



How specific resilience pillars mitigate the impact of drought on food security: Evidence from Uganda

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Received: 1 January 2022 / Accepted: 22 July 2022 / Published online: 21 September 2022
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Abstract

Uganda continues to be prone to climate shocks especially drought which has adverse impact on food security. This paper studies household resilience capacities with special focus on how different resilience capacities mitigate the impact of drought on food security. The study follows the TANGO framework to identify resilience components, and two-step factor analysis to construct three resilience capacity indexes (absorptive, adaptive, and transformative) and overall resilience capacity index. To examine the mitigating role of resilience capacities, we interact resilience capacity indexes with the different measures of drought. The study employs a panel data from the Uganda National Panel Surveys (UNPS) undertaken between 2010/11 and 2018/19, spanning five waves. To minimise the bias arising from subjective self-reported drought shock, we introduce an objective measure of drought from the global SPEI database into the UNPS data. We also address attrition bias by controlling for attrition hazard estimated from the attrition function. Our analysis reveals that households in Uganda exhibit significantly low and nearly static resilience capacities. This implies majority of households in Uganda remain highly vulnerable to food insecurity in the event of severe drought. The study shows that building resilience capacities is an effective way of protecting households from such devastating situation. Whereas there are mixed results on the effectiveness of different resilience capacities in mitigating the effects of drought depending on the measure of food security and drought, decomposition of each of the three resilience capacities reveals critical aspects in each capacity. Succinctly, access to climate related information and linking social capital are very critical under adaptive capacity, infrastructure services are very key under transformative capacity, while informal safety nets are critical under absorptive capacity. Therefore, interventions that enhance households' access to the above aspects are very important in building resilience to shocks, especially drought.

Keywords Drought · Resilience capacities · Food security

JEL Codes D10 · I32 · Q18

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1 Introduction and motivation

Over the years, drought has been a growing concern globally due to its debilitating direct and indirect effects on livelihoods (Shiferaw et al., 2014). Globally, drought has affected more people, compared to any other natural hazard and its adverse effects have more than doubled in the last 40 years (FAO, 2020).¹ Approximately 55 million people globally are affected by drought annually (WHO, 2020).² In Africa, drought on average affects 14 percent of the people living in drylands in any given year (Raffaello & Michael, 2016).³

¹ <http://www.fao.org/land-water/water/drought/droughtandag/en/>.

² <https://www.who.int/health-topics/drought#>.

³ Drylands make up about 43 percent of the continent's land surface, account for about 75 percent of the area used for agriculture, and are home to about 50 percent of the population (Raffaello & Michael, 2016).

The situation is likely to be exacerbated by ongoing climate change (in form of increased frequency and intensity of extreme weather conditions, such as high temperatures) which is likely to intensify droughts in many parts of the world (Nsubuga & Rautenbach, 2018).

The recurrence of drought particularly threatens food security across different countries (FAO, 2011) through its negative impact on agricultural production (Majaliwa et al., 2010; Mbolanyi et al., 2017) and farm household incomes (Shiferaw et al., 2014). More specifically, drought results in lower yields in both crop and livestock production, and increased livestock deaths (FAO, 2011; Kogan et al., 2019), thus affecting food availability, access, and utilization (FAO, 2011). For instance, between 2005 and 2015, drought caused 30 percent of agricultural loss in developing countries, which amounted to over USD 29 billion (FAO, 2017).

In Uganda, drought has been identified as the most challenging climate hazard with devastating effects on food security given that almost 70 percent of Ugandans rely heavily on farm production (FAO et al., 2015). For instance, in 2017 when the country reportedly experienced severe drought, about 10.9 million people experienced food insecurity, with 1.6 million at the brink of starvation (UNFPA Uganda, 2019). The adverse impact of drought on food security is likely to be greater for households with weak resilience capacities (Mannke, 2011; Shiferaw et al., 2014). In this regard, building resilience is critical for preparedness, mitigation, recovery and adaptation to drought.

Resilience is also a critical analytical and policy concept because it allows the understanding of household vulnerabilities and the strategies they adopt to manage shocks (d'Errico et al., 2018). To effectively moderate the adverse effects of drought, much deeper scientific evidence on the unmitigated impacts of drought and the role of resilience capacities and related factors in mitigating shocks is needed. This paper therefore addresses the question “*what are the most important resilience pillars in mitigating the impact of drought on food security in Uganda?*”.

Whereas there is a growing body of literature on resilience and food security, analytical gaps still exist especially given the diversity in resilience measurement approaches. For instance, the seminal work by Alinovi et al. (2008, 2010) heavily relied on proxies such as index of coping mechanisms rather than the actual shocks due to data limitations (d'Errico et al., 2018). Most of the subsequent work that builds on Alinovi et al.'s ideas of estimating resilience as a latent variable (such as Vaitla et al., 2020; Feed the Future FEEDBACK, 2015; FAO, 2015; d'Errico & Di Giuseppe, 2018, among others), follow a static approach largely due to data limitations as most of them rely on cross-sectional data. While d'Errico et al. (2018) attempted to address the shortcomings of static analytical framework in the context of Uganda and Tanzania, their study does not account

for evolution of resilience over time since resilience construction is based on one wave. More so, their study only assessed the effectiveness of overall resilience capacity index which masks the differences in the mitigating role of different resilience capacities. Other studies on drought and food security in Uganda (such as Twongyirwe et al., 2019) are limited in geographical scope (only focused on one district) and did not consider the role of resilience capacities.

This study therefore contributes to exiting literature on drought, resilience, and food security in a number of ways. First, unlike the aforementioned studies, this paper makes use of a rich, nationally representative household panel data (Uganda National Panel Surveys) spanning five waves (2010/11, 2011/12, 2013/14, 2015/16, and 2018/19). In so doing, the study accounts for the temporal dynamics of resilience by measuring resilience capacity index in each wave with a view that household's resilience capacity is not static, and as it changes, its moderating role on the impact of drought also changes. Second, this study provides empirical evidence on the effectiveness of not just the general resilience capacity index, but also the different resilience capacities and components in mitigating the impact of drought on food security. In so doing, our study makes a practical contribution regarding prioritisation and focusing resources on critical aspects of resilience building.

Evidence provided by this study is particularly important in guiding interventions aimed at mitigating the potential losses from drought. This is because prior interventions such as Disaster Risk Finance (DRF)⁴ and Social Assistance Grants for Empowerment (SAGE) have been ad-hoc and less effective partly because they are not informed by strong evidence (Maher, 2017).⁵ Furthermore, the study provides knowledge-based basis for the need to invest in adaptation to drought, especially for a country where food security is increasingly becoming an issue of great concern.

The rest of the paper is organized as follows. Section 2 explores the existing literature on drought, the resilience concept, resilience measurement and food security. Section 3 advances a conceptual framework that links drought shocks to food security while explaining the roles of resilience factors. Section 4 provides information on the empirical strategy and models, description of the data, the construction and discussion of the resilience capacity indexes. Section 5 contains the results regarding estimated mitigating effects of resilience on the impact of drought on food

⁴ Disaster risk finance (DRF) is a component of the governments' Third Northern Uganda Social Action Fund (NUSAF III) project, that seeks to build the resilience against shocks mainly drought of poor and vulnerable households in northern Uganda by providing income support in the form of labor-intensive public works (LIPW).

⁵ <https://blogs.worldbank.org/psd/building-resilience-against-drought-case-uganda>.

security. Section 6 provides a summary, conclusions and policy recommendations.

2 Review of literature

This section highlights existing knowledge regarding drought shocks, food security, the resilience concept, and the linkages between all three. More specifically, we highlight the literature on impact of drought on food security and the mitigating role of resilience. In this section, we further emphasize our identified research gap and provide a basis for developing an appropriate conceptual framework and methodology.

2.1 Drought and food security

Globally, drought⁶ remains a major source of food risk and income, especially for the rural households in developing countries (FAO, 2017). Kogan et al. (2019) argue that drought is one of the main reasons for hunger and undernourishment for nearly a quarter of the world's population that lacks enough food for normal living. In 2019, the shortage in world grain production which resulted into food insecurity was a result of drought-triggered crop stress which resulted into grain production loss (*ibid*).

In Africa, drought has been found to affect three times more people than all other natural disasters combined (Dinkelman, 2017). Indeed, drought poses a huge threat to food security⁷ by undermining agricultural production and household income (Shiferaw et al., 2014; Twongyirwe et al., 2019). As such, the rising malnutrition and famine in many SSA countries, has been largely attributed to drought (Shiferaw et al., 2014; Watuleke, 2015; Funk et al., 2012; d'Errico et al., 2018). This is because drought increases the vulnerability of crop production especially in Sub-Saharan Africa where rain-fed agriculture constitutes more than 95 percent of agricultural land use (Wani et al., 2011).

East Africa is among the most affected regions especially the horn of Africa where the frequency of drought is much higher compared to other regions (IGAD, 2017). Indeed, drought represents one of the most important natural triggers of malnutrition and famine as it affects the four dimensions of food security-availability, stability, access and utilization (FAO, 2011) amidst a high population and food demand

growth. For the case of Uganda especially in the Karamoja sub-region, drought is reportedly the main cause of food insecurity (Akwango et al., 2017). This further highlights the need to mitigate the effects of drought through building household resilience.

2.2 The concept of resilience and its measurement

Resilience is a multifaceted concept, with different definitions offered by various disciplines, agencies (such as FAO, USIAD, and OECD) and scholars (such as d'Errico et al., 2018). As such, the definition and measurement of resilience are widely contested. It is however worth noting that the most dominant definition of resilience is that by the Resilience Measurement Technical Working Group (Constas et al., 2014) which defines resilience as “the capacity that ensures adverse stressors and shocks do not have long-lasting adverse development consequences”.

This definition alludes to the absorptive,⁸ adaptive⁹ and transformative¹⁰ capacities of victims of a shock/stressor which result into persistence, adjustments and transformational responses, respectively (Aldrich & Meyer, 2015; Jones & Tanner, 2017). These capacities are the core components of resilience that need to be considered in a household resilience conceptual and analytical framework (Béné et al., 2012; Frankenberger et al., 2013; Weldegebriel & Amphune, 2017; Asmamaw et al., 2019).

In constructing the above resilience capacities and the overall resilience capacity index, researchers have adopted different frameworks and methodologies, which can be grouped into subjective and objective approaches. While the subjective approach is based on an individual's self-evaluation of his/her household's capabilities in responding to shocks (Choptiany et al., 2015; Jones et al., 2018), the objective approach (used by most scholars) is mainly based on observable key socioeconomic indicators and other types of capital that support livelihoods (Bahadur et al., 2015; Jones & Samman, 2016). In the later approach, resilience is measured as a latent/unobservable variable based on observable indicators (Alinovi et al., 2008; Smith & Frankenberger, 2018; d'Errico et al., 2018).

For instance, using a two-stage factor analysis, Alinovi et al. (2008, 2010) estimated resilience as an unobservable variable using observable indicators such as social safety nets, access to public services, assets, income and food access,

⁶ The Inter-Governmental Panel Climate Change (IPCC) (2012) defined drought as “a period of abnormally dry weather, long enough to cause a serious hydrological imbalance”.

⁷ United Nations refers to food security as “People having at all times, physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life”.

⁸ Absorptive capacity in this sense refers to the ability to minimize exposure to shocks and stresses (ex-ante) where possible and to recover quickly when exposed (ex post).

⁹ Adaptive capacity refers to the ability to adjust to changes, moderate damage and to take opportunities.

¹⁰ Transformative capacity refers to the ability to create a new system to make conditions attainable.

adaptive capacity and stability. In the same vein, Feed the Future FEEDBACK (2015) estimated community resilience in Ethiopia along three capacities (absorptive, adaptive and transformative) using Principal Component Analysis (PCA).

Building on Alinovi et al.'s (2008, 2010) seminal idea that resilience is a latent variable, the FAO developed an overarching framework for estimating resilience known as Resilience Index Measurement Analysis (RIMA) framework. This framework is based on four pillars (access to basic services, assets, social safety nets and adaptive capacity) where Resilience Capacity Index (RCI) was estimated through a two-stage procedure using a structural equation model (FAO, 2016). Using the FAO's RIMA framework, TANGO international developed a significantly modified version of the same that focuses on household and community level capacities—absorptive, adaptive and transformative (Upton et al., 2021), which the paper seeks to analyse—see Sect. 4.3 for more details.

2.3 Mitigating role of resilience on the impact of drought on food security

The moderating role of resilience may vary depending on the resilience capacities possessed by a household. For instance, a report by Feed the Future FEEDBACK (2015) shows that absorptive capacity poses stronger mitigation power compared to adaptive and transformative as far as the impact of drought on food security in Ethiopia is concerned. Similarly, scholars such as Bahadur et al. (2015) emphasize the role of absorptive and adaptive capacities while transformative was regarded as a reshaping approach that enables a household to adapt, anticipate and absorb shocks like drought.

Cognizant of the role played by the household resilience, the government of Uganda and other stakeholders have undertaken initiatives such as Social Assistance Grants for Empowerment (SAGE) aimed at developing resilience capacities of vulnerable households (Ulrichs & Slater, 2017). However, these interventions do not specifically target the impacts of drought on households' food security. More so, most of such programmes have been generally reactive in nature and poorly coordinated (Duguma et al., 2017; Gerber & Mirzabaev, 2017).

3 Conceptual frameworks

This section presents the conceptual frameworks linking drought, resilience and food security. More specifically, the conceptual framework highlights the pathways through which drought affects food security while demonstrating the role of resilience in mitigating the impact of drought on food security.

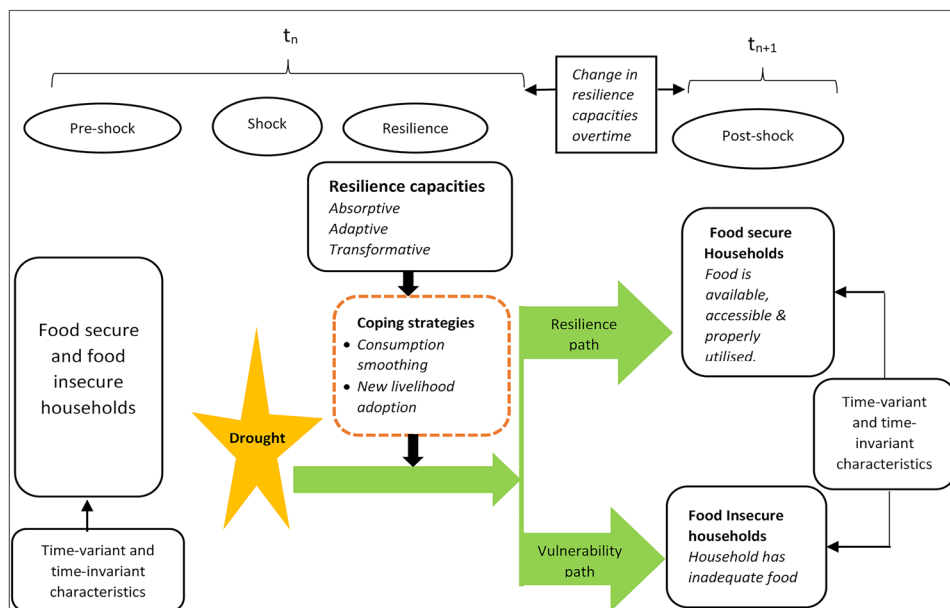
Based on the literature surveyed in the previous section, this study conceptualizes resilience as a latent variable (Alinovi et al., 2008, 2010; FAO, 2016; d'Errico et al., 2018) which moderates the impact of drought on household food security. In line with studies such as Aldrich and Meyer (2015), Jones and Tanner (2017), and Asmamaw et al. (2019), we categorize resilience into three capacities; absorptive, adaptive, and transformative, which enables us to examine the effectiveness of each resilience capacity in mitigating the impact of drought on food security. In the study, we regard absorptive, adaptive and transformative capacities as the ability of households to resist, adapt, and transform, respectively, against the negative impacts of drought.

By considering the three resilience capacities, the conceptual framework integrates ex-ante preparedness and prevention plus the response and recovery activities (ex-post) into resilience analysis (Ansah et al., 2019). The conceptual framework for this paper (Fig. 1) also recognizes resilience as an intrinsically dynamic concept. As such, it allows analysis of the temporal dynamics of resilience and the dynamic role of different resilience pillars in mitigating the impact of drought on food security.

The conceptual framework shows the pathways from drought to food security while accounting for the mitigating role of household resilience capacities. As shown in Fig. 1, a household is either food secure or insecure pre-drought, depending on time variant and time invariant household characteristics. When drought sets in, it is presumed to affect the livelihood strategies which transmits to food availability, accessibility, and utilization. For instance, drought affects food production resulting in scarcity of food, thus inducing a rise in food prices. This negatively affects all dimensions of food security. However, the extent to which drought affects food security depends on the household's ability to absorb, adapt and transform livelihood. Figure 1 specifically shows that when drought occurs, household resilience mechanisms are activated which induce coping strategies for consumption smoothing and adoption of new livelihoods in the bid to counter its impact on food security. Conceptually, there are two possible pathways: *the resilience pathway and the vulnerability pathway* (Fig. 1). A household with high capacity to absorb drought, adapt and transform livelihood by adopting coping strategies (such as, livelihood diversification, selling assets, borrowing, etc.) follows the resilience pathway and bounces back to the normal state or even better. On the other hand, a household with weak capacity to absorb drought, adapt and transform livelihood follows the vulnerability pathway and ends up in a dire situation of food insecurity in the subsequent period. Note that between the two extremes, there are varying degrees of resilience. This also implies varying bounce-back abilities and time frames.

Notably, resilience is a dynamic concept that is subject to change over time. On one hand, the coping strategies owing

Fig. 1 Conceptual framework linking drought, household resilience and food security. Source: Author's own construction (2020) based on the ideas of FAO (2016) and Frankenberger (2015)



to the shock in period t_n such as selling assets, draining income sources, etc., may limit future capacity to react to shocks (FAO, 2016). On the other hand, positive changes in social-economic and institutional factors (such as access to basic social service) boost households' capacity to respond to drought. Therefore, the net change in resilience capacity between t_n and t_{n+1} for a household that experienced drought in period t_n depends on which of the two effects outweighs the other, assuming other factors constant. For a household that did not experience drought in period t_n , the change in resilience over time depends on positive changes in social-economic and institutional factors (such as access to basic social services), keeping other factors constant.

4 Data and methods

In this section, we describe the dataset used in the analysis. We also provide details on the methods used in constructing the resilience capacity indexes and the indicators of both the resilience capacities (absorptive, adaptive and transformative) and household food security. Furthermore, we discuss the empirical strategy adopted to examine the relationships between drought and food security while accounting for the mitigating role of resilience capacities.

4.1 Data

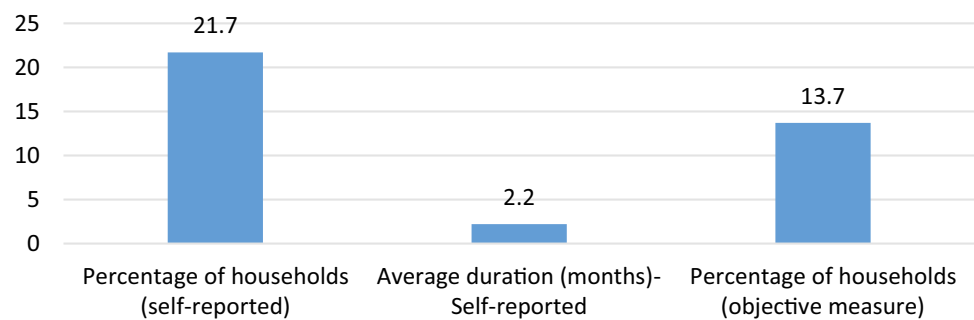
This paper uses five waves (2010/11, 2011/12, 2013/14, 2015/16, 2018/19) of the Uganda National Panel Survey (UNPS) dataset whose design and implementation were supported by the World Bank Living Standards Measurement Study. These integrated surveys on Agriculture (LSMS-ISA)

were implemented by the Uganda Bureau of Statistics (UBoS). Each wave covers a cross section of a nationally representative sample of households surveyed over a twelve-month period (a wave). The initial wave of 2009/10 had 3,123 households which were tracked up to 2011/12. However, in 2013, there was a sample refresh which resulted in dropping of one-third of the original sample as new households were brought on board. Therefore, 2,082 households transited to 2013/14 and the subsequent waves. Cognizant of the possible attrition that is likely to be worsened by the sample refresh, we accord special attention to addressing attrition bias as discussed in the preceding sections.

The UNPS surveys entail household, community and agriculture modules. At the household level, the questionnaire collects information on aspect ranging from household demographics, shocks and coping strategies, labour market participation, asset ownership, welfare & food security, among others. The community-level questionnaire captures the socio-economic characteristics of the community such as access to; markets, health facilities, financial services, schools, roads etc. and Community-Based Organizations (CBOs) and groups. The agricultural questionnaire is administered to agricultural households to gather information on agricultural inputs such as land, agricultural inputs and outputs. The surveys therefore provide sufficient data for analyzing household resilience capacities. Note that we do not use the wave for 2009/10 because the community questionnaire for this wave misses the section on community characteristics, community groups, and communal resources which have been suggested to form part of resilience capacities (Feed the Future FEEDBACK, 2015).

In the section on shocks and coping strategies, households were asked whether they experienced listed shocks (drought

Fig. 2 Percentage of households that experienced drought and the average duration. Source; Author's own construct using data from UNPS 2010/11 to UNPS 2018/19



inclusive) in the twelve months prior to the survey. In the analysis, we use this self-reported incidence of drought alongside an objective measure of drought from global Standardized Precipitation Evapotranspiration Index (SPEI) database. The SPEI database offers long-time, robust information about drought conditions at the global scale, with a 0.5 degrees spatial resolution which allows extraction of country, region, or community specific data. The SPEI is preferred because it takes into account both precipitation and potential evapotranspiration in determining drought (Vicente-Serrano et al., 2010). In addition, the multi-scalar nature of the SPEI enables identification of different drought types and drought impacts on diverse systems (Vicente-Serrano et al., 2012). Similar to d'Errico et al. (2018), we generate a dummy variable equal to 1 if SPEI average is below one standard deviation from long-term average, and 0 otherwise. Nonetheless we also use the index in its continuous form to account for variations in drought severity.

Preliminary analysis shows drought remains a significant shock to Ugandan households. Succinctly, about 22 percent of the households in the pooled sample reported to have experienced drought, with an average duration of 2 months and 6 days (Fig. 2).¹¹ However, there could be a tendency of over reporting since the objective measure suggests 14 percent of the households experienced drought during the period under consideration.

4.2 Construction of resilience indexes

Resilience is a nascent and multidimensional concept whose measurement and quantification is arguable. Given that resilience capacities are used as explanatory variables and mitigating factors, moderating the impact of drought on food security in this study, it is more pragmatic to adopt the TANGO approach which does not incorporate food security in resilience measurement (d'Errico & Smith, 2019).

The TANGO framework uses factor analysis to construct resilience capacity index based on three types of resilience

capacity—absorptive capacity, adaptive capacity and transformative capacity (Smith & Frankenberger, 2018; Upton et al., 2021). This approach allows for construction of resilience capacity index without incorporating the outcome variable (food security) (d'Errico & Smith, 2019), thus allowing resilience capacity index to be used as an explanatory variable in subsequent analysis of food security.

There is a difference between the TANGO approach and the FAO's RIMA-II framework. The former entirely employs factor analysis (in two steps) using only indicators of resilience capacity while the RIMA-II framework combines factor analysis with Multiple Indicators Multiple Causes (MIMIC) estimation using both indicators of resilience capacities and food security (d'Errico & Smith, 2019). The TANGO approach analyses resilience along the three capacities (mentioned above) while the FAO approach uses four resilience pillars—access to basic services, assets, social safety nets and adaptive capacity (d'Errico & Smith, 2019). Notably, all the four resilience pillars under the FAO framework fall under at least one of the three capacities of TANGO's approach (d'Errico & Smith, 2019).

More so, the TANGO framework provides potential indicators which have already been organised under the three capacities according to the original framework. Nonetheless, both approaches tantamount to Structural Equations Modelling (SEM) since they rely on multiple observed indicators to measure a single, latent unobserved variable. Markedly, both approaches have been found to yield similar policy implications (d'Errico & Smith, 2019) even though they possess several disagreements in out-of-sample predictions which result into false positives and false negatives (Upton et al., 2021).

As already mentioned, we use the TANGO approach to construct resilience capacity index given that it contains all the indicators of FAO's RIMA framework. Specifically, we adopt a two-step factor analysis to construct resilience capacity index for Uganda's households in five waves of Uganda National Household Panel Surveys. In the first step, indexes of three resilience capacities – *absorptive*, *adaptive*, and *transformative*, are constructed using factor analysis based on observable variables as suggested by TANGO. In the second step, the overall resilience capacity index is constructed by combining

¹¹ Assuming a months has 30 days.

Table 1 Resilience capacities and their respective components Resilience capacities and components

Resilience capacities and components	Proxy measures for the components
Absorptive capacity	
<ul style="list-style-type: none"> • Availability of informal safety nets • Access to remittances • Asset ownership 	<p>Availability of groups such as women's groups, saving groups, mutual help groups, youth groups, and religious groups in the community</p> <p>Amount of remittance received monthly per capita</p> <p>Principal component index based on a list of dummy variables assuming a value of 1 or 0, depending on whether or not the household has specific assets</p>
Adaptive capacity	
<ul style="list-style-type: none"> • Linking social capital • Human capital or Education/training • Livelihood diversification • Exposure to information • Availability of financial resources 	<p>This represents people's ability to form vertical linkages with sources of power and authority outside of their community. Similar to Feed the Future FEEDBACK (2015), we proxy linking capital using the quality of services provided in a households' community (roads, educational facilities, health services, veterinary services, and agricultural services)</p> <p>Years of schooling of the household head</p> <p>Principal component index based dummies for different livelihood sources; agriculture, non-agriculture enterprise, wage employment, transfers</p> <p>Principal component index based on a list of dummy variables assuming a value of 1 or 0, depending on whether or not the household owns source of information; radio, TV, mobile telephone</p> <p>Principal component index based on a list of dummy variables assuming a value of 1 or 0 depending on whether the community has commercial bank, microfinance institution, or a SACCO</p>
Transformative capacity	
<ul style="list-style-type: none"> • Availability of/access to formal safety nets • Availability of markets • Availability of/access to communal natural resources • Availability of/access to infrastructure • Availability of/access to agricultural extension services 	<p>Food assistance, direct transfers from government or NGOs</p> <p>Principal component index based on a list of dummy variables assuming a value of 1 or 0 depending on whether the community has; a market selling agriculture inputs; a market selling agriculture produce; a market selling non-agriculture produce; a primary livestock market</p> <p>Principal component index based on a list of dummy variables assuming a value of 1 or 0 depending on whether the community has; communal crop land; communal pasture, communal forest, communal water bodies</p> <p>weighted index based on the dummy variables capturing whether the community has; a tarmac road; murrum road, feeder road, and community road</p> <p>Whether there are agriculture extension service within the community</p>

Author's own construction 2020

the three indexes of resilience capacities using factor analysis. Note that we analyse resilience for all households, regardless of whether they experienced drought or not.

To calculate an index for the latent variable, factor analysis finds one or more common factors that linearly reconstruct the observed variables by predicting their correlation matrix. It then calculates factor loadings for possibly multiple common factors. These loadings are used to identify which common factor appears to be the one representing the concept being measured. Such identification takes place by examining the signs and magnitudes of the loadings. After identifying a common factor, the loadings are used to calculate the desired index, as a weighted average. The overall resilience capacity index is calculated as follows;

$$RCI = \beta_1 ABC + \beta_2 ADC + \beta_3 TC, \quad (1)$$

where *RCI* is resilience capacity index, *ABC* is absorptive capacity, *ADC* is adaptive capacity and *TC* is transformative capacity, β s are factor analysis coefficients estimated using inter-correlations among the three resilience capacity indexes. They are interpreted as weights given to the capacities in the estimation of an overall resilience capacity index, with greater weights given to capacities that correlate more highly with the overall index. The components of each resilience capacities drawn from the TANGO framework are summarised in Table 1.

The constructed indexes are normalised to the range between 0 and 100 by using the formula;

$$index_{norm} = \left(\frac{x - min}{max - min} \right) * 100, \quad (2)$$

where $index_{norm}$ is the normalise index, x is the value of the index before normalising, min and max are the minimum and maximum values. Note that we construct resilience in each wave separately but normalise the values after appending the waves. As such, normalisation is premised on the same base within the panel which allows for comparison of the index over time. Whereas this type of normalisation allows for comparison over time and across households, it does not reveal information about absolute resilience. Therefore 0 and 100 should be treated as extreme points within the sample but not as absolute vulnerability and resilience respectively.

4.3 Empirical strategy

To address the main question of the paper, we setup a simple empirical strategy showing how resilience capacity moderates the impact of drought on food security. In general, two models are specified. First, we estimate the mitigating impact of overall resilience capacity index, and then introduce the three resilience capacities. The general specifications of the empirical models are shown in Eqs. (3) and (4).

$$FS_{it} = \alpha + \gamma RCI_{it} + \beta' X_{it} + \theta D_{it} + \Phi(RCI_{it} * D_{it}) + \mu_i + e_{it}, \quad (3)$$

$$FS_{it} = \alpha + \gamma' RC_{it} + \beta' X_{it} + \theta D_{it} + \Phi'(RC_{it} * D_{it}) + \mu_i + e_{it}, \quad (4)$$

where FS is food security, measured by the indicators discussed below. RCI is the overall Resilience Capacity Index, RC is a vector of the three resilience capacities and D is drought shock. X is a vector of household demographics (age of household head, gender of household head, marital status of household head, family-size) and location variables (urban/rural and regions).

The interaction between RCI and D enables us to examine the extent to which resilience mitigates the impact of drought on food security. The interaction between resilience capacities (Eq. 3) and drought enables us to examine which capacities have the highest mitigating effect on the impact of drought on household food security. The inclusion of interactive terms in the model indicates that the impact of drought on food security is dependent upon household's resilience capacity and that households are affected differently depending on their level of resilience. Based on Eqs. (3) and (4), the marginal impact of drought is given by Eqs. (5) and (6);

$$\frac{\partial FS_{it}}{\partial D_{it}} = \theta + \Phi RCI_{it} \quad (5)$$

$$\frac{\partial FS_{it}}{\partial D_{it}} = \theta + \Phi' RC_{it} \quad (6)$$

From existing literature, θ is expected to be negative since it measures that direct impact of drought on food security. Φ is predicted to be a positive coefficient, neutralising the negative impact of drought on food security. Therefore, the full impact of drought is only transmitted to food security if resilience capacity index is equal to zero.

In the empirical analysis, two measures of food security have been used; per capita food consumption and number of meals per day. Food security measures were identified based on literature on food security and food security indicators in the UNPS. These are highlighted below;

- *Per capita food consumption*: Similar to d'Errico et al. (2018), we use per capita monthly food consumption, including expenditure on food, the monetary value of own-produced food, and monetary value of food received as gifts. For comparability across waves, the monetary value is expressed in constant US dollars using the official exchange rate for the years when the data was collected. Given that the relationship between drought and per capita food consumption is likely not to be instantaneous, per capita food consumption is estimated with a one period lead.
- *Number of meals consumed by a household per day*: The household questionnaire captures the number of meals that a household consumes in a day, including breakfast which allows us to examine how drought affects meals consumed by a household and which resilience capacities mitigates the impact of drought.

Given that we have two measures of food security, each of the Eqs. (3 and 4) represents a set of two specific equations based on the different measures of food security. The relationships specified in Eqs. (3) and (4) were examined using pooled OLS and fixed effects estimation technique. The major justification for choosing fixed effects over random effects is the need to control for unobserved heterogeneity which is very common with household data. Furthermore, household fixed effects are more likely to be correlated with regressors which might bias estimates in case of random effects. Whereas we are cognizant of potential endogeneity due to non-random exposure to drought by households, the fixed effects estimators control for all time invariant factors which could cause this bias. Furthermore, the reverse causation from food security indicators to resilience capacities is mitigated by using one period lead of consumption in regression analysis.

Another potential source of bias is attrition, which is likely to be worsened by the sample refresh in 2013 (as highlighted in the data section). To control for attrition bias, we follow the approach adopted by Cheng and Trivedi (2015) which involves specifying and estimating attrition function (probability of dropping out of the sample) from which the

Table 2 Trends in estimated resilience capacities and resilience capacity index

Resilience capacities	2010/11	2011/12	2013/14	2015/16	2018/19	Average
Absorptive Capacity	31.4	33.4	35.2	37.2	37.0	34.8
Adaptive Capacity	29.3	47.2	23.1	26.6	27.8	30.8
Transformative Capacity	22.9	23.9	20.6	31.4	30.4	25.8
Resilience Capacity Index	29.9	27.9	31.4	31.3	30.5	30.2

Source: Author’s own construction (2021) using data from UNPS 2010/11–2018/19

attrition hazard (aka inverse mills ratio) is computed. The regression models are then re-estimated while controlling for attrition hazard. Given that attrition hazard is a generated regressor, we use bootstrap standard errors to obtain efficient estimates (Cheng & Trivedi, 2015). The probit specification of the attrition function is given by;

$$Pr[A_{it} = 1] = \Phi[Z'_{it}\gamma] \tag{7}$$

where; A_{it} is attrition variable which takes the value 1 if the household dropped out of the sample along the way, 0 otherwise. Z_{it} is a vector of covariates which include; age of the household head, gender of the household head, marital status of the household head, household size, education of the household head, and region.

5 Results

5.1 Household resilience capacities

Table 2 shows the measured levels of resilience based on the methodology discussed in the preceding section. Our analysis suggests stagnation of resilience capacity index over

time, with majority of the households being highly susceptible to the impacts of shocks due to low resilience capacity index. This suggests that majority of the households rely on negative coping strategies (such as selling assets, depletion of savings, changing diet patterns, borrowing) to deal with the impact of shocks, drought inclusive. This has adverse implications for resilience to future shocks. Furthermore, the distribution of all resilience capacities (Fig. 3) and overall resilience capacity index (Fig. 4) is skewed to the lower end, suggesting massive room for expansion of resilience capacity for majority of the households. Notably, there is a higher variation in adaptive capacity (especially at the higher levels of resilience) compared to absorptive and transformative, suggesting higher levels of inequality in terms of household resilience. Nonetheless, households in Uganda exhibit relatively higher capacity to absorb shocks, compared to adapting and transforming the impact of shocks (Table 2).

Further descriptive analysis of the resilience capacity index and resilience capacities reveals that resilience capacities for Ugandan households are unstable and exhibit significant variation over time. Results in Table 3 show that households exhibit high within standard deviations for all resilience capacities, more so absorptive capacity. Given the stagnation in resilience capacities earlier observed, the high

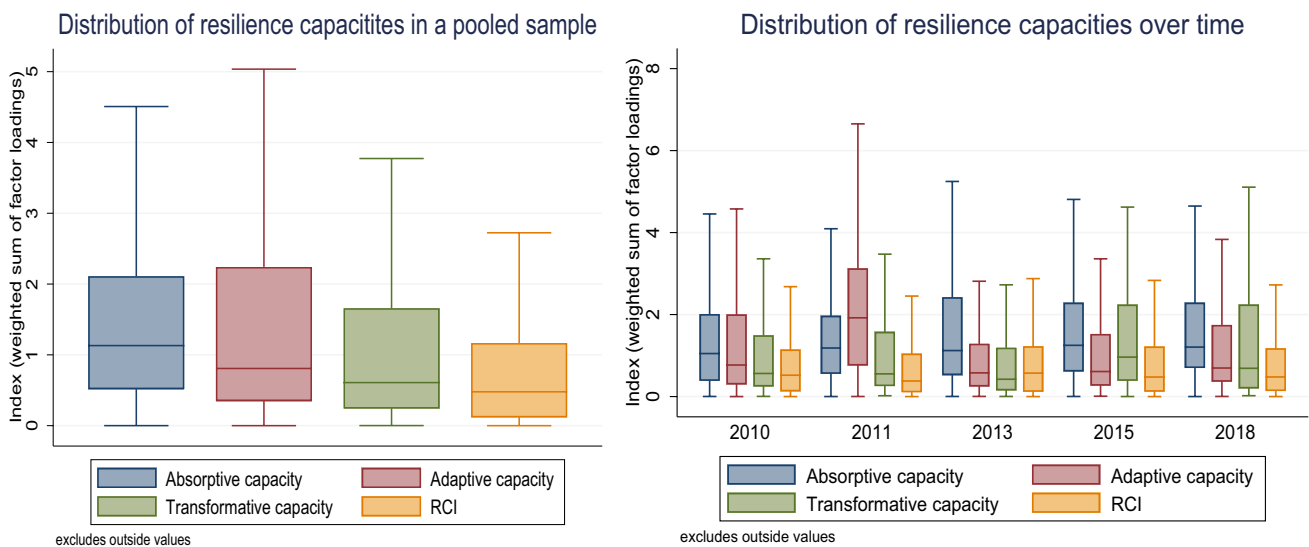
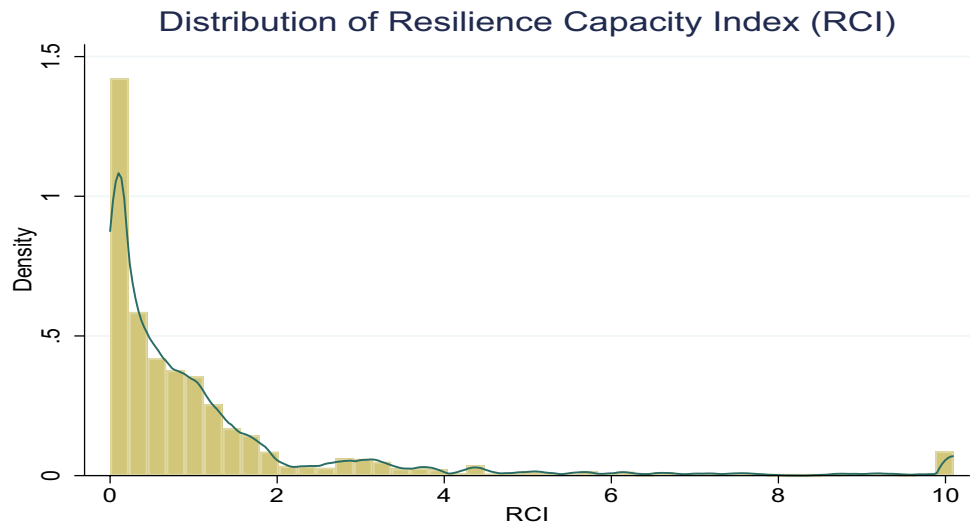


Fig. 3 Distribution of resilience capacities. Source: Author’s own construction (2021) using data from UNPS 2010/11–2018/19

Fig. 4 Distribution of Resilience Capacity Index. Source: Author's own construction (2021)



variation in resilience capacities alludes to limited capacity to sustain gains in household livelihoods and resilience in Uganda. Although the between variation is less than the within variation, it is also quite high, reaffirming high degree of inequality in terms of resilience earlier observed. This implies that some households are highly vulnerable while others are highly resilient. According to the data, most of the vulnerable households are from the northern and eastern regions of the country.

Similar to d'Errico et al. (2018), results from factor analysis show that adaptive capacity contributes the highest to building resilience capacity among households in Uganda. More specifically, uniqueness values from factor analysis suggest that adaptive capacity if left alone would explain an average of 59 percent of the variation in resilience capacity index across the waves while transformative capacity and absorptive capacity would explain 38 percent 31 percent respectively (Table 4).

Further analysis shows that access to informal safety nets is the most important factor contributing to absorptive capacity of Ugandan households. Results suggest that informal safety nets, if left alone would individually explain an average of 97 percent of the variation in absorptive capacity across the waves (Table 4). This alludes to the need to reinvigorate informal safety nets such as saving groups, agriculture cooperatives, farmers' groups as a way of building households capacity to absorb shocks.

Regarding adaptive capacity, availability of financial services, *linking social capital* and exposure to information are the most important factors. For instance, availability of financial resources if left alone would explain 62 percent of the variations in adaptive capacity, *linking social capital* if left alone would explain 59 percent, while exposure to information would also explain 59 percent of the variations in adaptive capacity if left alone (Table 4). Transformative capacity is mainly driven by access to

Table 3 Descriptive statistics for resilience capacities

Variables		Mean	Std. Dev	Min	Max	Observations		
Resilience Capacity Index	Overall	29.6	21.5	0.1	89.7	N	=	2305
	Between		12.0	0.5	81.6	n	=	461
	Within		17.8	-36.1	95.6	T	=	5
Absorptive Capacity	Overall	35.1	32.1	0.0	100.0	N	=	2302
	Between		18.4	0.7	100.0	n	=	461
	Within		26.4	-35.4	112.5	T-bar	=	5
Adaptive Capacity	Overall	28.2	31.6	0.0	101.1	N	=	2302
	Between		18.5	2.3	101.1	n	=	461
	Within		25.6	-52.7	107.5	T-bar	=	5
Transformative Capacity	Overall	21.0	27.4	0.5	94.8	N	=	2305
	Between		15.8	2.3	94.8	n	=	461
	Within		22.4	-44.6	95.7	T	=	5

Source: Author's own construction (2021) using data from UNPS 2010/11–2018/19

Table 4 Factor analysis uniqueness values for the different components of resilience capacities

Components of resilience capacities	Factor 1	Factor 2	Uniqueness
Absorptive Capacity			
Availability of informal safety nets	-0.16	0.97	0.03
Access to remittances	0.73	-0.02	0.47
Asset ownership	0.71	0.24	0.45
Adaptive Capacity			
<i>Linking Social capital</i>	0.33	0.69	0.41
Human capital/education	0.73	-0.14	0.45
Livelihood diversification	0.55	-0.29	0.62
Exposure to Information	0.75	-0.16	0.41
Availability of financial resources	0.20	0.76	0.38
Transformative Capacity			
Access to formal safety nets	-0.04	-0.23	0.95
Availability of markets	0.71	-0.25	0.44
Access to communal natural resources	0.06	0.95	0.10
Availability/access to infrastructure	0.74	0.03	0.45
Availability of agricultural extension services	0.74	0.11	0.45
Resilience Capacity Index			
Absorptive Capacity	0.55	-	0.69
Adaptive Capacity	0.76	-	0.41
Transformative capacity	0.62	-	0.62

Source: Author's own construction (2021) using data from UNPS 2010/11–2018/19

communal resources, availability/access to markets, and availability of extension services (Table 4).

5.2 Empirical results and discussion

As earlier mentioned, one of the potential sources of bias in the regression analysis is attrition which was addressed by estimating the attrition function. Indeed, results in Table 5 suggest that attrition was non-random and highly explained by some household demographics and location. Female headed, bigger households, and those headed by highly educated individuals were more likely to drop out of the sample. Accordingly, attrition hazard was estimated and introduced in the outcome models (food security models) as a generated regressor. Whereas the significance tests on attrition hazard in the outcome models suggest presence of attrition for most of the models, there is no evidence of attrition bias in the coefficient estimates since the estimated coefficients before and after adjusting for attrition are close in magnitude and level of significance especially in the pooled sample.

In the outcome models, we present results of the pooled OLS, fixed effects and attrition adjusted. We discuss the results of the fixed effects model in comparison to the pooled sample and attrition adjusted results especially where there is a contradiction in the results. Our results are in line with previous studies (such as Funk et al., 2012; Watuleke, 2015; Akwango et al., 2017; Twongyirwe et al., 2019), whereby drought undermines food security by reducing both the

amount of food consumed and the number of times households eat in a day (number of meals per day) regardless of the estimation technique. Table 6 shows that households that report to have experienced drought are associated with 21 to 22% lower per capita food consumption and are likely to consume fewer meals compared to their counterparts. Remarkably, the adverse impact of drought on both per capita food consumption and meals consumed diminishes with the duration of drought although households still experience negative changes in food consumption (Table 7). Therefore, the onset of drought has more devastating effects on household food security. This suggests that households and humanitarian agencies are reactionary in nature, triggering resilience mechanisms after the shock has happened as opposed to building resilience ex-ante.

Regarding the impact of resilience on food security, the results of the fixed effects model are contrary to our prior expectations. The results show that, no significant impact is realized under the fixed effects estimation for meals per day and negative impact on per capita food consumption. This however suggest that households undertake precautionary measures by investing in assets that help them respond to shocks, but this comes at cost in terms of reducing consumption expenditure. Nonetheless, the results from the pooled sample (Tables 6 and 7; Model 1) suggest that increase in resilience capacity index enhances household's food security through both per capita food consumption and number of meals per day (regardless of the measure of drought

Table 5 Estimated marginal effects from the attrition function

Variables	Marginal effects for Probit estimation
Age of the household head	-0.021*** (0.002)
Age squared	0.017*** (0.002)
Gender (Ref: male)	
Female	0.044*** (0.015)
Marital status (Ref: Unmarried)	
Married	-0.033** (0.016)
Household size	0.008*** (0.002)
Education (Ref: Primary)	
Secondary	0.016 (0.016)
Post-secondary	-0.036 (0.030)
Degree and above	0.153*** (0.045)
Region (Central)	
East	-0.076*** (0.013)
North	-0.332*** (0.014)
West	-0.190*** (0.014)
<i>N</i>	7,388

Standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

incorporated in the model). However, the results of the pooled sample cannot be over emphasised since it ignores unobserved heterogeneity.

Notwithstanding the mixed results on the relationship between resilience capacity and food security, our results show that resilience capacity mitigates the adverse effects of self-reported drought. The interactive terms between drought and resilience in Tables 6 and 7 (Models 2 and 5) show that households with high resilience capacity are more likely to sustain their food consumption in the event of drought (since the coefficients are positive and significant). The results in Table 7 (Models 2 and 5) also show that resilience plays an important role in mitigating the devastating effects of prolonged drought (measured by drought duration) on food security.

Notably, exogenous measure of drought (SPEI data) shows no significant impact of drought on per capita food consumption regardless of the estimation technique (Tables 8 and 9, Models 1 to 3). However, households that experienced drought are likely to have fewer meals per day compared to those that did not experience drought regardless of the estimation technique (Tables 8 and 9; Models 4 to 6). Since per capita food consumption is expressed in monetary values, the neutrality of the effect of drought on per capita food consumption could be attributed to the fact that drought effects spill over to prices of food which may offset the effect of reduction in quantities consumed.

Similar to self-reported shock, under the SPEI data, resilience plays an important role in mitigating the impact of drought on food security. In this regard, as resilience capacity increases, drought ceases to have a significant impact on meals consumed by a household. Moreso, households with higher resilience capacities can increase their per capita food consumption (Tables 8 and 9). This implies an increase in resilience capacity not only prevents reduction in number of

Table 6 Drought (self-reported) and food security: Mitigating effect of RCI

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought dummy (Self-reported)	-0.221** (0.087)	-0.208** (0.083)	-0.212** (0.088)	-0.167*** (0.045)	-0.133*** (0.036)	-0.163*** (0.040)
Resilience Capacity Index (RCI)	0.096*** (0.017)	-0.056*** (0.016)	0.089*** (0.016)	0.033*** (0.008)	-0.008 (0.011)	0.029*** (0.007)
Drought*RCI	-0.085* (0.049)	0.093* (0.050)	-0.079 (0.052)	-0.013 (0.028)	0.050** (0.021)	-0.010 (0.028)
Attrition hazard (χ^2)			7.52			6.30
Attrition hazard (p-value)			(0.006)			(0.012)
<i>N</i>	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author’s own construction using data from UNPS 2010/11 to 2018/19

Table 7 Drought duration (self-reported) and food security: Mitigating effect of RCI

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought duration	-0.059** (0.026)	-0.058** (0.024)	-0.056*** (0.022)	-0.041*** (0.014)	-0.037*** (0.011)	-0.040** (0.016)
Resilience Capacity Index (RCI)	0.094*** (0.017)	-0.055*** (0.016)	0.087*** (0.018)	0.033*** (0.008)	-0.007 (0.011)	0.029*** (0.009)
Drought duration*RCI	-0.019 (0.015)	0.028** (0.014)	-0.017 (0.015)	-0.003 (0.009)	0.015** (0.007)	-0.002 (0.009)
Attrition hazard (χ^2)			7.52			6.30
Attrition hazard (p-value)			(0.006)			(0.012)
N	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author's own construction using data from UNPS 2010/11 to 2018/19

meals consumed by a household per day, but also enables them to sustain the quantity of food consumed.

Broadly and regardless of the measures of drought, our results confirm the assertion that households with weaker resilience capacities are more susceptible to drought (Shiferaw et al., 2014; Twongyirwe et al., 2019; Gerber & Mirzabaev, 2017), offering support for the findings of d'Errico et al. (2018) that resilience ameliorates the negative effect of drought on households' future food security. Accordingly, building household resilience is critical for mitigating the adverse effects of drought on food security.

Regression analysis based on the three resilience capacities show that resilience capacities have insignificant effect (based on fixed effects model) on food security however their role is activated when households experience drought. Results of the fixed effects model (Tables 10 and 11) show that the three

resilience capacities on their own have a mute effect on food security. Nonetheless, the pooled sample and attrition adjusted results suggest absorptive capacity significantly enhances per capita food consumption and the number of times households eat regardless of the measure of drought (Tables 10 to 12; Models 1, 3, 4, and 6). Adaptive and transformative capacities are only effective in enhancing per capita food consumption. As such, the role of resilience capacities in enhancing food security on their own cannot be disputed completely.

In line with Feed the Future FEEDBACK (2015), we find the mitigating role of resilience on the impact of drought on food security to vary, depending on the resilience capacities possessed by households and the indicator of food security. Households with high adaptive capacity are more likely to be resilient to the adverse impacts of drought on food security by resisting a decline in the per capita food consumption (under

Table 8 Drought (SPEI) and food security: Mitigating effect of RCI

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought dummy (SPEI)	0.019 (0.074)	0.070 (0.065)	-0.009 (0.065)	-0.173*** (0.035)	-0.059** (0.030)	-0.192*** (0.035)
RCI	0.078*** (0.020)	-0.060*** (0.016)	0.072*** (0.018)	0.033*** (0.009)	-0.002 (0.011)	0.028*** (0.009)
Drought*RCI	0.041 (0.039)	0.071** (0.029)	0.041 (0.038)	0.001 (0.020)	0.003 (0.015)	0.001 (0.020)
Attrition hazard (χ^2)			9.22			16.67
Attrition hazard (p-value)			(0.002)			(0.000)
N	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author's own construction using data from UNPS 2010/11 to 2018/19

Table 9 Drought severity (SPEI) and food security: mitigating effect of RCI

	(1) Per capita food consumption			(4) Number of meals per day by the HH		
	(2)	(3)	(5)	(6)		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought severity (SPEI dummy*SPEI index)	-0.091 (0.199)	0.102 (0.188)	-0.150 (0.209)	-0.388*** (0.082)	-0.142* (0.074)	-0.427*** (0.085)
RCI	0.076*** (0.019)	-0.060*** (0.016)	0.070*** (0.020)	0.031*** (0.009)	-0.001 (0.011)	0.026*** (0.010)
Drought severity*RCI	0.173* (0.100)	0.247*** (0.086)	0.163 (0.111)	0.008 (0.055)	-0.006 (0.044)	0.002 (0.063)
Attrition hazard (χ^2)			14.78			15.13
Attrition hazard (p-value)			(0.000)			(0.000)
N	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author’s own construction using data from UNPS 2010/11 to 2018/19

fixed effects model) and decline in number of meals (after adjusting for attrition) (Table 10).

Transformative capacity completely dampens the adverse effects of drought on the number of times households eat (under fixed effects model), but has a mute effect on per capita food consumption (Table 10; Models 2 and 5). Furthermore, the interactive term between drought (exogenous) and transformative

capacity under per capita consumption (Table 11-Model 2 & Table 12-Model 2) suggests households with higher transformative capacity are protected from a decline in per capita food consumption in the event of drought. Note that the pooled sample suggests that transformative capacity only ameliorates the negative effects of drought (self-reported) on per capita food consumption and has a mute effect on number of meals eaten

Table 10 Drought (self-reported) and food security: Mitigating effect of resilience capacities

	(1) Per capita food consumption			(4) Number of meals per day by the HH		
	(2)	(3)	(5)	(6)		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought (self-reported)	-0.316*** (0.099)	-0.281*** (0.094)	-0.303*** (0.097)	-0.132*** (0.041)	-0.093** (0.040)	-0.200*** (0.043)
Absorptive capacity	0.033*** (0.010)	-0.008 (0.008)	0.033** (0.015)	0.012*** (0.004)	0.006 (0.005)	0.017*** (0.005)
Drought*Absorptive	0.011 (0.031)	0.030 (0.023)	0.014 (0.033)	0.004 (0.011)	0.003 (0.011)	0.012 (0.024)
Adaptive capacity	0.034*** (0.008)	0.006 (0.008)	0.031*** (0.009)	0.002 (0.004)	-0.005 (0.004)	0.006* (0.003)
Drought*Adaptive	0.080* (0.045)	0.106** (0.046)	0.077* (0.044)	-0.006 (0.019)	-0.023 (0.019)	0.032* (0.018)
Transformative capacity	0.020** (0.008)	-0.007 (0.008)	0.017* (0.010)	-0.001 (0.004)	-0.002 (0.005)	-0.002 (0.004)
Drought*Transformative	-0.068*** (0.023)	-0.022 (0.025)	-0.067*** (0.023)	0.009 (0.011)	0.024** (0.011)	-0.017 (0.014)
Attrition hazard (χ^2)			5.52			8.02
Attrition hazard (p-value)			(0.019)			(0.005)
N	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author’s own construction using data from UNPS 2010/11 to 2018/19

Table 11 Drought (SPEI) and food security: Mitigating effect of resilience capacities

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought dummy (SPEI)	-0.025 (0.079)	0.047 (0.072)	-0.045 (0.085)	-0.199*** (0.036)	-0.088*** (0.032)	-0.216*** (0.040)
Absorptive Capacity	0.037*** (0.010)	-0.002 (0.008)	0.037*** (0.010)	0.018*** (0.004)	0.004 (0.005)	0.018*** (0.005)
Drought*Absorptive	0.039 (0.036)	0.034 (0.033)	0.042 (0.057)	0.015 (0.017)	0.032** (0.016)	0.018 (0.021)
Adaptive Capacity	0.027*** (0.010)	0.011 (0.009)	0.025** (0.012)	0.005 (0.004)	-0.007 (0.005)	0.003 (0.005)
Drought*Adaptive	0.030 (0.021)	0.005 (0.013)	0.027 (0.028)	0.013** (0.005)	-0.001 (0.007)	0.010 (0.009)
Transformative capacity	0.011 (0.009)	-0.020** (0.009)	0.008 (0.010)	-0.001 (0.004)	-0.001 (0.006)	-0.003 (0.005)
Drought*transformative	0.008 (0.019)	0.033*** (0.013)	0.009 (0.019)	0.001 (0.008)	0.006 (0.008)	0.002 (0.010)
Attrition hazard (χ^2)			6.33			24.89
Attrition hazard (p-value)			(0.012)			(0.000)
N	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author's own construction using data from UNPS 2010/11 to 2018/19

Table 12 Drought severity (SPEI) and food security: Mitigating effect of resilience capacities

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
Drought severity (SPEI dummy*SPEI index)	-0.201 (0.225)	0.007 (0.217)	-0.247 (0.216)	-0.453*** (0.085)	-0.252*** (0.079)	-0.492*** (0.089)
Absorptive capacity	0.041*** (0.010)	-0.004 (0.008)	0.041*** (0.013)	0.018*** (0.004)	0.004 (0.005)	0.018*** (0.005)
Drought severity*Absorptive	-0.008 (0.090)	0.142 (0.088)	-0.002 (0.135)	0.044 (0.040)	0.120*** (0.039)	0.049 (0.098)
Adaptive capacity	0.025** (0.010)	0.009 (0.009)	0.022** (0.011)	0.006 (0.004)	-0.006 (0.005)	0.004 (0.006)
Drought severity*Adaptive	0.111** (0.053)	0.029 (0.034)	0.103 (0.078)	0.027 (0.018)	-0.010 (0.018)	0.021 (0.020)
Transformative capacity	0.008 (0.009)	-0.017** (0.008)	0.005 (0.008)	-0.002 (0.004)	-0.002 (0.005)	-0.004 (0.004)
Drought severity*Transformative	0.087* (0.052)	0.107** (0.046)	0.088* (0.050)	0.009 (0.028)	0.025 (0.028)	0.009 (0.031)
Attrition hazard (χ^2)			0.52			11.52
Attrition hazard (p-value)			(0.001)			(0.001)
Observations	1,840	1,840	1,840	1,839	1,839	1,839

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author's own construction using data from UNPS 2010/11 to 2018/19

Table 13 Drought (Self-reported) and food security: Mitigating effect of different components of resilience capacities

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
<i>Absorptive capacity</i>						
Drought*informal safety nets	0.007 (0.052)	0.004 (0.059)	0.009 (0.057)	-0.004 (0.030)	-0.022 (0.028)	-0.003 (0.035)
Drought*Assets	-0.279*** (0.103)	-0.167 (0.101)	-0.280*** (0.101)	-0.107* (0.056)	-0.088* (0.051)	-0.107* (0.057)
Drought*remittances	-0.378 (0.230)	-0.350 (0.248)	-0.387 (0.265)	-0.177 (0.130)	-0.191* (0.108)	-0.178 (0.136)
<i>Adaptive capacity</i>						
Drought*linking social capital	0.049 (0.049)	0.023 (0.052)	0.049 (0.054)	0.046** (0.023)	0.051** (0.023)	0.046* (0.024)
Drought*livelihood diversification	-0.141 (0.173)	-0.185 (0.150)	-0.136 (0.184)	0.048 (0.079)	0.099 (0.069)	0.048 (0.074)
Drought*access to information	0.496*** (0.130)	0.347*** (0.126)	0.496*** (0.125)	0.237*** (0.077)	0.138** (0.069)	0.237*** (0.084)
Drought*Financial services	-0.431** (0.202)	-0.404 (0.247)	-0.415** (0.184)	-0.234** (0.110)	0.094 (0.108)	-0.233* (0.119)
Drought*formal education	0.179 (0.223)	0.371 (0.239)	0.161 (0.251)	0.056 (0.090)	0.064 (0.088)	0.055 (0.113)
<i>Transformative capacity</i>						
Drought* access to markets	-0.056 (0.053)	0.005 (0.060)	-0.053 (0.057)	-0.041 (0.031)	-0.027 (0.029)	-0.041 (0.037)
Drought*infrastructure	0.309*** (0.092)	0.193* (0.099)	0.303*** (0.100)	-0.018 (0.043)	0.020 (0.038)	-0.018 (0.048)
Drought*extension services	-0.112 (0.083)	-0.159** (0.079)	-0.119 (0.081)	-0.023 (0.041)	-0.057* (0.034)	-0.024 (0.044)
Drought*communal resources	-0.168* (0.087)	-0.181* (0.105)	-0.174* (0.091)	0.013 (0.066)	0.012 (0.047)	0.013 (0.081)
Drought*formal safety nets	0.396 (0.316)	0.471 (0.338)	0.410 (0.362)	0.246 (0.181)	0.225 (0.162)	0.247 (0.207)
Attrition hazard (χ^2)			4.51			-0.020
Attrition hazard (p-value)			(0.034)			(0.085)
N	1,530	1,530	1,530	1,530	1,530	1,530

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

Source: Author's own construction using data from UNPS 2010/11 to 2018/19

(Table 10). The mitigating effect of absorptive capacity only manifest with exogenous measure of drought and with regards to meals per day, possibly suggesting that self-reported measures underestimate the role absorptive capacity.

The preceding results about mitigating role of resilience capacities reveal significant variations in the effectiveness of different resilience capacities depending on the measure of drought. This warrants a deeper analysis of each of the three resilience capacities. Accordingly, a detailed analysis of mitigating role of various components of the resilience capacities (based on fixed effects model) shows that; (i)

access to information and linking social capital (proxied by quality of social services) are the most critical components of adaptive capacity under self-reported drought (Table 13); (ii) access to better infrastructure services are the most critical under transformative capacity (Table 13); (iii) informal safety nets are critical under absorptive capacity (Table 14). Nonetheless, the pooled sample and attrition adjusted suggest asset accumulation could enable households absorb the impact of drought on per capita food consumption, while extension services and access to communal resources could enable households to transform

Table 14 Drought (SPEI) and food security: Mitigating effect of different components of resilience capacities

	(1)	(2)	(3)	(4)	(5)	(6)
	Per capita food consumption			Number of meals per day by the HH		
	Pooled OLS	Fixed Effects	Attrition adjusted	Pooled OLS	Fixed Effects	Attrition adjusted
<i>Absorptive capacity</i>						
Drought*informal safety nets	-0.025 (0.045)	0.002 (0.048)	-0.032 (0.044)	0.072*** (0.025)	0.046* (0.025)	0.070*** (0.024)
Drought*Assets	0.180** (0.088)	0.016 (0.080)	0.172* (0.099)	0.075* (0.039)	0.039 (0.037)	0.073* (0.038)
Drought*remittances	-0.321 (0.198)	0.218 (0.315)	-0.339 (0.237)	-0.074 (0.118)	-0.185 (0.132)	-0.078 (0.110)
<i>Adaptive capacity</i>						
Drought*linking social capital	-0.157*** (0.033)	-0.095** (0.048)	-0.154*** (0.034)	-0.045** (0.018)	0.018 (0.020)	-0.045** (0.018)
Drought*livelihood diversification	-0.208*** (0.063)	0.009 (0.074)	-0.209*** (0.069)	-0.031 (0.031)	-0.010 (0.034)	-0.031 (0.043)
Drought*access to information	0.005 (0.134)	0.090 (0.133)	0.009 (0.142)	-0.017 (0.056)	-0.098* (0.056)	-0.017 (0.064)
Drought*Financial services	-0.259 (0.238)	-0.077 (0.291)	-0.184 (0.249)	-0.085 (0.138)	-0.013 (0.169)	-0.069 (0.153)
Drought*formal education	-0.226 (0.164)	-0.242 (0.193)	-0.218 (0.170)	-0.044 (0.078)	0.084 (0.081)	-0.042 (0.085)
<i>Transformative capacity</i>						
Drought* access to markets	0.082 (0.064)	0.042 (0.075)	0.078 (0.059)	0.024 (0.029)	0.024 (0.027)	0.023 (0.032)
Drought*infrastructure	-0.157* (0.083)	-0.106 (0.071)	-0.155** (0.079)	-0.030 (0.037)	-0.025 (0.036)	-0.030 (0.033)
Drought*extension services	0.126* (0.067)	-0.002 (0.066)	0.117 (0.079)	0.150*** (0.028)	0.022 (0.027)	0.148*** (0.032)
Drought*communal resources	-0.028 (0.070)	-0.027 (0.071)	-0.014 (0.078)	0.143*** (0.044)	0.053 (0.044)	0.146*** (0.042)
Drought*formal safety nets	0.627** (0.280)	-0.144 (0.426)	0.654* (0.347)	0.179 (0.170)	0.276 (0.173)	0.185 (0.154)
Attrition hazard (χ^2)			3.06			0.58
Attrition hazard (p-value)			(0.080)			(0.448)
N	1,530	1,530	1,530	1,530	1,530	1,530

Robust standard errors used in column 1 to 3. Bootstrap standard errors used in column (4) to (5). Additional covariates include age of the household head, age squared, gender of the household head, household size, marital, and status of the head

the effects of drought on the number times households eat. However, as earlier mentioned, the results of the pooled sample cannot be over emphasised since they ignore unobserved household heterogeneity.

6 Conclusion and recommendations

Due to the growing concern about food security amidst continued climate shocks, especially drought in Uganda, this paper analyses household resilience capacities with

special focus on how different resilience capacities mitigate the impact of drought on food security in the country. Following the TANGO framework, indexes of three resilience capacities (absorptive, adaptive, and transformative) were constructed upon which the resilience capacity index was constructed and analysed. In line with the TANGO framework, two-step factor analysis was adopted to develop resilience capacity index. Analysis of household resilience and food security was undertaken using panel data from the Uganda National Panel Surveys spanning five waves.

Our analysis shows that Ugandan households remain susceptible to the negative impact of drought and other shocks due to persistently low resilience capacities. In addition, all resilience capacities exhibit skewed distribution towards the lower end, suggesting room for increasing resilience for majority of households. Results from factor analysis show that adaptive capacity is the most contributing factor to household resilience followed by transformative capacity.

Regression analysis to establish the impact of drought on food security and the mitigating role of resilience on the impact of drought on food security was undertaken using pooled OLS and fixed effects estimation while controlling for potential attrition bias. Results confirm that drought undermines food security by affecting both amount of food consumed, and the number of times households eat in a day. However, the fixed effects results show that resilience capacity index effectively dampens the negative impact of drought on food security, albeit mute effect on number of meals under exogenous measure of drought. This implies households with high resilience capacity can withstand the adverse effects of drought.

A breakdown into resilience capacities reveals mixed results regarding the effectiveness of the different resilience capacities. Under self-reported drought, adaptive capacity mitigates the impact of drought on per capita food consumption, while controlling for unobserved heterogeneity. Under the objective measure of drought, transformative capacity is more effective in mitigating the effect of drought on per capita food consumption while absorptive capacity is more effective in mitigating the effect of drought on number of meals per day (based on the fixed effects models).

Given the above mixture, we explored the specific aspects in each resilience capacity that are effective in mitigating the impact of drought on food security. In this regard, a detailed analysis of the components of the three resilience capacities (based on fixed effects model) reveals that; (i) access to information and linking social capital (proxied by quality of social services) are the most important components of adaptive capacity under self-reported drought; (ii) access to better infrastructure services is the most critical aspect of transformative capacity; and (iii) informal safety nets is an important aspect of absorptive capacity. Our results therefore suggest that supporting households to build capacity to adapt to, transform, and absorb the impact of drought can help reduce reliance on humanitarian assistance as this is hardly sustainable.

Based on the evidence in this paper, there is need to invest in early warning systems and enhance access to climate related information to the vulnerable groups to enhance their preparedness and adaptation. The results also suggest need for provision of better-quality infrastructure services, especially transport infrastructure as these are critical for

accessing services (such as markets, credit institutions, among others) that aid in adapting and transforming the impacts of the shock.

It is also important to promote informal safety nets by rejuvenating and supporting informal institutions such as women's groups, saving groups, mutual help groups, youth groups, agriculture cooperatives and other community-based associations as these are critical for households to absorb the impact of the shock. These institutions can provide a platform for interventions by both Government and development partners at community level. The proposed Parish Development Model presents an opportunity to leverage informal institutions by channelling support through these groups and providing the necessary capacity building. In addition, there is need to educate households about informal schemes and support formation and sustainability of Rotating Saving and Credit Associations (ROSCA) and Village Saving and Loans Associations (VLSA). Furthermore, agriculture cooperatives need to be awakened to support households that rely on agriculture for their livelihood.

Acknowledgements The paper is an outcome of the STAAARS+ fellowship of the Food Security Policy Research, Capacity and Influences (PRCI) program of the USAID Feed the future initiative administered by Michigan State University, Cornell University and the International Food Policy Research Institute. This research is supported by the PRCI.

Declarations

Conflict of interest Authors declare no conflict of interest.

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