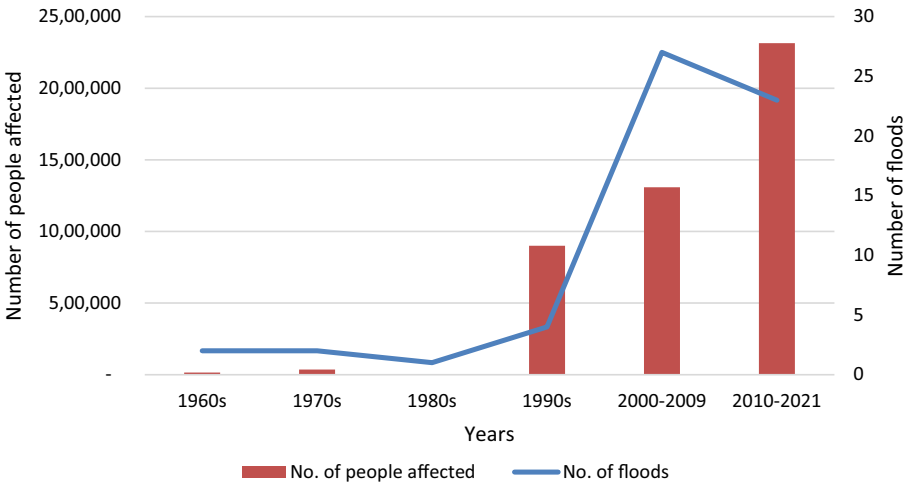

Fig. 3 Incidences of floods and people affected, 1960–2021 (Kenya). (UCL)-CRED (2021) *Source*: Author's illustration from Université Catholique de Louvain

particularly in the ASALs. The county governments in the affected areas also provide support in the form of cash transfers, in-kind support and public works.

2.3 Econometric model

Given that households employ multiple measures to cope with climate change-induced hazards (Mulwa et al., 2017), this study utilised bivariate probit models to concurrently estimate probabilities that households employ two decisions simultaneously. The observed outcomes of bivariate probit regressions are obtained based on the underlying latent variables (Greene, 2018) as follows:

$$y_1^* = \boldsymbol{x}_1^{'}\boldsymbol{\beta}_1 + \boldsymbol{\varepsilon}_1, y_1 = 1(y_1^* > 0), \tag{1a}$$

$$y_2^* = \boldsymbol{x}_2^{'}\boldsymbol{\beta}_2 + \boldsymbol{\varepsilon}_2, y_2 = 1(y_2^* > 0), \tag{1b}$$

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} |\boldsymbol{x}_1, \boldsymbol{x}_2 \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right] \tag{1c}$$

with normally and jointly distributed errors as follows: $E(\varepsilon_1) = E(\varepsilon_2) = 0$; $var(\varepsilon_1) = var(\varepsilon_2) = 1$; and c $ov(\varepsilon_1, \varepsilon_2) = \rho$. The parameters, $\boldsymbol{\beta}_s$ and ρ, are obtained through maximum likelihood methods, such that ρ is a conditional tetrachoric (correlation or 'rater agreement' for two dichotomous variables, y_1 and y_2). The vector $\boldsymbol{x}$ comprises the covariates that include household characteristics, agro-climatic and locational variables. The simultaneously determined dependent variables, y_1 and y_2, refer to the coping measures. The inclusion of the vector $\boldsymbol{x}$ was as per the extant empirical literature and theory. For instance, the frameworks suggesting households' consumption smoothing behaviour (Morduch, 1995) and theories related to the life cycle of consumption behaviour (Modigliani & Brumberg, 1980) suggest that financial choices made by individuals change with the life cycle. Thus, financial choices such as savings are projected to increase during productive years, but subsequently diminish over time. Therefore, the age of an individual is considered a relevant variable in the choice of coping measures. The use of coping mechanisms could also depend on exposures such as agro-climatic and socio-economic factors (Shiferaw, et al., 2014), given that the impacts of climate change-induced hazards vary with these conditions. The bivariate probit model leads to the following possible probabilities:

$$P_{00} = P(y_1 = 0, y_2 = 0)$$

$$P_{10} = P(y_1 = 1, y_2 = 0)$$

$$P_{01} = P(y_1 = 0, y_2 = 1)$$

$$P_{11} = P(y_1 = 1, y_2 = 1)$$

The probabilities of using different coping mechanisms (finance, non-finance and the social safety net) in conjunction are symbolised by P_{00}, P_{10}, P_{01} and P_{11}, whereP_{00} means neither y_1 nor y_2 are selected; P_{10} means only y_1 is selected, but not y_2; P_{01} means only y_2 is selected, but not y_1; and finally, P_{11} means both y_1 and y_2 are selected. There are four sets of estimations corresponding to these probabilities, as shown in Table 2, estimated separately for the droughts and floods.

For each of the four coping measures shown in Table 2, latent variable models are estimated, which serve as the basis for bivariate probit model observed outcomes as illustrated in equations $1a - 1c$:

$$\begin{aligned} y_{1i}^* = {} & \beta_0 + \beta_1 \text{cluster}_i + \beta_2 \text{hhsize}_i + \beta_3 \text{hhincome}_i \\ & + \beta_4 \text{educ}_i + \beta_5 \text{age}_i + \beta_6 \text{agesq}_i + \beta_7 \text{gender}_i + \beta_8 \text{asal}_i + \varepsilon_i \end{aligned} \tag{2a}$$

Table 2 Possible bivariate probit model outcomes and choice of coping measures

Coping measures	Bivariate probit model possible outcomes
Formal finance and informal finance (y_1= Formal finance; y_2=Informal finance)	P_{00}: use neither formal nor informal finance
	P_{10}: use only formal finance
	P_{01}: use only informal finance
	P_{11}: use both formal and informal finance
Social safety net and formal finance (y_1=Social safety net; y_2=Formal finance)	P_{00}: use neither the social safety net nor formal finance
	P_{10}: use only the social safety net
	P_{01}: use only formal finance
	P_{11}: use both the social safety net and formal finance
Social safety net and informal finance (y_1=Social safety net; y_2=Informal finance)	P_{00}: use neither the social safety net nor informal finance
	P_{10}: use only the social safety net
	P_{01}: use only informal finance
	P_{11}: use both the social safety net and informal finance
Social safety net and non-finance (y_1=Social safety net; y_2=non-finance)	P_{00}: use neither the social safety net nor non-finance
	P_{10}: use only the social safety net
	P_{01}: use only non-finance
	P_{11}: use both the social safety net and non-finance

Source: author's construct

$$y_{2i}^{*} = \alpha_0 + \alpha_1 \text{cluster}_i + \alpha_2 \text{hhsize}_i + \alpha_3 \text{hhincome}_i + \alpha_4 \text{educ}_i + \alpha_5 \text{age}_i + \alpha_6 \text{agesq}_i + \alpha_7 \text{gender}_i + \alpha_8 \text{asal}_i + u_i. \quad (2b)$$

2.4 Variable measurements for regression analysis

The variable definitions and their measurements are provided in Table 3. The analyses first proceed with the use of formal finance and then go on to the analyses of informal finance, before turning the focus to the use of the social safety nets in conjunction with other choices.

3 Results and discussions

3.1 3.1 Summary statistics

The summary statistics for valid responses regarding the explanatory variables are provided in Table 4. The distribution of the sampled households between urban and rural clusters are almost equally distributed, with 48.2% residing in urban areas. The average number of household income earners is 1.2, which is much lower than the average number of household members at 4.9, suggesting a high dependency ratio. As shown in previous studies, a high dependency ratio erodes capacity to adapt to climate change, thus weakening the resilience of households (Adeagbo et al., 2021). With regard to education level,

Table 3 Variable definitions and their measurements

Dependent variables
Model 1: Formal finance and informal finance measures: If the household reported to employ any form of formal finance it was assigned 1, or else 0. Similarly, if a household reported to employ any form of informal finance it was assigned 1, or else 0. Formal finance includes savings and borrowings from banks, SACCOs, microfinance institutions, crop and livestock insurance, and investments in capital market instruments for coping with droughts and floods. Informal finance includes savings and borrowings from family, friends, shylocks, informal groups and savings outside formal financial institutions such as secret places (also known as 'saving under the mattresses')
Model 2: The social safety net and formal finance: If a household reported to employ any form of the social safety net it was assigned 1, or else 0. Likewise, if a household reported to employ any form of formal finance it was assigned 1, or else 0. The social safety net includes government cash transfers, in-kind transfers (e.g. food), targeted subsidies for basic need products and participation in public works for food or cash support
Model 3: The social safety net and informal non-finance: If a household reported to employ any form of the social safety net it was assigned 1, or else 0. Similarly, if a household reported to employ any form of informal finance, it was assigned 1, or else 0
Model 4: The social safety net and non-finance coping mechanisms: If a household reported to rely on any form of the social safety net it was assigned 1, or else 0. The adoption of any form of sustainable non-finance measure was likewise assigned 1, or else 0. Sustainable non-finance coping mechanisms includes membership of community initiatives such as infrastructure (e.g. dykes, dams, water pans), investments in productive physical assets, rainwater harvesting, food stocking and livelihood diversification
Explanatory variables
cluster : The *cluster* variable represents households' locational residence: coded 1 for urban and 0 for rural. The categorisation of urban and rural locations is based on classifications by the Kenya's national statistical agency (Kenya National Bureau of Statistics, 2018): Rural areas are expansive agricultural land with population of less than 2000 people while urban areas are characterised by high concentration of economic activities, with built-up and compact human settlement of 2000 people or more. Urban *cluster* is postulated to positively influence use of formal finance owing to access to formal financial institutions within urban settings. In contrast, informal finance is expected to be dominant in rural areas. Some elements of the social safety net such as cash transfers are dominant in rural areas, but subsidies, public works for cash or food, and school feeding programmes are also common in urban clusters
hhsize : A large household size (*hhsize*) is expected to lower use of formal finance, but increases use of other coping mechanisms such as the social safety net. For instance, a large household size increases dependency ratio that require support in form of the social safety net
hhincome : Household income proxied by the number of household income earners. A priori, a higher household income is conjectured to positively affect the use of formal finance measures as well as adoption of non-finance measures, but negative effects with regard to using informal finance and the social safety net
educ : Number of years of education completed, reflecting improvements in human capital is expected to have positive effects on the adoption of formal finance, as well as non-finance measures such as the ability to diversify into alternative sources of livelihoods. However, this variable is expected to lower the adoption of informal finance coping mechanisms
age : This variable measures household head's age in years. Considering prediction of the life cycle theory, choice of formal finance would increase with age, but beyond some level the relationship could turn negative. An opposite relationship is expected for the use of informal finance
agesq : This variable is included to control for any nonlinearity in the variable age as defined above
gender : This variable is coded 1 for male and 0 for female to control for sex attributes of head the household. In line with the general literature on access to finance, male-headed households are priori expected to adopt formal finance for coping with climate change-induced hazards. In contrast, female-headed households are expected to have a higher adoption of informal finance, considering their deep-rooted informal social networks within developing country contexts (Gannon et al., 2022; Johnson, 2004)

Table 3 (continued)

Dependent variables
asal : An emerging area of research interest in climate change adaptations strategies and coping mechanisms is the role of agro-climatic contexts as it contributes to exposure of the households to hazards (Aryal et al., 2021; Rahut et al., 2021). This study controls for the agro-climatic contexts by distinguishing arid and semi-arid lands (ASALs) and further considers different levels of aridity, that is, the long-term dryness in relation to the soil moisture of a region resulting from low precipitation and high temperature (Zomer et al., 2022). The counties' ASAL classification is an agro-climatic variable, for which households residing within non-ASAL zones are coded 0. Residence in areas with aridity of 10 – 29% was coded 1 while residence in aridity of 30 – 84% was coded 2. Finally, residence in extreme aridity of 85 – 100% was coded 3. Extreme weather events, particularly droughts within ASALs are expected to trigger households to employ a mix of coping strategies (Crick et al., 2018), including the social safety net, informal finance and non-finance measures

Source: Author's compilation

the mean of 8.4 years suggests that the majority of the sampled households are headed by persons having only primary education (8 years in Kenya). A related study established the average education level for household heads at 8.1 years for five Eastern and Southern African countries (Rahut et al., 2021), suggesting regional similarities. The majority of the sampled households are headed by male (74.6%), which closely mirrors the national average of male-headed households at 67.6% (Kenya National Bureau of Statistics, 2018). Other related studies have established proportions of female-headed households at 26.0% for Kenya and 18.0% for a sample of Eastern and Southern African countries (Rahut et al., 2021). The higher proportion of male-headed households in the sample reflects the fact that the majority of the ASAL counties covered by this study are inhabited by pastoral communities with strong patriarchal cultural values (McPeak & Doss, 2006; Miedema et al., 2018). By agro-climatic distributions, only 44.3% of the sampled households reside in non-ASAL areas, with the majority 55.7% residing in ASAL areas with varying levels of aridity, as earlier illustrated in Fig. 1 and Table 1. Households residing in ASALs with an aridity level of 30% or more are 45.8%, suggesting high exposure and vulnerability to climate change-induced hazards. The average age of the household head at 45.1 years closely mirrors that of prior studies at 48.3 years for five Eastern and Southern African countries (Rahut et al., 2021).

3.1.1 Use of finance coping mechanisms

Among the sampled households, 87.0% reported using finance to cope with droughts and floods. Further disaggregation reveals that this overall usage of financial services was on account of informal finance use, reported by 74.0% of the sampled households compared to 12.7% who reported to employ formal finance. The low adoption of credit instruments, particularly within the formal financial services in coping with droughts and floods, corroborates related studies within SSA (Abid et al., 2020), with negative implications on consumption smoothing and investments in productive assets.

Further, the employment of formal finance among rural households was established to be only 7.6%, compared to 18.2% for those residing in urban areas, revealing rural–urban disparities. The analyses further reveal gaps by gender of the household head, an indication of related institutional and cultural barriers that may exist (Gannon et al., 2022; Johnson, 2004). For instance, 15.4% of female-headed households reported using neither formal nor

Table 4 Descriptive statistics for explanatory variables

Explanatory variables	Observation	Mean	Standard deviation	Minimum	Maximum	Frequencies for categorical variables
cluster	1369	0.4820	0.4860	0	1	Urban = 48.2%
						Rural = 51.8%
hhsize	1370	4.9320	0.0863	1	22	n/a
hhincome	1357	1.2290	0.0362	0	10	n/a
educ	1357	8.4266	0.1601	0	23	n/a
age	1351	45.0802	0.5623	16	100	n/a
gender	1369	0.7462	0.0193	0	1	Male = 74.6%
						Female = 25.4%
asal	1370	1.1091	1.0822	0	3	Non-ASAL = 44.3%
						10–29% aridity = 9.9%
						30–84% aridity = 36.4%
						85–100% aridity = 9.4%

Source: author's calculations based on KIPPRA survey data

informal finance, compared to male-headed households at 12.8%. This gender gap reveals that households headed by females are disproportionately vulnerable due to limited options in coping with weather-related shocks (Gannon et al., 2022).

3.1.2 Use of the social safety net and non-finance coping mechanisms

A large proportion of the sampled households (76.3%) reported to rely on the social safety net as a coping mechanism, while 46.2% reported to use non-finance coping mechanisms such as income diversification, stocking of food reserves, irrigation, rainwater harvesting and participation in community joint initiatives such as the construction of dykes in flood-prone areas and water pans in ASALs. However, the use of these coping mechanisms varies with aridity levels. Only 58.5% of non-ASAL households reported using the social safety net, compared to 71.0, 94.3 and 96.1% of those residing in areas with aridity levels of 10–29, 30–84 and 85–100%, respectively. This is in line with the targeting of the social safety net to those considered to be the most vulnerable (Rahut et al., 2021; Rana et al., 2022; World Bank, 2018). The use of non-finance coping mechanisms initially increases with aridity levels, but diminishes at much higher levels of aridity. Among the non-ASAL households, 31.2% reported to have adopted non-finance coping mechanisms compared to 41.4 and 64.4% for those residing in agro-climatic zones with aridity levels of 10–29 and 30–84%, respectively. Among the households residing in areas with aridity levels of 85–100%, the adoption of non-finance coping mechanisms falls to 51.4%. This finding reflects that while there is a push for non-finance coping mechanisms, the households are constrained beyond some limit due to factors such as poverty (Fankhauser & McDermott, 2014; Tran, 2015). Majority of the households residing in Kenya's ASALs are poor (Kenya National Bureau of Statistics, 2018) and therefore face severe impacts of climate change-induced hazards associated with high levels of aridity.

3.2 Regression results

Bivariate probit models were used to analyse the coping mechanisms employed by the sampled households, except in cases where econometric diagnostic tests suggest the use of the binary univariate probit model is ideal.

3.2.1 Determinants of droughts coping mechanisms

The bivariate probit's correlation, $\rho = -0.0985$, was found to be statistically insignificant Prob > $\text{chi}^2 = 0.3985$) in relation to the use of formal and informal finance. This suggests that the substitution between formal and informal finance as shown by the negative ρ is not statistically significant, hence supporting the use of univariate probit model. Regarding the use of the social safety net in conjunction with non-finance coping mechanisms, $\rho = 0.3836$ is statistically significant (Prob > $\text{chi}^2 = 0.0000$), hence supporting the use of the bivariate probit model. This finding also implies that the social safety net does not dampen households' use of non-finance coping mechanisms such as livelihood diversification and investments in productive assets, but rather complements. This is in line with recent literature that challenges claims that access to the social safety net like cash transfers and subsidies create household dependencies, which dampen the adoption of other resilience-enhancing coping mechanisms (Beegle et al., 2018; Rana et al., 2022). The joint usage of the social safety net and formal finance is statistically significant (Prob > $\text{chi}^2 = 0.0000$), but ρ is

negative ($\rho = -0.5416$); thus, the application of bivariate probit model was considered appropriate. The negative coefficient for ρ implies that the use of the social safety net and formal finance tend to be substitutes, and this could be due to the fact that by policy design, the social safety net interventions target the poorest and most vulnerable households that are unable to access formal financial services and other market-based coping mechanisms (Beegle et al., 2018). The cross-sectional nature of this study does not allow for dynamic analysis over time to establish whether households benefiting from the social safety nets are eventually able to transition to formal finance for coping with droughts. Nonetheless, a recent systematic review of the literature hints that use of the social safety net could support transformative adaptations, though more empirical evidence is needed to support this argument (Rana et al., 2022). The joint usage of the social safety net and informal finance was found to be statistically insignificant (Prob > $chi^2 = 0.1682$), although ρ is negative ($\rho = -0.8290$); thus, the use of the bivariate probit model was considered inappropriate. The negative ρ implies that use of the social safety net and informal finance usage tend to be substitutes, though not statistically significant. It is possible that households receiving the social safety nets are cushioned from depending on informal finance that heavily hinges on ineffective social networks in the face of covariate shocks.

Table 5 provides the regression results for the households' coping mechanisms with droughts. The univariate probit marginal effects reveal that the use of formal finance is higher among households residing in urban areas, those having more income earners and those with household heads having more years of education. These results corroborate overall trends in utilisation of financial services (Finaccess, 2021). A larger household size lowers the use of formal finance as coping mechanisms, suggesting the burden of a higher dependency ratio in climate change adaptations (Adeagbo et al., 2021; Ofosu et al., 2022). More years of formal education enhance capacity to respond to climate change (Rahut et al., 2021), which could explain higher usage of formal finance. Regarding the use of informal finance separately, the important variables are the age of the household head and its squared term. While the marginal effects for the age variable have a positive sign that is statistically significant, its squared term shows a negative relationship, implying that the use of informal finance first increases with age of the household head, but decreases at a much older age. These age relationships in the use of finance coping mechanisms corroborate the life cycle hypothesis (Modigliani & Brumberg, 1980) that predicts financial behaviour is dependent on an individual's life cycle, for instance, increasing savings rate during active years that tends to diminish over time. The use of the social safety net in isolation is positively influenced by residence in areas with higher aridity levels, urban residence and the household head's years of formal education. The use of non-finance measure is positively influenced by a higher number of household income earners, more years of formal education and residence in locations with higher levels of aridity. The role of educational attainment corroborates prior studies (Rahut et al., 2021), which show that households with more years of formal education have a lower probability of engaging in unsustainable coping mechanisms such as reduced consumption or, conversely, higher probability of undertaking more sustainable measures such as diversification of livelihood sources. Higher levels of aridity create exposure to extreme drought incidences, and this may trigger households to seek livelihood diversification strategies as a survival mechanism (Crick et al., 2018).

When considering the use of the social safety net jointly with formal finance, the latter is positively influenced by residence in urban clusters and areas characterised with low aridity, although at higher levels of aridity the relationship becomes negative but not statistically significant. The use of the social safety net is positively influenced by household

Table 5 Regression marginal effects for droughts coping measures

Explanatory variables	Univariate Probit marginal effects				Bivariate Probit: Social safety net and formal finance measures				Bivariate Probit: Social safety net and non-finance measures			
	Formal finance	Informal finance	Social safety net	Non-finance	*P*(00) Neither social safety net nor formal finance	*P*(01) Formal finance	*P*(10) Social safety net	*P*(11) Social safety net and formal finance	*P*(00) Neither social safety net nor non-finance	*P*(01) Non-finance	*P*(10) Social safety net	*P*(11) Social safety net and non-finance
cluster: Urban	0.1260*** (0.0420)	0.0081 (0.0270)	0.216*** (0.0329)	− 0.0599 (0.0403)	0.00416 (0.00443)	0.0172** (0.00778)	− 0.129*** (0.0417)	0.108*** (0.0403)	− 0.126*** (0.0256)	− 0.0796*** (0.0154)	0.185*** (0.0355)	0.0202 (0.0352)
hhsize	− 0.0158* (0.0089)	0.0045 (0.0081)	− 0.00656 (0.00641)	− 0.00635 (0.00806)	0.000931 (0.000723)	0.000790 (0.00133)	0.0145* (0.00877)	− 0.0163* (0.00859)	0.00566 (0.00506)	0.000823 (0.00231)	5.71e− 05 (0.00699)	− 0.00654 (0.00694)
hhincome	0.0414** (0.0202)	0.0062 (0.0169)	0.00959 (0.0160)	0.0569*** (0.0208	− 0.00472* (0.00275)	− 0.00679 (0.00488)	− 0.0373* (0.0202)	0.0488** (0.0197)	− 0.0202 (0.0140)	0.00799* (0.00464)	− 0.0370** (0.0145)	0.0492** (0.0199)
educ	0.0269*** (0.0042)	− 0.0020 (0.0032)	0.0123*** (0.00403)	0.0116** (0.00457)	− 0.000835 (0.000635)	0.000296 (0.00107)	− 0.0262*** (0.00428)	0.0268*** (0.00410)	− 0.0112*** (0.00319)	− 0.00153 (0.00145)	− 0.000430 (0.00434)	0.0131*** (0.00397)
age	0.0063 (0.0075)	0.0129** (0.0052)	− 0.00507 (0.00578)	0.0108 (0.00670)	0.000610 (0.000686)	0.00178 (0.00170)	− 0.00703 (0.00749)	0.00464 (0.00717)	0.00204 (0.00431)	0.00391* (0.00234)	− 0.0122* (0.00652)	0.00622 (0.00552)
agesq	− 4.48e− 05 (7.23e− 05)	− 0.000129*** (4.73e− 05)	5.51e− 05 (5.46e− 05)	− 9.03e− 05 (6.17e− 05)	− 6.62e− 06 (7.08e− 06)	− 1.75e− 05 (1.71e− 05)	5.26e− 05 (7.21e− 05)	− 2.85e− 05 (6.88e− 05)	− 2.69e− 05 (4.10e− 05)	− 3.69e− 05* (2.20e− 05)	0.000111* (6.07e− 05)	− 4.73e− 05 (5.10e− 05)
gender: Male	0.0544 (0.0548)	0.0578 (0.0375)	− 0.0296 (0.0356)	− 0.0524 (0.0511)	− 0.00477 (0.00630)	− 0.00507 (0.0135)	− 0.0482 (0.0554)	0.0581 (0.0513)	0.0320 (0.0289)	− 0.000247 (0.0127)	0.0188 (0.0402)	− 0.0505 (0.0457)
asal: 10–29% aridity	0.0657 (0.0697)	− 0.0173 (0.0525)	0.330*** (0.0452)	0.0912 (0.0557)	0.0288*** (0.0105)	0.0620** (0.0249)	− 0.0975 (0.0688)	0.00678 (0.0649)	− 0.253*** (0.0414)	− 0.0696*** (0.0207)	0.164*** (0.0436)	0.158*** (0.0463)
asal : 30–84% aridity	0.0091 (0.0584)	0.0366 (0.0412)	0.524*** (0.0305)	0.345*** (0.0431)	0.000380 (0.00447)	0.00139 (0.0100)	− 0.0104 (0.0579)	0.00862 (0.0562)	− 0.405*** (0.0307)	− 0.104*** (0.0178)	0.0584* (0.0340)	0.451*** (0.0337)
asal 85–100% aridity	− 0.0777 (0.0651)	0.0296 (0.0477)	0.554*** (0.0299)	0.307*** (0.0549)	− 0.00280 (0.00573)	− 0.00856 (0.0111)	0.0814 (0.0649)	− 0.0700 (0.0628)	− 0.426*** (0.0305)	− 0.118*** (0.0179)	0.118** (0.0484)	0.426*** (0.0485)
Observations	1053	1061	1324	1324	1053	1053	1053	1053	1324	1324	1324	1324

Source: own estimations based on KIPPRA survey data; in parentheses are standard errors; with significance levels for marginal effects shown as ***$p<0.01$, **$p<0.05$, *$p<0.1$; base for categorical variables: cluster: rural, gender: female and aridity: non− ASALs

size and negatively influenced by urban clusters, a larger number of household income earners and the educational attainment of the household head. A larger household size increases dependency ratio and therefore vulnerabilities that warrant the social safety net support, which contrasts with the number of household income earners. The joint usage of the social safety net with formal finance is positively influenced by residence in urban clusters, a larger number of household income earners and the household head's educational attainment, but negatively by household size.

With regard to the use of the social safety net in conjunction with non− finance measures, the latter is positively influenced by additional members of household income earners but negatively influenced by residence in urban clusters, the squared age variable (although the magnitude of marginal effects is very small) and residence in areas with higher levels of aridity, with the magnitude of marginal effects increasing with higher levels of aridity. Having elderly household heads is associated with lower usage of non-finance coping measures such as income diversification, investments in productive assets and employment choices, which can be explained by factors such as limited skills and fragile health conditions at an older age (Rahut et al., 2021). The use of the social safety net only is positively influenced by residence in urban clusters, the squared age variable (though again with a small magnitude of marginal effects) and residence in areas with higher levels of aridity. On the contrary, the use of the social safety net only is negatively influenced by additional household income earners and the age variable. The joint use of the social safety net and non-finance coping mechanisms is positively influenced by more household income earners and residence in locations classified as arid.

3.2.2 Determinants of floods coping mechanisms

The correlation, ρ, among the different coping mechanisms were all found to be statistically significant, suggesting the appropriateness of using bivariate probit regressions. The correlation, ρ, for the use of formal and informal finance was statistically significant ($Prob > chi^2 = 0.0000$), with a negative sign (−0.8132). This suggests the substitutability of using formal and informal finance in coping with floods. This is in line with prior studies that found the two forms of finance can be substitutes or complements, with the possibility of substitution increasing where there are segmented markets and a less competitive formal financial sector (Madestam, 2014). Further, households with access to formal finance may not consider using informal finance, which is ineffective in the face of covariate shocks. The correlation, ρ, for the use of the social safety net and non-finance coping measures was found to be negative (−0.6885) and statistically significant ($Prob > chi^2 = 0.0046$). This also suggests the substitutability of using the social safety net and non-finance coping mechanisms with floods. The explanation here can be due to the social safety net interventions targeting the most vulnerable households (Rahut et al., 2021; World Bank, 2018), such as those residing in ASALs where settlement is expansive, with lower vulnerability to floods. Another perspective is that flood hazards are more sporadic within specific geographical locations, such as urban locations and areas closer to river banks, with limited options for livelihood diversification. As shown in previous studies (Ofosu et al., 2022), households affected by floods within SSA contexts employ measures such as temporary relocations or moving to elevated grounds; placing household assets on elevated structures, dredging and desilting of waterways, use of sandbags; and modification of household building materials to reduce soaking when floods occur—all being short-term coping measures that are not directly related to livelihood diversifications. Further, permanent

relocation as a coping mechanism with floods is constrained by cost barriers and emotional attachments to the communities in which the households live (Ofosu et al., 2022). These barriers limit livelihood diversifications of households affected by floods.

The correlation, ρ, for the use of the social safety net and formal finance measures demonstrates negative relationships (−0.8560) that is statistically significant ($Prob > chi^2 = 0.0000$). The negative ρ implies that the usage of the social safety net and formal finance tends to be substitutes, and this can be due to the social safety net interventions targeting the poorest households who are unable to access formal finance and other market-based coping mechanisms (Beegle et al., 2018). The cross-sectional nature of this study does not allow for dynamic analysis to establish whether households benefiting from the social safety nets are able to transition to formal finance and other market-related coping measures. In terms of the reliance on the social safety net, together with informal finance, the correlation, ρ, shows a positive relationship (0.8253) and is statistically significant ($Prob > chi^2 = 0.0000$), suggesting complementarity between the two coping measures. As discussed in prior studies, households leverage reciprocal relationships anchored on social networks in the form of financial and material support from families and friends when faced with flood hazards (Ofosu et al., 2022). Thus, households can use informal finance to complement gaps that remain to be filled by any available social safety net support. On comparative perspectives, the magnitude of covariate impacts of floods in Kenya may be lower than that of droughts, providing opportunities to still utilise informal finance by leveraging available social networks. This is also considering that floods tend to be relatively sporadic, compared to droughts that tend to be protracted.

Turning focus to the formal and informal finance coping mechanisms, Table 6 reveals that for the use of informal finance only, households within ASALs with aridity levels of 30–84% have a higher incidence of utilisation relative to those in non-ASALs. Considering the adoption of only formal finance measures, urban residence and a larger household size lower the probabilities of usage. The sporadic and rapid-onset nature of floods can slow down use of formal finance such as credit instruments due to the lengthy screening process involved. However, for households in ASALs, the probability of using formal finance relative to those in non-ASALs is initially lower for 30–84% aridity, but becomes positive for aridity levels of 85–100%. The results with regard to the combined adoption of formal and informal finance show that urban households as well as larger households have a higher chance of usage. On the other hand, the probability of combined use of formal and informal finance for ASAL households compared to those in non-ASALs was established to be initially lower (for 10–29% aridity), higher for 30–84% aridity and lower for aridity levels of 85–100%.

With regard to the reliance on the social safety net and non-finance measures, the use of non-finance measures only is positively influenced by the squared age variable and negatively by residence in urban clusters, the age variable and residence within semi-arid areas of 30–84% aridity. The usage of the social safety net only was established to be positively influenced by residence in urban clusters. The combined adoption of the social safety net with non-finance coping measures is positively influenced by residence in urban clusters, the age variable and residence within agro-climatic zones having 30–84% aridity. A marginal increase in the squared term of the age variable is, however, associated with a negative change in probability for a combined usage of the social safety net and non-finance measures.

With regard to using the social safety net and formal finance, residence in urban clusters, the household head's additional age and residence in areas with an aridity of 30–84% lower the usage of formal finance only. The squared age variable lowers the probability of

Table 6 Regression marginal effects for floods coping measures

Explanatory variables	Formal finance and informal finance				Social safety net and non-finance				Social safety net and formal finance				Social safety net and informal finance			
	Neither formal nor informal finance	Informal finance	Formal finance	Formal and informal finance	Neither social safety net nor non-finance	Non-finance	Social safety net	Social safety net and non-finance	Neither social safety net nor formal finance	Formal finance	Social safety net	Social safety net and formal finance	Neither social safety net nor informal finance	Informal finance	Social safety net	Social safety net and informal finance
cluster: Urban	− 0.0103 (0.00662)	0.00803 (0.0212)	− 0.170*** (0.0589)	0.172*** (0.0545)	0.00839 (0.00627)	− 0.202*** (0.0513)	0.0325* (0.0188)	0.161*** (0.0482)	− 0.00294 (0.00368)	− 0.189*** (0.0502)	0.0169 (0.0136)	0.175*** (0.0476)	− 0.222*** (0.0649)	0.0559 (0.0410)	0.0444*** (0.0167)	0.122*** (0.0396)
hhsize	− 0.00120 (0.00128)	0.00194 (0.00341)	− 0.0279* (0.0158)	0.0272* (0.0140)	− 0.00226 (0.00186)	0.0111 (0.0102)	− 0.00390 (0.00275)	− 0.00493 (0.00997)	− 0.000428 (0.000862)	0.00963 (0.0106)	− 0.00190 (0.00209)	− 0.00731 (0.00977)	− 0.0210 (0.0151)	0.0290** (0.0126)	− 0.00859* (0.00471)	0.000608 (0.00678)
hhincome	− 0.00255 (0.00407)	− 0.0107 (0.0110)	0.0346 (0.0268)	− 0.0213 (0.0250)	− 0.00472 (0.00591)	0.0356 (0.0270)	− 0.00989 (0.00929)	− 0.0210 (0.0237)	− 0.00158 (0.00414)	0.0326 (0.0265)	− 0.00668 (0.0106)	− 0.0244 (0.0236)	0.0435 (0.0300)	0.00597 (0.0217)	− 0.0153 (0.0109)	− 0.0342 (0.0213)
educ	− 0.000258 (0.000853)	0.000182 (0.00216)	− 0.00451 (0.00739)	0.00458 (0.00670)	2.79e− 05 (0.000790)	0.00122 (0.00488)	− 0.000139 (0.00115)	− 0.00111 (0.00420)	0.000632 (0.000605)	0.000689 (0.00481)	0.00116 (0.00141)	− 0.00248 (0.00416)	− 0.00805 (0.00780)	0.00651 (0.00526)	− 0.000990 (0.00158)	0.00252 (0.00394)
age	0.000332 (0.00131)	− 0.00118 (0.00323)	0.0118 (0.0124)	− 0.0109 (0.0112)	− 0.000294 (0.00113)	− 0.0182* (0.0101)	0.00221 (0.00274)	0.0163* (0.00841)	0.000570 (0.000869)	− 0.0189* (0.0101)	0.00320 (0.00327)	0.0151* (0.00812)	0.00323 (0.0129)	− 0.0184* (0.00964)	0.00831** (0.00374)	0.00689 (0.00641)
agesq	− 2.09e− 06 (1.15e− 05)	1.49e− 05 (2.74e− 05)	− 0.000121 (0.000113)	0.000108 (0.000103)	4.33e− 06 (1.04e− 05)	0.000152* (9.23e− 05)	− 1.65e− 05 (2.26e− 05)	− 0.000140* (7.85e− 05)	− 4.88e− 06 (7.67e− 06)	0.000161* (9.37e− 05)	− 2.73e− 05 (2.91e− 05)	− 0.000129* (7.42e− 05)	− 5.37e− 05 (0.000116)	0.000166* (9.03e− 05)	− 6.80e− 05** (3.32e− 05)	− 4.44e− 05 (5.60e− 05)
gender: Male	− 0.0144 (0.00963)	− 0.0481 (0.0325)	0.104 (0.0882)	− 0.0413 (0.0740)	− 0.00756 (0.0114)	0.0205 (0.0636)	− 0.0111 (0.0218)	− 0.00178 (0.0484)	− 0.0171 (0.0111)	0.0286 (0.0606)	− 0.0528 (0.0326)	0.0414 (0.0475)	0.0893 (0.0893)	− 0.0774 (0.0651)	0.0119 (0.0167)	− 0.0239 (0.0454)
asal: 10–29% aridity	0.117 (0.0905)	0.121* (0.0730)	− 0.110 (0.122)	− 0.128* (0.0752)	− 0.00919 (0.00607)	− 0.0679 (0.116)	− 0.0169 (0.0111)	0.0940 (0.116)	− 0.00143 (0.00130)	− 0.0746 (0.116)	− 0.00818 (0.00711)	0.0842 (0.116)	− 0.0235 (0.161)	− 0.0460 (0.0632)	0.0377 (0.0339)	0.0318 (0.0932)
asal: 30–84% aridity	0.00485 (0.00365)	0.127*** (0.0414)	− 0.362*** (0.0767)	0.230*** (0.0769)	− 0.00866 (0.00592)	− 0.264*** (0.0974)	− 0.000670 (0.0146)	0.273*** (0.0969)	0.0184 (0.0195)	− 0.282*** (0.0893)	0.0825** (0.0387)	0.181* (0.0968)	− 0.325*** (0.0855)	0.0883 (0.0694)	0.0182 (0.0253)	0.218*** (0.0785)
asal: 85–100% aridity	0.0242 (0.0214)	0.00110 (0.0141)	0.141*** (0.0539)	− 0.166*** (0.0442)	0.0256 (0.0353)	− 0.121 (0.0913)	0.0524 (0.0406)	0.0427 (0.0837)	− 0.00143 (0.00130)	− 0.0801 (0.0998)	− 0.00818 (0.00711)	0.0897 (0.0999)	0.0762 (0.0870)	− 0.116*** (0.0336)	0.0793 (0.0666)	− 0.0391 (0.0322)
Observations	279	279	279	279	261	261	261	261	261	261	261	261	258	258	258	258

Source: own estimations based on KIPPRA survey data; in parentheses are standard errors; with significance levels for marginal effects shown as *** $p<0.01$, ** $p<0.05$, * $p<0.1$; base for categorical variables: cluster: rural, gender: female and aridity: non-ASALs

employing only formal finance. For the use of the social safety net only and a combined utilisation of the social safety net with formal finance, household residence in arid areas is associated with a higher usage. Furthermore, residence in urban clusters and an incremental age variable increase the probability of using both the social safety net and formal finance.

Turning focus to the use of the social safety net and informal finance coping mechanisms, urban households demonstrate higher chances of employing only informal finance and a combined utilisation of the social safety net with informal finance. As discussed in prior literature (Ofosu et al., 2022), the use of informal finance that leverages social networks is an important channel for households coping with floods, though it could be ineffective due to the covariate nature of climate change-induced hazards. A larger household size increases the likelihood of using only informal finance while decreasing the likelihood of only using the social safety net. An incremental age variable lowers incidences of using only informal finance, but increases the chance of using only the social safety net, possibly due to the targeting of the social safety net to elderly headed households as segments of the vulnerable groups. The sign for the marginal effect of the squared age variable, however, reverses, suggesting nonlinear relationships of age. Considering the combined use of the social safety net with informal finance, residence in urban clusters and locations classified as 30–84% arid increase the adoption probability.

4 Conclusion

The incidences and extents of droughts and floods are predicted to escalate owing to a rapid climate change that affects households through the erosion of human capital and the loss of lives, income and asset. To investigate households' use of formal and informal finance, the social safety net and sustainable (livelihood diversification) non-finance measures in coping with droughts and floods, a bivariate probit model was used. By considering these variables, this study bridges the knowledge gap in previous studies by unpacking formal and informal finance in households' coping mechanisms with droughts and floods. While informal finance has the advantage of leveraging social networks (Ofosu et al., 2022; Rana et al., 2022; Silchenko & Murray, 2023), it is argued to be ineffective due to the covariate impacts of droughts and floods (Agrawal & Perrin, 2009; Jensen et al., 2017). By employing bivariate probit regressions, this study further provides empirical insights on whether policy interventions in the form of a social safety net encourage household dependency, a concern noted in previous studies (Vera-Cossio, 2022; Weldegebriel & Prowse, 2013; World Food Programme, 2019).

The results suggest that households employ multiple coping measures and that the use of the social safety net does not dampen the use of sustainable non-finance coping mechanisms such as income diversification and investments in productive assets in managing the adverse impacts of climate change-induced hazards like droughts. Further, the analysis reveals that the adoption of coping decisions is influenced by household income, household dependency ratio, geographic and agro-climatic contexts, and demographics such as the household head's age and educational attainment. ASAL households depend to a large extent on the social safety net and non-finance livelihood diversification coping mechanisms. Corroborating previous studies (Crick et al., 2018; Gannon et al., 2022), the findings from this study underscore the importance of promoting private sector development for nurturing measures to cope with climate

change-induced hazards, for instance through an enabling environment for incentivising the financial institutions to expand access to formal financial services to households facing extreme climate change-induced hazards. It is also notable that enhancing household income is imperative to coping with climate change hazards through avenues such as livelihood diversification. These findings reflect on goal number 13 of the sustainable development goals, which calls for actions towards combating the impacts of climate change, including through building resilience, adaptive capacity and strengthening policy planning, human and institutional capacity (United Nations, 2015). The negative bivariate probit correlation, ρ, between the adoption of the social safety net and formal finance coping measures for both droughts and floods suggests, on the one hand, that the design of the social safety net intervention is reaching the most vulnerable households, particularly those excluded from formal markets for climate change adaptations. On the other hand, however, an important policy issue is how to transition these households to market-enabled decisions such as access to formal finance and non-finance measures to enhance livelihood diversifications.

Research on households' adaptions to climate change-induced hazards like droughts and floods is hitherto at a nascent stage, presenting opportunities for empirical contributions. Future research can consider leveraging longitudinal data for providing insights on how households cope and adapt with climate change-related hazards and for building resilience in dynamic contexts. By looking at coping mechanisms, this study is oriented towards households' short-term responses to climate change-induced hazards as opposed to relatively long-term adaptation measures. Future research can also consider exploring whether households benefiting from the social safety net can transition to market-based coping measures such as formal financial services. It will also be imperative to further disaggregate the coping mechanisms to establish some granularity, such as disaggregating the use of finance coping measures into key components like savings, credit and insurance services to build on the current and other related work (Crick et al., 2018; Ofosu et al., 2022). The use of the social safety net can also be disaggregated into its constituents, such as cash transfers, subsidies and public works for cash or food. The disaggregated analyses can advance empirical understanding besides providing policy insights from more granular perspectives. Finally, future research can also consider undertaking separate analyses focused on droughts, which tend to be protracted and frequent in ASALs, and floods, which tend to be sporadic and frequent in non-ASALs or in specific locations such as along rivers and other waterways. Previous research has shown that, while climate change is a common factor, other complex factors, such as waste disposal that clogs waterways, urban planning and residential development, all contribute to flooding (Amoako & Boamah, 2015; Ofosu et al., 2022). Thus, future research can also investigate the role of public policies such as urban planning and solid waste disposal management as a trigger to floods within urban settings.

Data availability The dataset that supports the findings of this study is available from the Kenya Institute for Public Policy Research and Analysis (KIPPRA), but restrictions apply to the availability of this dataset, which was used due to the affiliation of the author, and so is not publicly available. The dataset is however available from the author upon reasonable request and with permission of KIPPRA.

Declarations

Competing interests The author has no competing interests to declare that are relevant to the content of this article.

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