World Development 146 (2021) 105546

Contents lists available at ScienceDirect

World Development

journal homepage: www.elsevier.com/locate/worlddev

Coping with climate shocks: The complex role of livestock portfolios

Alejandro Acosta [a,*], Francesco Nicolli [b,d], Panagiotis Karfakis [c]

[a] Animal Production and Health Division, Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
[b] Department of Economics and Management, University of Ferrara, Via Savonarola 9, 44121 Ferrara, Italy
[c] Agrifood Economics Division, Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
[d] Florence School of Regulation – Climate, European University Institute, Italy

ARTICLE INFO

Article history:
Accepted 7 May 2021
Available online 10 June 2021

Keywords:
Climate shocks
Household livelihood
Coping strategies
Resilience
Livestock

ABSTRACT

The effects of climate change are alarming, with projections suggesting that weather events will become more extreme and frequent, affecting households in regions that are already highly vulnerable. This study explores the role of livestock as a household coping strategy against climate shocks. Using quantile regression analysis, we examine the potential of different animal species to buffer the effects of drought on income and consumption. We assemble a unique global dataset that combines household-level socioeconomic information with a multi-scalar climatic drought index. Our study confirms the significant, yet context-dependent, role of livestock portfolios as a buffering mechanism against the effects of drought on household income and consumption. The effect is driven by the specific type of animal species, length of the shock, and socioeconomic features. These findings could assist the design of livestock-oriented policy interventions. The novel contributions of this study include the first cross-country analysis of the buffering effect of livestock against drought; use of the standardized precipitation-evapotran spiration index as a multi-scalar drought indicator -; and a uniquely extensive dataset allowing for the analysis of interactions.

© 2021 The Food and Agriculture Organization of the United Nations. Published by Elsevier Ltd.

1. Introduction

Developing countries are plagued by risks—including droughts, floods, and storms—afflicting large numbers of people every year. Exogenous shocks to income and consumption can be devastating for poorly equipped low-income households (Fafchamps & Lund, 2003). This is particularly true for rural households in areas where formal and informal safety nets are absent and there is no financial support (Banks et al., 2001). The difficulties are magnified when shocks hit all members of a community simultaneously, as is the case with climate shocks. A severe drought, for instance, may inflict dire conditions on an entire village, inhibiting local-based consumption smoothing schemes that, under normal circumstances, may effectively provide some insurance against unexpected consumption reductions (Binswanger & Rosenzweig, 1986).

Households can employ a wide array of mechanisms to mitigate the adverse effects of extreme weather events. Common ex-ante coping strategies include precautionary savings to smooth consumption or diversification into income-generating activities. The ex-post strategies include selling productive assets during hard times or using formal or informal safety nets (Gao & Mills, 2018). The role of livestock as an asset that allows vulnerable households to cope with income-reducing shocks has been widely discussed in the literature (Alary et al., 2011; Fafchamps et al., 1998; Hänke & Barkmann, 2017).

However, the empirical literature does not provide unanimous support for the buffering capacity of livestock assets in smoothing external shocks from weather (Hänke & Barkmann, 2017). Whereas a significant number of studies have noted that livestock assets may build resilience to climatic risks (Alary et al., 2011; Ellis & Mdoe, 2003; Hänke & Barkmann, 2017), others have found a small or insignificant effect as a coping strategy for climatic stress (Fafchamps & Lund, 2003; Fafchamps et al., 1998; Kazianga & Udry, 2006).

Using an original and unique database and applying quintile regression analysis, this study sheds empirical light on the role of the livestock portfolio as a coping strategy against severe drought. We assemble a global dataset that combines socioeconomic and livestock asset information from more than 150,000 rural households from 19 countries worldwide (FAO, 2018) with a multi-scalar drought index based on climate data (Bequeria et al., 2017).

The quintile regression approach examines whether climatic effects are regressive or progressive with respect to income. By contrast, the standardized precipitation-evapotranspiration index

* Corresponding author.
E-mail addresses: alejandro.acosta@fao.org (A. Acosta), nclfnc@unife.it (F. Nicolli), panagiotis.karfakis@fao.org (P. Karfakis).

https://doi.org/10.1016/j.worlddev.2021.105546
0305-750X/© 2021 The Food and Agriculture Organization of the United Nations. Published by Elsevier Ltd.

(SPEI) allows quantification of the specific effect of the shock depending on the magnitude and duration of the drought. This database is, therefore, particularly appropriate to test the capacity of livestock assets to buffer severe droughts.

The results show that livestock portfolios play a significant role as a coping strategy against droughts for rural households. However, the buffering potential tends to be context-specific and varies depending on the length of the shock, composition of the livestock portfolio, buffering capacity of different livestock species, household socioeconomic features, and specific geographical conditions. These findings could assist the design and effectiveness of livestock-oriented policy interventions.

This analysis extends the existing literature in several directions. First, we provide cross-country evidence on the contribution of livestock to households' buffering mechanisms against severe drought. Second, we study how this relationship varies depending on socioeconomic quintiles, drought length, and animal species. Third, unlike most studies, we use the SPEI as a proxy for drought, which has the advantage of accounting for anomalies in temperature and their effect on drought intensity. To the best of our knowledge, this study is the first to carry out a cross-country analysis that empirically assesses this research question.

2. Literature review: The complex role of the livestock portfolio as a coping mechanism

The academic literature on the role of livestock as a coping mechanism for households has evolved over recent decades. The literature explores three main directions: one strand focuses on analyzing rural households' coping strategies, including livestock. A second strand examines the role of specific livestock species as an income smoothing mechanism against external shocks, and a third strand concentrates on the buffering capacity of livestock assets against extreme climate events.

The effects of drought on rural households go beyond physical environments, also affecting social systems and, therefore, the economy (Paul, 1998; Wilhite & Glantz, 1985). According to Paul (1998), drought effects can be classified as direct and indirect. The direct effects lead to a reduction in the supply of food, whereas the indirect effects include income reduction. Wilhite and Glantz (1985) provide a list of the potential consequences of drought, the majority of which concern the agricultural sector. Livestock are affected by the limited availability of water, feed, and grazing land. Indeed, the lack of water affects the entire agricultural sector by hindering crop production and damaging pastures (Ding, Hayes, & Widhalm, 2011). Further, according to Campbell (1984), owing to the lack of feed, livestock suffer from starvation and become more vulnerable to diseases, leading to an increased rate of animal death.

To respond to the indirect shock on income, farmers implement a variety of strategies and tend to first rely on stocks of grain to ensure consumption and preserve their livestock assets (Kazianga & Udry, 2006; Paul, 1998). To smooth the consumption shock, livestock holders are usually forced to first sell small animals, such as poultry, pigs, sheep, and goats; whereas major livestock assets, such as cows, are left to be sold when the drought causes more severe negative shocks (Devereux, 1993Devereux, 1993; Fafchamps et al., 1998; Speranza, 2010). The shock is partially transmitted to consumers through increased food prices (Ding, Hayes, & Widhalm, 2011). Finally, some rural households respond to the income shock by migrating to seek jobs in non-agricultural sectors (Gray & Mueller, 2012; Paul, 1998).

Using panel data collected from a sample of households in Burkina Faso between 1981 and 1985, a period that coincides with some of the most severe drought years, Fafchamps et al. (1998) applied a variety of statistical methods to estimate the extent to which households use livestock to smooth income against climate shocks. Contrary to optimal saving theory predictions, the authors argued that livestock plays a less significant role in insulating consumption from income variation shocks than commonly believed. Kazianga and Udry (2006) examined the consumption consequences of income shocks generated by a severe drought. The authors found no evidence that livestock served as an effective buffer that compensated for income losses compared with other sources.

Several studies identified a mixed crop-livestock system as the most effective strategy for farmers attempting to adapt and respond to climate shocks (Altieri, Nicholls, Henao, & Lana, 2015; Schiere, Ibrahim, & Van Keulen, 2002; Thornton & Herrero, 2014). According to Jones and Thornton (2009), the combination of crops and livestock is critical to the survival of populations in arid areas as a response to stronger and more frequent climate shocks. Gao and Mills (2018) showed that the consumption level of households owning livestock assets tends to be significantly less affected by weather shocks. Megersa et al. (2014) highlighted that livestock portfolio diversification is significantly associated with a shorter period of food deficit and better dietary intake under severe drought. Alary et al. (2011) found that the contribution of livestock to poverty reduction is not direct but comes through interactions with other economic activities.

Hänke and Barkmann (2017) emphasized the role of livestock portfolios, particularly chickens, goats, and sheep, as an insurance mechanism to compensate for crop failure. The authors' findings showed that approximately 54% of total cash income comes from livestock sales, helping to compensate for approximately 57% of cash expenditure on food. Seo et al. (2009) estimated the probability of a farmer choosing a livestock species under different climate conditions in a cross-country study in Africa. The results showed that the likelihood of choosing goats and chicken increases at high elevations, whereas sheep are more likely to be chosen in lowlands. By contrast, dairy cattle decrease in semi-arid zones, and beef increases in dry agroecological zones. In Zimbabwe, Mutenje et al. (2008) identified goats and poultry as the livestock species with the greatest potential to improve the economic conditions of HIV-affected households.

In Africa, Seo (2010) compared the climate resilience of a mixed livestock-crop farm with farms specializing in either crops or livestock. Their results show that when temperatures increase, the net revenue of both farms specializing in crops and mixed farms decreases, whereas the net revenue of farms specializing in livestock increases. By contrast, with higher precipitation, the net revenue of farms specializing in crops increases, whereas the net revenue of mixed farms and livestock farms decreases.

Whereas livestock might buffer households' income or consumption, animals are themselves directly affected by drought through water and feed scarcity, heat, and physical stress. In an assessment of farmers' perceptions on the effects of drought on cattle production, Dzavo et al. (2019) ranked water shortage as the constituent of drought with the most severe effect in semi-arid environments; whilst feed shortage ranked first in sub-humid environments. El-Tarabany et al. (2017) found that high levels of thermal stress decreased goat milk production by around 19–27% under subtropical conditions. Several studies (Kekana et al., 2018; Salama et al., 2014; Broucek et al., 2007) have employed a thermal-humidity index to assess the physiological effect of heat load on different animal species. According to Das et al. (2016), the vulnerability of livestock to high temperatures can vary according to species, genetic potential, life stage, management, production system, and nutritional status.

Studies have highlighted the greater resilience of small ruminants (particularly goats) to droughts in comparison with larger ruminants (Lallje et al., 2018; Feldt, 2015; Lebbie, 2004). This is because of small ruminants' higher rusticity and hardiness, and ability to graze and utilize a wider range of poor-quality foraging and browsing. According to Salama et al. (2014), goats are more tolerant to thermal stress than dairy cows because of their greater sweating rate and lower body weight to surface area ratio, allowing greater heat dissipation. Although it is important to consider the differences in adaptation between sheep and goats, the current evidence is mixed and inconclusive as to the favored species. Indeed, surveying farmer perceptions of the drought tolerance of goats and sheep, Kosgey et al. (2008) found as much intra-species variability (between breeds) as inter-species variability.

Overall, substantial work in the literature has examined the role of livestock as a coping strategy against external shocks. Although several studies revealed the relevance of the livestock portfolio as a resilience mechanism, others questioned the effect of livestock portfolios as a coping strategy against exogenous shocks. Recent evidence suggests that this combination of results can be partially explained by the complexity of the underlying factors that link livestock, shocks, and well-being outcome interactions. Our study contributes to this discussion by showing that the role of the livestock portfolio as a buffering mechanism tends to be context-specific and varies depending on the length of the shock, the composition of the livestock portfolio, the buffering capacity of different livestock species, household socioeconomic features, and the specific regional conditions.

3. Data

We assembled a unique and original dataset of more than 150,000 observations from 19 countries spread across 4 continents. This dataset combines household-level socioeconomic information across the world from the FAO Smallholders Dataportrait (FAO, 2018) with a multi-scalar drought index from the Global SPEI database (Bequeria et al., 2017).

3.1. Household data

The FAO Smallholders Data Portrait (FAO, 2018) provides consistent measures of income, consumption, farm size, labor, production, inputs, livestock, crops, input markets, technology, and demographics. This dataset uses household surveys developed by national statistical offices. All the surveys are nationally representative and cover urban and rural areas, except for the Ethiopian survey, which covers only rural households. In this study, we consider only rural households. This dataset collects information from 19 countries worldwide. For some of the countries, data are reported for more than one round, resulting in 29 surveys.

After merging all available information, we obtained a cross-sectional dataset covering 156,472 rural households. Annex 1 shows that the information is not equally distributed across continents, with most respondents originating from Africa and Asia. Appendix A summarizes the number of households per country by continent. We note that not all surveys have been conducted in the same year, and some surveys were repeated across time for some countries.[1] In these cases, however, it was not possible to construct a longitudinal panel dataset at the household level as the sample of households is not constant over time. However, it was possible to merge the different survey waves because the questionnaire and the overall design mostly remained consistent. Overall, the first surveys were conducted in 1992, and the last surveys were conducted in 2013. Fifty percent of the observations were collected between 2002 and 2007 (see Table A5).

[1] For Tanzania, we have three surveys, from 2009, 2011, and 2013. For similar cases, see the last columns in Tables A1 to A4 of Appendix A.

3.2. Climate data

Our climate variable is the SPEI, which is a multi-scalar index employed in several disciplines to measure drought severity according to intensity and duration. One of the main advantages of the SPEI index is that it can be calculated over a wide array of climatic zones, and it guarantees comparability across time and space (Vicente-Serrano et al., 2010). In climatologic literature (Asfaw et al., 2018), there is a common alternative index: the standardized precipitation index (SPI; McKee et al., 1993). In comparison with precipitation-only-based indicators such as the SPI, the SPEI has the main advantage of accounting for warming-induced drought stress.

Use of the SPEI in an empirical analysis requires several decisions. The first regards space. In a research framework such as ours for which the unit of analysis is a single household, ideally, researchers combine each household's data with the narrowest possible climatic information. A localized value for the SPEI, which has a 0.5° spatial resolution, is preferable. However, the precise locations of households are often missing in the original dataset or censored for privacy purposes. For this reason, the best approximation is to compute an average SPEI index at the administrative regional level (sub-country regions) and pair it with households residing in that administrative region, which is available information.

The second decision regards time. The SPEI has a monthly resolution and can be calculated over different time scales: conventionally, between 1 and 48 months (Fig. 1). The choice of the index time length is relevant because it enables the identification of different drought types. Time scales below 12 months show a high frequency of drought and moist periods of short duration. Longer time scales account for droughts of longer duration and lower frequency. Therefore, different time scales are useful for monitoring different drought conditions in different hydrological subsystems.

To clarify this point, the graphical example in Fig. 1 refers to the grid cell at latitude 8.75 and longitude 38.75 in the Oromia Region, Ethiopia, which is approximately 30 kms south of Addis Ababa, for the years 1990–2016. The figure shows that short time scales are volatile and change rapidly, whereas longer time scales represent more structural tendencies. If we consider, for instance, the years 2015 and 2016, which were extremely dry, Fig. 1 shows that different types of SPEI provide evidence of different tendencies. SPEI 1 (one month), for instance, shows that precipitation was erratic: from one-half to three-quarters less than the usual magnitude in many months of the year, but particularly from February to September. However, SPEI 1 also had positive values for some months, registering the occurrences of higher-than-average precipitation and lower temperatures.

Consequently, we believe that SPEI 1 is not suitable for an economic analysis such as ours in which researchers are interested in determining how persistent climatic events affect productive systems and farmers' living conditions. On the contrary, SPEIs 24 and 48 clarified that the area experienced a severe two-year drought, as shown by the trend of the two indices that are constantly below zero. For these reasons, we exploit three indices—SPEIs 12, 24, and 48—in the following analysis. This allows us to avoid short and probably insignificant climatic anomalies while employing three indices that have different degrees of flexibility and persistence. As the analysis shows, the choice is non-neutral; welfare outcomes respond differently to different drought events. In our analysis, where otherwise not stipulated, we have opted to default to the SPEI 24 index, which still has some of the flexibility of monthly indices while also accounting for a more structural and persistent drought. To appreciate the geographical heterogeneity of the SPEI index, Appendix B presents the average regional value of the SPEI 24 index in the survey years.

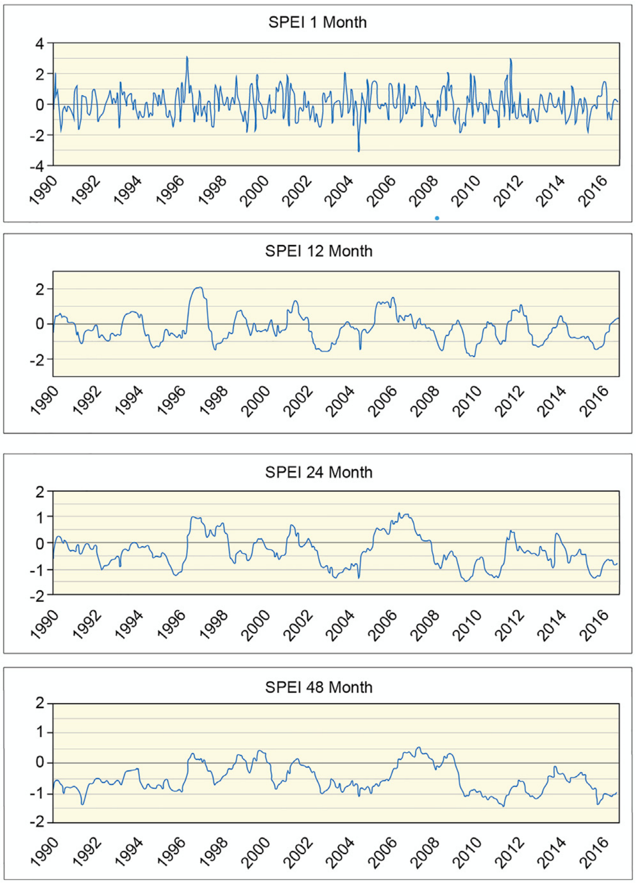

Fig. 1. Changes in the standardized precipitation-evapotranspiration index (SPEI) time scale. Note: SPEI: standardized precipitation-evapotranspiration index.

3.3. Variables

The study applies two dependent variables: i) the natural logarithm of household income and ii) the natural logarithm of household consumption expenditure. Income is composed of all receipts, whether monetary or in kind, received or produced by the household annually. Consumption expenditures refer to annual regular per capita outflows from the household. For poorer households, food expenditure typically makes up the largest component of consumption. The main independent variables are the SPEI described above and livestock units (LU). Using the original SPEI index would produce estimates that are difficult to interpret because the SPEI also considers positive values (low temperature and high precipitation). These values have an effect on consumption and income levels that is difficult to predict *a priori*. Thus, based on the SPEI index, we built a proxy for severe drought. This proxy is a dummy variable that takes the value of one if the SPEI is in the lowest five percentiles of the SPEI distribution and zero otherwise. Finally, in the analysis, the SPEI variable always refers to the year in which the survey was conducted (see Tables A1 to A4 of Appendix A).

Two similar indicators, Livestock Unit (LU) and Tropical Livestock Unit (TLU), can be used to aggregate and compare the number of different categories of livestock (FAO, 2011). However, for global comparisons, LU is preferred because TLU focuses on livestock raised in the tropics, reducing inter-regional comparability (Chilonda & Otte, 2006). We employed LU as our measure of livestock rather than heads of livestock for several reasons. First, the coefficients for small livestock (e.g., chickens) are small in magnitude when measured by heads. This creates difficulty in interpreting the contribution of small animals and comparing the effects of small animals with any other species. As LU allow some comparison in terms of body weight, we believe this is a better approach as one goal of this study is interspecies comparison. However, caution is required when interpreting these coefficients as the resources required to increase chickens by one LU (the marginal effect reported in the coefficient estimates) are not equal to those needed to increase cattle by one LU. Annex 2 provides the list of LU coefficients used (FAO, 2011).

Other variables of interest include a number of household attributes such as age, gender, education level, and household size. Table 1 provides a brief description of each of the variables employed as descriptive statistics.

4. Empirical framework

This study examines the role of the livestock portfolio as a coping strategy against drought. Conceptual models of household income and consumption dynamics imply that weather shocks show a low correlation with changes in household welfare if households have access to liquid assets and if shocks are transitory (Gao & Mills, 2018; Kazianga & Udry, 2006). Furthermore, we expect the relationship between a livestock portfolio and welfare outcomes to be non-linear across income groups (Asfaw et al., 2018). To account for this non-linearity and to improve robustness against outliers and distributional assumptions, we employ a quantile regression framework.

The model specification can be written as Equation (1):

$$\ln(O_{it}) = \alpha_i + t_t + \beta_1 SPEI_{it} + \beta_2 Cattle_{it} + \beta_3 SPEI_{it} * Cattle_{it} + \beta_4 Sheep_{it} + \beta_5 SPEI_{it} * Sheep_{it} + \beta_6 Goats_{it} + \beta_7 SPEI_{it} * Goats_{it} + \beta_8 Pigs_{it} + \beta_9 SPEI_{it} * Pigs_{it} + \beta_{10} Poultry_{it} + \beta_{11} SPEI_{it} * Poultry_{it} + \gamma_{it} X_{it} + \varepsilon_{it} \quad (1)$$

where, O_{it} is total consumption or income of household *i* in year *t*, our two chosen measures of household welfare; α_i is a set of country dummy variables; and t_t is the year fixed effect. $SPEI_{it}$ is the severe drought dummy derived from the SPEI index. We replicated all regressions with three different SPEI indexes: 12, 24, and 48 months. *Poultry* refers to the total poultry LU, *Pigs* represents pigs, *Sheep* represents sheep, *Goats* represent goats, and *Cattle* represents cattle. SPEI**Cattle* refers to the climate-shock livestock-portfolio interactions, and the subsequent interactions refer to the livestock portfolio species-specific interactions. Finally, X_{it} is a vector of household characteristics including agricultural income, non-agricultural income, male labor availability, female labor availability, food production, education, household size, female head, age of head, married head, and widowed head (for more details on the variables, see Table 1). α_i and t_t are country and time effects, which capture country-specific unobserved characteristics and possible differences across different survey waves (for the same country). For many countries, different surveys were conducted in different years. For instance, in the case of Tanzania, we have three different survey waves: 2009, 2011, and 2013 (for a full list, see Table A1 in the Appendix). ε_{it} is the stochastic error term.

Using this regression framework, we estimate the effect of the climate shock (β_1), proxied here by the SPEI dummy; the direct conditional correlation between different livestock species and income or consumption ($\beta_2; \beta_4; \beta_6; \beta_8; \beta_{10}$), and the buffering effect of different livestock species on an extreme climatic event ($\beta_3; \beta_5; \beta_7; \beta_9; \beta_{11}$). Specifically, a negative and significant value of (β_1) implies that the presence of a severe drought has an adverse effect on income or consumption. A significant and positive value of ($\beta_2; \beta_4; \beta_6; \beta_8; \beta_{10}$) implies that livestock contributes to income or consumption, and a significant and positive value of β_3

Table 1
Descriptive statistics for rural households; total sample and average value by continent.

Variable name	Obs.	Mean	St Dev	Mean (Africa)	Mean (Asia)	Mean (South America)	Mean (Europe & Central Asia)	Variable Description
Income	154,671	4,487.39	23,535.86	3,174.31	4,668.28	8,183.21	6,568.21	Total gross household income (Const. 2009 Int. $). This consists of all receipts, whether monetary or in kind (for food, goods, and services), that are received or produced by the household or by the individual members of the household at the annual level, but it excludes windfall gains and other such irregular and typical onetime receipts. Natural log in the analysis.
Consumption	156,472	948.05	2,439.61	868.51	731.80	1,675.28	1,697.63	Per capita household consumption expenditure (Const. 2011 Int. $). This consists of all expenditure, whether monetary or in kind (for food, goods, and services), thatis spent by the household or by the individual members of the household annually. It excludes irregular and typical onetime expenditure. Natural log in the analysis.
Agricultural income	154,696	0.49	0.37	0.54	0.51	0.23	0.44	Share of income from farm activities, which include crop production, crop by-products (only when it is possible to distinguish them from crop production), livestock, and livestock by-products.
Non-agricultural income	154,696	0.29	0.36	0.27	0.28	0.41	0.27	Share of household income from non-agricultural economic activities.
Male labor availability	153,821	1.25	0.98	1.14	1.34	1.22	1.70	Number of males in the household aged from 14 to 60 years.
Female labor availability	153,821	1.34	0.94	1.22	1.41	1.3	1.89	Number of females in the household aged from 14 to 60 years.
Food production	153,242	0.34	0.34	0.36	0.33	0.24	0.37	Share of food produced and consumed by the household.
Education	155,252	4.85	4.29	4.40	5.27	3.4	9.17	Education of the household head (years).
Household size	156,472	5.05	2.59	5.15	4.73	5.1	6.37	Number of persons per household.
Female head	153,744	0.22	0.41	0.24	0.19	0.19	0.13	Proportion of households with female heads.
Age head	153,672	46.39	15.51	45.76	46.51	46.4	51.31	Age of head of household.
Married head	151,340	0.73	0.44	0.71	0.82	0.46	0.84	Proportion of households with married heads.
Widowed head	151,340	0.10	0.30	0.11	0.11	0.07	0.05	Proportion of households with widowed heads.
SPEI 12	156,472	0.04	0.21	0.06	0.08	0.09	0.09	Dummy for severe drought based on the SPEI – 12 months. The variable equals one if the value of the SPEI is in the lowest five percentiles of the SPEI distribution and zero otherwise.
SPEI 24	156,472	0.05	0.22	0.09	0.12	0.05	0.09	Dummy for severe drought – 24 months. (Calculated as per SPEI 12).
SPEI 48	156,472	0.05	0.23	0.05	0.06	0.08	0.10	Dummy for severe drought – 48 months. (Calculated as per SPEI 12).
Cattle	156,472	0.45	4.39	0.53	0.11	1.06	0.86	Livestock unit – cattle.
Sheep	156,472	0.05	0.34	0.06	0.01	0.09	0.20	Livestock unit –sheep.
Goats	156,472	0.11	0.9	0.21	0.01	0.02	0.14	Livestock unit – goats.
Pigs	145,783	0.21	1.3	0.04	0.45	0.23	0.01	Livestock unit – pigs.
Poultry	146,136	0.069	0.46	0.06	0.09	0.04	0.04	Livestock unit – chicken.

Note: SPEI : Standardized precipitation-evapotranspiration index.

(and$\beta_5; \beta_7; \beta_9; \beta_{11}$) implies that livestock can buffer the effect of climatic shocks on household income or consumption. Unless specified differently, the analysis is conducted on the sample of 154,671 rural households, and the regional subsets of these households, in the regional robustness check in Section 6.

5. Results

We used a quintile regression analysis to investigate the role of the rural household livestock portfolio as a buffering mechanism against drought. We favored the quintile regression approach because of the high degree of heterogeneity observed among socioeconomic quintiles such that the aggregated results often do not reflect the significance and magnitude of the underlying disaggregated quintile coefficients. We estimated different versions of Equation (1) to assess the income, consumption, and regional effects. The first part of the results section illustrates the income effect, the second section discusses the consumption effect, and the third section is a robustness check of the regional effects. To reduce the family-wise error rate due to disaggregating results by quintile, we used the first quintile (i.e., the poorest households) as a benchmark for interpretation and comparison purposes (Hochberg & Thamhane, 1987).

5.1. Income effects

The results illustrate the high level of interrelations between livestock species, drought length, socioeconomic quintile, and household well-being during a severe drought (see Table 2). The complexity of these interrelations creates difficulty in determining general effects. Nonetheless, we find specific inferences that shed significant light on the nature of the results.

The contribution to income of livestock portfolios differs by animal species and income quintile. The income contribution of different animal species (as per the first five coefficients), under quintile one, varies between 5% and 11%, except for cattle, which contributes approximately 2%. The species with the highest income contribution is goats, followed by poultry, pigs, sheep and, finally, cattle. Pica-Ciamarra et al. (2015) found similar results in a cross-country study –that the direct contribution of livestock to the income of rural households is limited- with an average of 12% across the sampled countries.

The magnitude of the livestock contribution to income varies among socioeconomic quintiles. Interestingly, from the first to fourth quintiles, the income contribution of most species tends to increase, whereas the contribution of goats and sheep tends to decrease. Surprisingly, the contribution of livestock to income tends to be lower or insignificant for the fifth quintile.

Traditionally, rural households use livestock assets to store wealth (Alary et al., 2014; Doran, Low, & Kemp, 1979). As the marginal propensity to save increases with wealth accumulation, this suggests that wealthier households save a higher percentage of their income in the form of livestock. This supports previous evidence (Wouterse & Taylor, 2008) suggesting that livestock contributes more to the income of wealthier households than to the income of poorer households. However, this marginal propensity contrasts with other studies that found that the contribution of livestock to income is greater for poorer households than richer households (Pica-Ciamarra et al., 2015; Ellis & Mdoe, 2003).

A severe drought can have a significant and devastating effect on the income level of a rural household. As depicted by the "SPEI" coefficient, our results show that the effect depends on the length

Table 2
Income effect of livestock portfolios as a buffering mechanism.

SPEI	SPEI 12		SPEI 24						SPEI 48	
Income	Quintile 1	Full Sample	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Full Sample	Quintile 1	Full Sample
Cattle	0.022***	0.014***	0.022***	0.028***	0.038***	0.047***	0.005	0.014***	0.023***	0.014***
	[0.001]	[0.004]	[0.001]	[0.001]	[0.001]	[0.001]	[0.004]	[0.004]	[0.001]	[0.004]
Sheep	0.062***	0.082***	0.060***	0.029***	0.029***	0.011	0.143***	0.083***	0.053***	0.079***
	[0.011]	[0.011]	[0.011]	[0.009]	[0.008]	[0.009]	[0.052]	[0.011]	[0.011]	[0.011]
Goats	0.103***	0.019	0.103***	0.091***	0.076***	0.049***	0.003	0.019	0.106***	0.020
	[0.004]	[0.020]	[0.004]	[0.003]	[0.003]	[0.003]	[0.018]	[0.020]	[0.004]	[0.020]
Pigs	0.067***	0.037***	0.067***	0.100***	0.104***	0.095***	0.009	0.037***	0.067***	0.037***
	[0.003]	[0.013]	[0.003]	[0.002]	[0.002]	[0.002]	[0.013]	[0.013]	[0.003]	[0.013]
Poultry	0.071***	0.062***	0.067***	0.116***	0.169***	0.178***	0.024	0.062***	0.072***	0.063***
	[0.008]	[0.017]	[0.008]	[0.006]	[0.006]	[0.006]	[0.036]	[0.017]	[0.008]	[0.018]
SPEI	−0.125***	−0.137***	−0.251***	−0.285***	−0.279***	−0.287***	−0.234**	−0.255***	−0.108***	−0.067***
	[0.023]	[0.018]	[0.022]	[0.017]	[0.016]	[0.018]	[0.102]	[0.022]	[0.023]	[0.022]
SPEI*Cattle	−0.004	0.004	0.060**	0.064***	0.072***	0.072***	0.052	0.078*	−0.020***	−0.011**
	[0.006]	[0.007]	[0.025]	[0.020]	[0.018]	[0.021]	[0.118]	[0.047]	[0.004]	[0.005]
SPEI*Sheep	−0.136*	−0.244***	0.093	−0.133	−0.256*	−0.199	1.076	−0.114	0.247***	0.115**
	[0.075]	[0.069]	[0.188]	[0.152]	[0.138]	[0.155]	[0.890]	[0.132]	[0.073]	[0.055]
SPEI*Goats	0.270***	0.334***	0.213***	0.277***	0.266***	0.233***	0.557**	0.326***	0.167***	0.180***
	[0.049]	[0.047]	[0.054]	[0.044]	[0.040]	[0.045]	[0.256]	[0.055]	[0.040]	[0.046]
SPEI*Pigs	0.025	0.116*	0.057	0.064	−0.026	−0.069	0.389	0.118*	0.002	0.097*
	[0.075]	[0.062]	[0.078]	[0.063]	[0.058]	[0.065]	[0.372]	[0.061]	[0.070]	[0.056]
SPEI*Poultry	0.228**	0.317**	1.726***	1.987***	2.001***	2.050***	−0.060	1.504***	−0.039	0.009
	[0.095]	[0.154]	[0.174]	[0.141]	[0.128]	[0.144]	[0.826]	[0.437]	[0.029]	[0.051]
Observations	136,405	136,405	136,405	136,405	136,405	136,405	136,405	136,405	136,405	136,405

Full sample columns are estimated via ordinary least squares ; the others are the results of a quintile regression. Robust standard errors are in parentheses (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$). All estimates include the following covariates: agricultural income, non-agricultural income, male labor availability, female labor availability, food production, education, household size, female head, age of head, married head, widowed head, and country and year fixed effects. Note: SPEI: standardized precipitation-evapotranspiration index.

of the drought index (reading across Table 2), following a “U” curve of negative effects. After a short-term drought of 12 months (SPEI 12), the level of income of the first quintile reduces by 12.5%. After 24 months (SPEI 24), the level of income of the first quintile reduces by 25.1%. After 48 months (SPEI 48), the level of income of the first quintile reduces by 10.8%. The last result suggests that under an extended period of stress, households might implement other coping mechanisms. Kochar (1999) noted that under a severe shock, rural households tend to shift labor from on-farm to off-farm employment. Gray and Mueller (2012) found that severe drought can induce labor migration.

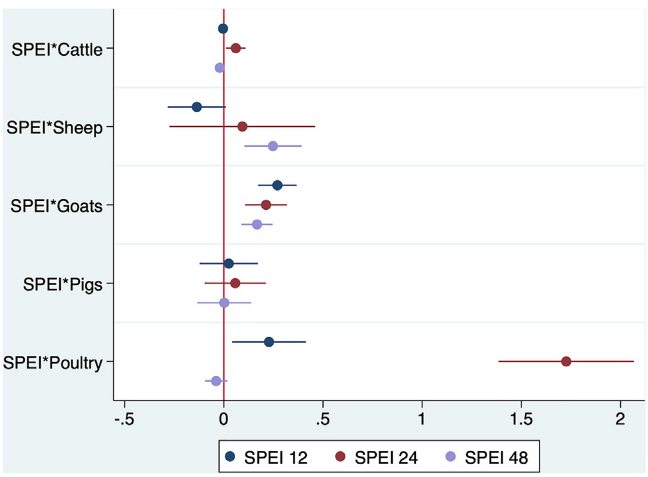

Fig. 2. Income buffering effect of livestock portfolios (Quintile 1). Note: SPEI: standardized precipitation-evapotranspiration index.

The interactions (the last five coefficients) show that the capacity of livestock portfolios to mitigate an income shock differs by animal species. For example, in the first quintile during a 24-month drought, poultry has a greater buffering effect than any other species (1.73), followed by goats (0.213), and cattle (0.06). This result emphasizes that households’ livestock-related strategies depend on the intrinsic value and liquidity of the species; both aspects are determined, in part, by the length of the drought. Although LUs allow for a degree of interspecies comparability in terms of biomass, these results should be interpreted cautiously for policy purposes, as the resources needed to increase the quantity of some animal species (poultry) by one LU will be different from those required for others (cattle).

The role of the livestock portfolio is dynamic, changing depending on the length of the drought and the species (Fig. 2). For example, for the first quintile during a 24-month drought, the buffering capacity of poultry is significantly higher than that of goats; however, the opposite is true during a 48-month drought. This makes intuitive sense as, in the short run, households might prefer to sell liquid assets, whereas goats are more weather-hardy and can thus provide greater value over a longer drought.

Surprisingly, for the first quintile, the buffering effect of cattle was negative (yet insignificant) under a 12-month drought , positive under a 24-month drought, and negative again under a 48-month drought. This result suggests that in the short-term (12 months), households might make use of income to maintain their cattle. However, when the drought stretches beyond a certain time threshold (24 months), households might start selling cattle as a destocking strategy. Nevertheless, as households might need to conserve a positive stock to maintain the reproductivity of the herd, if the drought is extended (48 months), households will need to drain more income to keep their cattle alive. Interestingly, this

Table 3
Consumption effect of livestock portfolios as a buffering mechanism.

	SPEI 12		SPEI 24						SPEI 48	
Income	Quintile 1	Full Sample	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Full Sample	Quintile 1	Full Sample
Cattle	0.005***	0.005***	0.005***	0.011***	0.016***	0.021***	0.001	0.005***	0.007***	0.006***
	[0.000]	[0.002]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.002]	[0.000]	[0.002]
Sheep	0.010	0.015***	0.011*	−0.008	−0.006	−0.006	0.026	0.014**	0.014**	0.015***
	[0.006]	[0.005]	[0.006]	[0.005]	[0.005]	[0.007]	[0.017]	[0.005]	[0.006]	[0.005]
Goats	−0.003	0.001	−0.003	0.011***	0.017***	0.048***	−0.073***	0.001	−0.002	0.001
	[0.002]	[0.005]	[0.002]	[0.002]	[0.002]	[0.002]	[0.006]	[0.005]	[0.002]	[0.005]
Pigs	0.023***	0.014***	0.023***	0.026***	0.025***	0.023***	0.004	0.014***	0.022***	0.014***
	[0.002]	[0.005]	[0.002]	[0.001]	[0.001]	[0.002]	[0.004]	[0.005]	[0.001]	[0.005]
Poultry	0.035***	0.032***	0.035***	0.052***	0.060***	0.072***	0.012	0.032***	0.043***	0.036***
	[0.004]	[0.007]	[0.004]	[0.004]	[0.004]	[0.005]	[0.012]	[0.007]	[0.004]	[0.009]
SPEI	−0.072***	−0.088***	−0.081***	−0.099***	−0.100***	−0.107***	−0.116***	−0.089***	0.041***	0.037***
	[0.013]	[0.011]	[0.012]	[0.010]	[0.011]	[0.013]	[0.034]	[0.011]	[0.013]	[0.012]
SPEI*Cattle	0.006*	0.004	0.015	0.023*	0.029**	0.009	−0.048	0.019**	−0.012***	−0.007**
	[0.003]	[0.003]	[0.014]	[0.012]	[0.012]	[0.015]	[0.039]	[0.010]	[0.002]	[0.003]
SPEI*Sheep	−0.239***	−0.204***	−0.273***	−0.029	0.169*	0.295***	−0.598**	0.005	−0.106***	−0.059
	[0.041]	[0.060]	[0.104]	[0.089]	[0.092]	[0.114]	[0.293]	[0.100]	[0.040]	[0.046]
SPEI*Goats	0.169***	0.135***	0.183***	0.132***	0.115***	0.078**	0.369***	0.140***	0.088***	0.123***
	[0.027]	[0.024]	[0.030]	[0.026]	[0.026]	[0.033]	[0.084]	[0.026]	[0.022]	[0.020]
SPEI*Pigs	0.080*	0.073**	0.106**	0.125***	0.066*	0.035	0.146	0.094***	0.150***	0.067*
	[0.041]	[0.029]	[0.043]	[0.037]	[0.038]	[0.048]	[0.123]	[0.029]	[0.038]	[0.041]
SPEI*Poultry	0.228***	0.315***	1.021***	1.127***	1.056***	0.961***	0.519*	0.920***	−0.035**	−0.035***
	[0.052]	[0.088]	[0.096]	[0.083]	[0.085]	[0.106]	[0.272]	[0.177]	[0.016]	[0.012]
Observations	136,405	136,405	136,405	136,405	136,405	136,405	136,405	136,405	136,405	136,405

Full sample columns are estimated via ordinary least squares ; the others are the results of a quintile regression. Robust standard errors are in parentheses (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$). All estimates include the following covariates: agricultural income, non-agricultural income, male labor availability, female labor availability, food production, education, household size, female head, age of head, married head, widowed head, and country and year fixed effects. SPEI: standardized precipitation-evapotranspiration index finding highlights the trade-offs that households face between using livestock assets to either smooth the effect of the shock, or protect future income generation capacity (Corbett, 1988). This evidence is aligned with that of previous studies.

Corbett (1988) examined sequences of coping strategies, showing that households tend to make use of store-of-value assets (e.g., goats) first, whereas they hold on to key productive or investment assets (e.g., cattle) for as long as possible. Leroy et al. (2018) highlighted the role of cattle as a source of prestige in many societies. Fafchamps et al. (1998) offered a possible explanation, showing that cattle are less liquid than other livestock assets, and a household that sells in a hurry will obtain a reduced price. Kazianga and Udry (2006) showed that returns on cattle production may increase substantially after a drought because of market factors, and households might decide to keep their animals to capture the expected benefits.

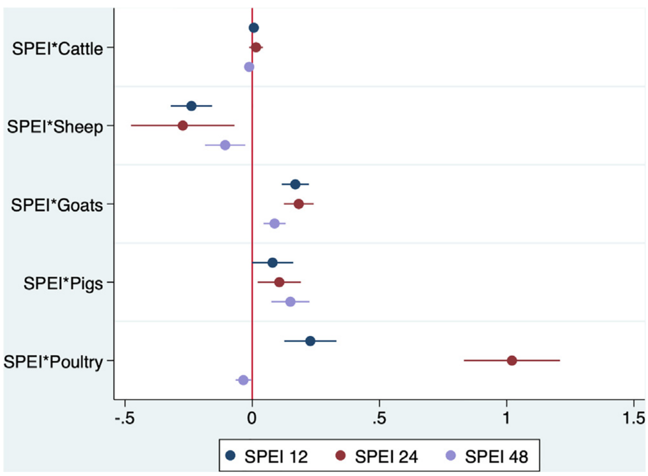

Fig. 3. Consumption buffering effects of livestock portfolios (Quintile 1). Note: SPEI: standardized precipitation-evapotranspiration index.

5.2. Consumption effects

The consumption and income effects were similar. The sign and level of significance of the core coefficients in Table 3 are qualitatively consistent with the main evidence found for income. The contribution of livestock portfolios to consumption is positive and significant for most species. Droughts of 12 and 24 months have a negative effect on consumption, but the effect is smaller than that on income. Unexpectedly, the consumption effect is positive under an extended 48-month drought. As in the case of income, this result likely reveals the use of an alternative longer-term adaptation strategy with a positive indirect effect on consumption (Glwadys et al., 2010).

A livestock portfolio can help to buffer the negative consumption effects of a drought. The climate-livestock interactions are positive and significant for most species, demonstrating the capacity of livestock portfolios to smooth a consumption shock (Fig. 3). However, as is the case for income, the buffering effect varies by species and drought length. For example, under the first quintile and a 24-month drought, only small species such as poultry, goats, and pigs show significant consumption buffering. This suggest that households might prefer to first use small species as a consumption buffering mechanism.

Some livestock species may be more relevant as consumption or income coping mechanisms. For example, the capacity of pigs to buffer the effect of a drought tends to be more significant for con-

Table 4
Income regional effects of livestock portfolios as a buffering mechanism—SPEI 24.

Income	Africa Q1	Africa Full Sample	Asia Q1	Asia Full Sample	Europe Central Asia Q1	Europe Central Asia Full Sample	South America Q1	South America Full Sample
Cattle	0.008*** [0.001]	0.008*** [0.003]	0.191*** [0.018]	0.126*** [0.013]	0.030*** [0.008]	0.040*** [0.010]	0.044*** [0.002]	0.045*** [0.003]
Sheep	0.171*** [0.020]	0.229*** [0.023]	−0.045 [0.115]	−0.037 [0.071]	0.101*** [0.023]	0.079*** [0.022]	0.040** [0.017]	−0.014 [0.011]
Goats	0.107*** [0.004]	0.016 [0.018]	0.060 [0.060]	0.073* [0.041]	0.067* [0.035]	0.051** [0.021]	0.082** [0.038]	0.034 [0.022]
Pigs	0.136*** [0.017]	0.133*** [0.029]	0.056*** [0.002]	0.030*** [0.011]	0.042 [0.044]	0.032* [0.017]	0.120*** [0.017]	0.106*** [0.012]
Poultry	0.085*** [0.017]	0.102*** [0.033]	0.027*** [0.007]	0.032*** [0.012]	2.047*** [0.214]	1.896*** [0.136]	1.326*** [0.107]	0.963*** [0.139]
SPEI24	−0.315*** [0.027]	−0.358*** [0.021]	−0.028 [0.022]	−0.024 [0.019]	−0.237*** [0.062]	−0.027 [0.060]	−0.319*** [0.062]	−0.356*** [0.045]
SPEI24*Cattle	0.114*** [0.030]	0.084 [0.053]	−0.105*** [0.034]	−0.075*** [0.025]	−0.026*** [0.009]	−0.035*** [0.011]	0.033** [0.017]	0.043*** [0.013]
SPEI24*Sheep	0.093 [0.217]	−0.074 [0.134]	−0.109 [1.276]	−0.557 [1.150]	0.243 [0.163]	0.303** [0.152]	0.025 [0.052]	0.046 [0.032]
SPEI24*Goats	0.230*** [0.072]	0.345*** [0.056]	−0.157 [0.192]	−0.193 [0.199]	0.816*** [0.308]	0.656*** [0.225]	−0.084 [0.070]	−0.028 [0.042]
SPEI24*Pigs	0.063 [0.101]	0.018 [0.057]	0.095*** [0.026]	0.115*** [0.024]	[n.a.]	[n.a.]	0.055 [0.118]	0.002 [0.063]
SPEI24*Poultry	1.091*** [0.242]	0.734* [0.420]	0.528*** [0.138]	0.444*** [0.108]	2.876** [1.289]	2.245** [1.101]	0.841 [0.535]	0.623** [0.289]
Observations	61,978	61,978	53,037	53,037	7,003	7,003	14,387	14,387

All columns report full sample results estimated with ordinary least squares (quintile results are presented in Appendix C); robust standard errors are in brackets (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$). All estimates include the following covariates: agricultural income, non-agricultural income, male labor availability, female labor availability, food production, education, household size, female head, age of head, married head, widowed head, and country and year fixed effects. SPEI: standardized precipitation-evapotranspiration index sumption than for income. This result emphasizes the different roles of species in smoothing consumption or income shocks (Opiyo et al., 2015). During a 48-month drought, the poultry interaction is negative and significant for most quintiles. In other words, having more chickens is associated with lower consumption levels. This result suggests that an extended drought with small monogastrics might cause a trade-off between the use of grain as food and as feed for livestock.

6. Regional robustness check

Regional heterogeneity can be hidden behind the global aggregate results. A strong aggregate effect can mask significant differences across diverse areas of the world. This is particularly relevant in our case, as the analyzed households come from different climatologic areas and live in heterogeneous socioeconomic systems. This section presents a robustness exercise to deal with the geographical dimensions of the dataset.

We split the full sample into four regions—Africa, Asia, Europe and Central Asia, and South America—and replicate the previous analysis by region (see Table 4). In other words, we interact the three drought lengths—12, 24, and 48 months—with the contribution of the livestock portfolio to income, effect of the drought, buffering capacity of different species, and all covariates. Overall, three main results emerge. First, the global effects are supported by regional analyses. Second, the relevance of different species varies among regions. Third, the aggregate results are mostly driven by Africa, which has the largest sample contribution.

We present a synthesis of the main results on income for each continent in Table 4 and Fig. 4. To limit the number of tables, we only show results for the first quintile and the full sample for each region and limit the analysis to SPEI 24—the preferred climatological index. Full quintile regression estimates, as well as results for consumption and the other drought indexes, are reported in Appendix D.

Taking quintile 1 under SPEI 24 as a reference, we find some interesting divergence in the order of income contribution of species among regions (Fig. 4). In Africa, sheep contribute the most to income, followed by pigs, goats, poultry, and cattle. In Asia, cattle contribute the most, followed by pigs and poultry. In Europe and Central Asia, poultry is the largest contributor, followed by sheep, goats, and cattle. In South America, poultry is the largest contributor, followed by pigs, goats, cattle, and sheep.

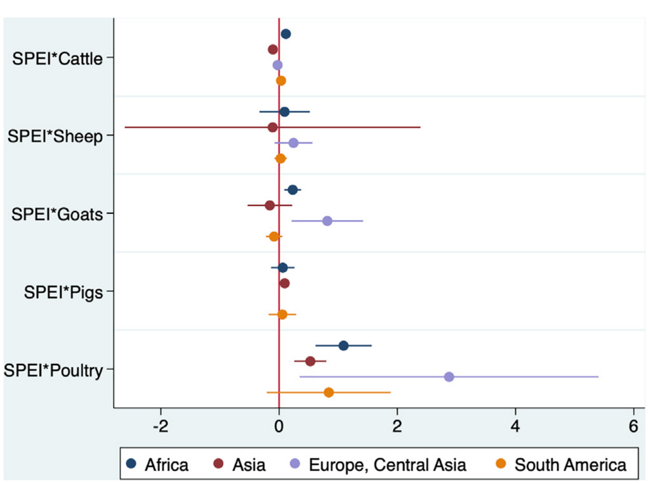

Fig. 4. Regional income buffering effects of livestock portfolios (Quintile 1 – SPEI24). Note: SPEI: standardized precipitation-evapotranspiration index.

Interestingly, and in line with the global full sample, the income shock tends to be higher for a 24-month drought than a 12-month or 48-month drought (Appendix D). This suggests that medium-length droughts, such as a 24-month drought determined by SPEI 24, are better suited to capture the effect of climatic shocks on farmers' welfare -a result which can be used as a reference for future studies-.

The buffering effect among species differs by region (Fig. 4). Benchmarked to a 24-month drought in the first quintile: in Africa, poultry have the highest buffering effect, followed by goats and cattle. In Asia, poultry have the largest buffering effect, followed by pigs, and cattle have a negative effect. In Europe and Central Asia, poultry remain the best buffering species, followed by goats, and cattle have a negative effect. In South America, only cattle have a buffering effect in the first quintile.

7. Conclusions

This study explores the role of the livestock portfolio as a potential coping strategy against climate shocks. Previous studies have highlighted the complexity of the underlying factors and interactions that link livestock, climate shocks, and well-being outcomes. Our study contributes to this discussion by showing that the role of livestock portfolios as a buffering mechanism tends to be context specific and varies depending on the length of the shock, composition of the livestock portfolio, buffering capacity of different livestock species, household's socioeconomic features, the region.

We assemble a unique global dataset that combines socioeconomic information with a multi-scalar drought index (the SPEI) that captures the length and severity of drought. Employing a quintile regression analysis allows us to capture the heterogeneity among socioeconomic groups and ensure robustness against outliers and distributional assumptions. The inclusion of covariates of several socio-economic, regional, and national factors reduces omitted variable bias. We ascertain the effects of our variables on household well-being, as determined by income and consumption.

A severe drought has a significant negative effect on rural households' well-being that is of a slightly higher magnitude for income than for consumption. We find that the buffering capacity of different animal species varies depending on the length of the drought. We further find that the magnitude of the contribution varies by income quintile. Some livestock species may be more relevant as income or consumption coping mechanisms. We show that under prolonged drought, some species can become a liability, hindering the household's coping capacity. The findings highlight the potential presence of trade-offs between using livestock assets to smooth shocks, or to protect future recovery. Finally, we illustrate the relevance of different species changes across regions.

Our study was limited by the geographic resolution of household data and the available covariates. As a result, it was not possible to replicate the analysis at the agro-climatic-zone or livestock-system level as the households are aggregated by region. There is also a need to better explain the pathways through which income and consumption are affected by drought, as climate shocks may affect the household's income through non-livestock related avenues such as crop losses, which also affect herd size and quality.

This latter point also raises the issue of endogeneity, which, to our knowledge, has never been examined empirically. However, a panel dataset is needed to account for omitted variable bias properly and identify drought effects precisely. This would improve the analysis of the household's response mechanism. When such data become available, these are potential areas for further research.

Further, the data did not allow us to examine in detail the role of different species, particularly cattle, as a source of income generation or accumulation, and neither did it allow us to capture the effects of animal products and by-products. This might help to explain the lower contribution of some species in helping households cope with severe drought events.

Protracted crises are among the most challenging contexts in which to fight hunger and poverty. Animal-assisted programs designed to build rural households' capacity to cope with severe droughts should carefully consider the intricate relationships among animal species, droughts, and socioeconomic groups. As we have shown, livestock portfolios can reinforce or hinder the coping capacity of rural households depending on the specific context. Thus, a deeper understanding of the complex role of the livestock portfolio to help cope with drought is fundamental to enhance the design and effectiveness of livestock interventions in protracted crises.

CRediT authorship contribution statement

Alejandro Acosta: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Francesco Nicolli:** Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Panagiotis Karfakis:** Data curation, Formal analysis, Writing - original draft, Writing - review & editing.

Declaration of competing interest

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

Acknowledgments

We thank the two anonymous reviewers whose comments helped improve this manuscript. We thank Peter Courtney for his research assistance, writing, and results analysis; Ester Venturelli for her research assistance; and Margherita Squarcina for data scrubbing.

This research was conducted by the Livestock Policy Lab (LPL). The LPL is a science-policy platform hosted by the Livestock Information, Sector Analysis, and Policy Branch at the Animal Production and Health Division at FAO.

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2021.105546.

References

Alary, V., Corniaux, C., & Gautier, D. (2011). Livestock's contribution to poverty alleviation: How to measure it?. *World Development, 39*(9), 1638–1648. https://doi.org/10.1016/j.worlddev.2011.02.008.

Alary, V., Messad, S., Aboul-Naga, A., Osman, M. A., Daoud, I., Bonnet, P., & Tourrand, J. F. (2014). Livelihood strategies and the role of livestock in the processes of adaptation to drought in the Coastal Zone of Western Desert (Egypt). *Agricultural Systems, 128*, 44–54. https://doi.org/10.1016/j.agsy.2014.03.008.

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development, 35*(3), 869–890. https://doi.org/10.1007/s13593-015-0285-2.

Asfaw, S., Pallante, G., & Palma, A. (2018). Diversification strategies and adaptation deficit: Evidence from rural communities in Niger. *World Development, 101*, 219–234. https://doi.org/10.1016/j.worlddev.2017.09.004.

Banks, J., Blundell, R., & Brugiavini, A. (2001). Risk pooling, precautionary saving and consumption growth. *Review of Economic Studies, 68*(4), 757–779.

Bequeria, S., Latorre, B. Reig, F., & Vicente-Serrano, S. (2017). SPEIbase v.2.5. Available at: http://spei.csic.es/. Open Database License.

Binswanger, H., & Rosenzweig, M. (1986). Behavioural and material determinants of pro- duction relations in agriculture. *Journal of Development Studies, 22*(3), 503–539. https://doi.org/10.1080/00220388608421994.

Broucek, J., Ryba, S., Mihina, S., Uhrincat, M., & Kisac, P. (2007). Impact of thermal-humidity index on milk yield under conditions of different dairy management. *Journal of Animal and Feed Sciences, 16*(3), 329–344.

Campbell, D. J. (1984). Response to drought among farmers and herders in southern Kajiado District, Kenya. *Human Ecology, 12*(1), 35–64. https://doi.org/10.1023/A:1018789623581.

Chilonda, P., & Otte, J. (2006). Indicators to monitor trends in livestock production at national, regional and international levels. *Livestock Research for Rural Development, 18*(8), 117.

Devereux, S. (1993). Goats before ploughs: Dilemmas of household response sequencing during food shortages. *Ids Bulletin, 24*(4), 52–59. https://doi.org/10.1111/j.1759-5436.1993.mp24004006.x.

Corbett, J. (1988). Famine and household coping strategies. *World development, 16*(9), 1099–1112.

Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati, et al. (2016). Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World, 9*(3), 260–268.

Ding, Y. A., Hayes, M. J., & Widhalm, M. (2011). Measuring economic impacts of drought: A review and discussion. *Disaster Prevention and Management, 20*(4), 434–446. https://doi.org/10.1108/09653561111161752.

Doran, M. H., Low, A. R. C., & Kemp, R. L. (1979). Cattle as a store of wealth in Swaziland: Implications for livestock development and overgrazing in Eastern and Southern Africa. *American Journal of Agricultural Economics, 61*(1), 41–47. https://doi.org/10.2307/1239498.

Dzavo, T., Zindove, T. J., Dhliwayo, M., & Chimonyo, M. (2019). Effects of drought on cattle production in sub-tropical environments. *Tropical Animal Health and Production, 51*(3), 669–675. https://doi.org/10.1007/s11250-018-1741-1.

Ellis, F., & Mdoe, N. (2003). Livelihoods and rural poverty reduction in Tanzania. *World Development, 31*(8), 1367–1384. https://doi.org/10.1016/S0305-750X(03)00100-1.

El-Tarabany, M. S., El-Tarabany, A. A., & Atta, M. A. (2017). Physiological and lactation responses of Egyptian dairy Baladi goats to natural thermal stress under subtropical environmental conditions. *International Journal of Biometeorology, 61*(1), 61–68.

Fafchamps, M., & Lund, S. (2003). Risk-sharing networks in rural Philippines. *Journal of Development Economics, 71*(2), 261–287. https://doi.org/10.1016/S0304-3878(03)00029-4.

Fafchamps, M., Udry, C., & Czukas, K. (1998). Drought and saving in West Africa: Are livestock a buffer stock?. *Journal of Development Economics, 55*(2), 273–305. https://doi.org/10.1016/S0304-3878(98)00037-6.

FAO (2011). Guidelines for the preparation of livestock sector reviews. Animal Production and Health Guidelines. No. 5. Rome. Retrieved 05/01/2021 from: http://www.fao.org/3/i2294e/i2294e00.pdf.

FAO (2018). Smallholders Dataportrait. Rome. Retrieved 25/09/2020 from: http://www.fao.org/family-farming/data-sources/dataportrait/farm-size/en/.

Feldt, T. (2015). Interrelatedness of grazing livestock with vegetation parameters and farmers' livelihoods in the Mahafaly region, southwestern Madagascar (Doctoral Dissertation). Witzenhausen, Germany: University of Kassel, Retrieved 25/09/20202 from https://kobra.bibliothek.uni- kassel.de/bitstream/urn:nbn:de:hebis:34-2015102749227/3/Disserta- tionTobiasFeldt.pdf

Gao, J., & Mills, B. F. (2018). Weather shocks, coping strategies, and consumption dynamics in rural Ethiopia. *World Development, 101*, 268–283. https://doi.org/10.1016/j.worlddev.2017.09.002.

Glwadys, G., Rashid, H., & Ringler, C. (2010). Modelling farmers' adaptation strategies for climate change and variability: The case of the Limpopo Basin. *Agrekon, 4*(2), 217–234. https://doi.org/10.1080/03031853.2010.491294.

Gray, C., & Mueller, V. (2012). Drought and population mobility in rural Ethiopia. *World Development, 40*(1), 134–145. https://doi.org/10.1016/j.worlddev.2011.05.023.

Hänke, H., & Barkmann, J. (2017). Insurance function of livestock, farmers coping capacity with crop failure in southwestern Madagascar. *World Development, 96*, 264–275. https://doi.org/10.1016/j.worlddev.2017.03.011.

Hochberg, Y., & Thamhane, A. (1987). Multiple comparison procedures. John Wiley and Sons. ISBN 0-471-82222-1.

Jones, P., & Thornton, P. K. (2009). Croppers to livestock keepers: Livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy, 12*(4), 427–437. https://doi.org/10.1016/j.envsci.2008.08.006.

Kazianga, H., & Udry, C. (2006). Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. *Journal of Development Economics, 79*(2), 413–446. https://doi.org/10.1016/j.jdeveco.2006.01.011.

Kekana, T. W., Nherera-Chokuda, F. V., Muya, M. C., Manyama, K. M., & Lehloenya, K. C. (2018). Milk production and blood metabolites of dairy cattle as influenced by thermal-humidity index. *Tropical Animal Health and Production, 50*(4), 921–924.

Kochar, A. (1999). Smoothing consumption by smoothing income: Hours-of-work responses to idiosyncratic agricultural shocks in rural India. *Review of Economics and Statistics, 81*(1), 50–61. https://doi.org/10.1162/003465399767923818.

Kosgey, I. S., Rowlands, G. J., van Arendonk, J. A. M., & Baker, R. L. (2008). Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research, 77*(1), 11–24.

Lallje, S. V., Soundararajan, C., Singh, Y. D., & Sargison, N. D. (2018). The potential of small ruminant farming as a means of poverty alleviation in rural southern India. *Tropical Animal Health Production, 51*(2), 303–311. https://doi.org/10.1007/s11250-018-1686-4.

Lebbie, S. H. B. (2004). Goats under household conditions. *Small Ruminant Research, 51*(2), 131–136.

Leroy, G., Hoffmann, I., Form, T., Hiemstra, S. J., & Gandini, G. (2018). Perception of livestock ecosystem services in grazing areas inside and outside Europe. *Animal: An International Journal of Animal Bioscience, 12*(12), 2627–2638. https://doi.org/10.1017/S1751731118001027.
McKee, T. B., Doesken, N. J., & Kleist, J. (1993). The relation of drought frequency and duration to time scales. In Proceedings of the 8th Conference on Applied Climatology, Anaheim, California, 17–22 January 1993, 179–184.
Megersa, B., Markemann, A., Angassa, A., & Valle Zárate, A. (2014). The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia. *Food Security, 6*(1), 15–28. https://doi.org/10.1007/s12571-013-0314-4.
J Mutenje, M., Mapiye, C., Mavunganidze, Z., Mwale, M., Muringai, V., S Katsinde, C., et al. (2008). Livestock as a buffer against HIV and AIDS income shocks in the rural households of Zimbabwe. *Development Southern Africa, 25*(1), 75–82. https://doi.org/10.1080/03768350701837754.
Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., & Munang, R. (2015). Drought adaptation and coping strategies among the Turkana pastoralists of Northern Kenya. *International Journal of Disaster Risk Science, 6*(3), 295–309. https://doi.org/10.1007/s13753-015-0063-4.
Paul, B. K. (1998). Coping mechanisms practiced by drought victims (1994/5) in North Bengal, Bangladesh. *Applied Geography, 18*(4), 355–373.
Pica-Ciamarra, U., Tasciotti, L., Otte, J., & Zezza, A. (2015). Livestock in the household economy: Cross-country evidence from microeconomic data. *Development Policy Review, 33*(1), 61–81. https://doi.org/10.1111/dpr.12092.
Salama, A. A. K., Caja, G., Hamzaoui, S., Badaoui, B., Castro-Costa, A., Façanha, D. A. E., et al. (2014). Different levels of response to heat stress in dairy goats. *Small Ruminant Research, 121*(1), 73–79.
Schiere, J. B., Ibrahim, M. N. M., & Van Keulen, H. (2002). The role of livestock for sustainability in mixed farming: Criteria and scenario studies under varying resource allocation. *Agriculture, Ecosystems and Environment, 90*(2), 139–153. https://doi.org/10.1016/S0167-8809(01)00176-1.
Seo, S., Mendelsohn, R., Dinar, A., & Kurukulasuriya, P. (2009). Adapting to climate change mosaically: An analysis of African livestock management by agro-ecological zones. *The B.E. Journal of Economic Analysis & Policy, 9*, 4. https://doi.org/10.2202/1935-1682.1955.
Seo, S. N. (2010). Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture. *Food Policy, 35*(1), 32–40. https://doi.org/10.1016/j.foodpol.2009.06.004.
Speranza, C. (2010). Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni District, Kenya, European. *Journal of Development Research, 22*(5), 623–642. https://doi.org/10.1057/ejdr.2010.39.
Thornton, P. K., & Herrero, M. (2014). Climate change adaptation in mixed crop–livestock systems in developing countries. *Global Food Security, 3*(2), 99–107. https://doi.org/10.1016/j.gfs.2014.02.002.
Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index - SPEI. *Journal of Climate, 23*, 1696–1718.
Wilhite, D. A., & Glantz, M. H. (1985). Understanding the drought phenomenon: The role of definitions. *Water International, 10*(3), 111–120.
Wouterse, F., & Taylor, J. E. (2008). Migration and income diversification: Evidence from Burkina Faso. *World Development, 36*(4), 625–640.