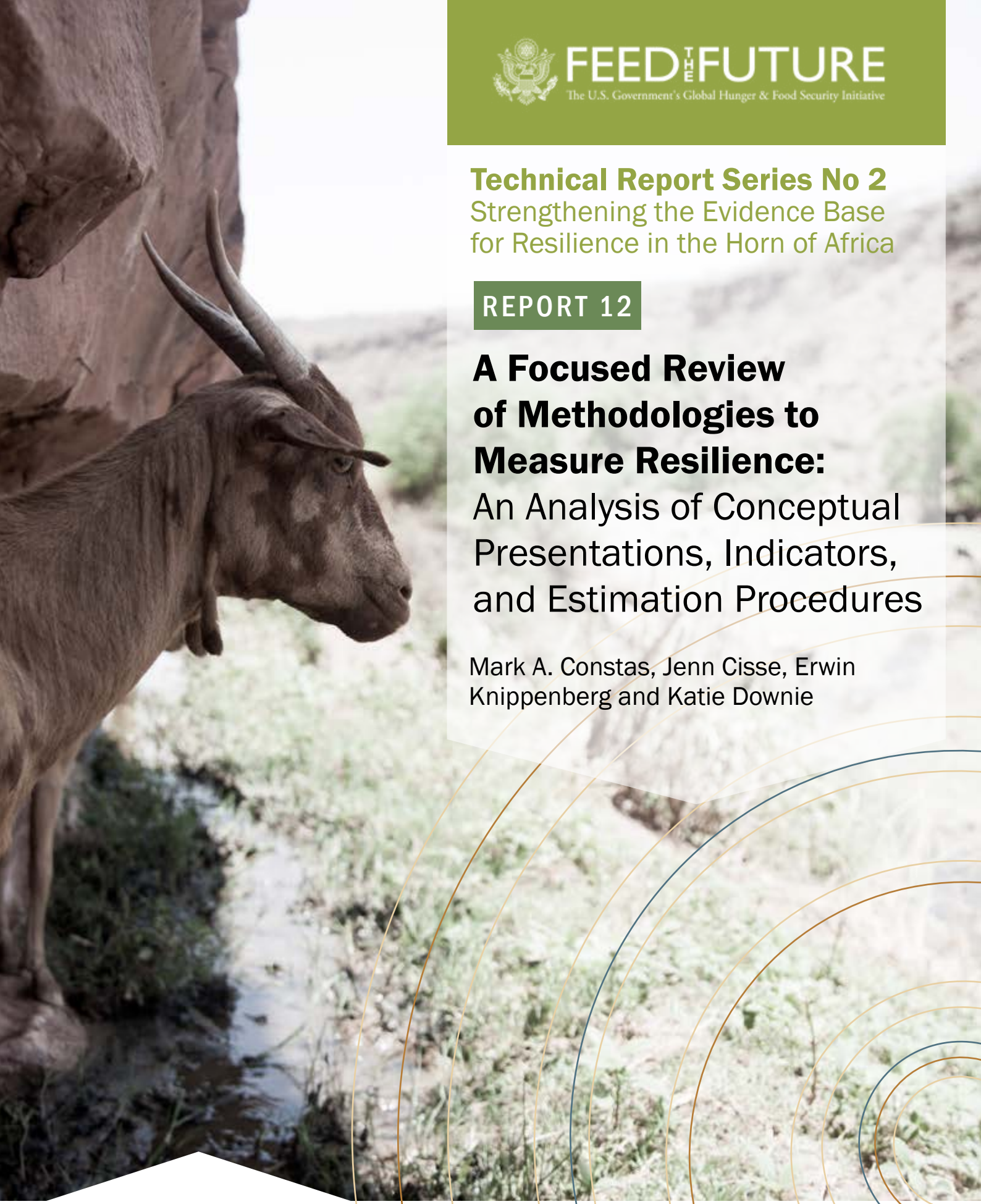

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REPORT 12

A Focused Review of Methodologies to Measure Resilience: An Analysis of Conceptual Presentations, Indicators, and Estimation Procedures

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Building Resilience in the Horn of Africa

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Background

Widespread acceptance of the increasing complexity regarding the configuration of stresses and shocks threatening the world's poor has fueled interest in development resilience among policy makers, implementers, and researchers. Increased levels of funding from donor agencies and the inclusion of resilience as a core element of strategic plans across United Nations agencies and among non-governmental organizations stand as evidence of a growing interest in resilience. As this interest has spread, discussion of the methods used to measure resilience has lagged behind (see Vaitla, Tesfay, Rounseville, & Maxwell, 2012). While the initial inattention to measurement was a cause for concern, one can now point to a growing body of work on resilience measurement. In the past few years, expert panels on resilience have been held (see Frankenberger & Nelson, 2013) and documents have been published that examine how the measurement of resilience might be approached conceptually, (Constas et al., 2014a), analytically (Constas et al., 2014b), and theoretically (Barrett & Constas, 2014). While there was some initial skepticism about the value of resilience as a concept that would help galvanize thinking and action for development and humanitarian aid (see Béné, Wood, Newsham & Davies, 2012), it now seems clear that interest in resilience is not a topic of fleeting interest. As investments continue to be made in resilience-focused programs and policies, the need for measurement will likely increase. Measurement is important because it underwrites efforts to track progress, monitor implementation, and assess the impact of investments that are meant to build resilience.

Measurement can be defined as the set of perspectives and tools needed to generate and analyze empirical data about some attribute, such as resilience. Together, the perspectives and tools constitute the measurement methodologies. Because measurement methodologies are intrinsically technical, the specific practices used to measure a given attribute are often opaque. Outside of the community of technical experts who practice measurement, measurement is therefore largely inaccessible. The lack of accessibility problem is worsened by the fact that resilience itself is often poorly defined[1]. This combination of technical opacity and semantic ambiguity creates a problem that makes it difficult to comprehend and compare measurement methodologies that are used for resilience, either to construct variables or to estimate relationships. The need to address this problem directly will become more vital as resilience programming matures and as the number of resilience measurement models increases.

Because resilience is a relatively new concept for development, there is not a large number of measurement models available. For some time, the only empirically tested models of resilience were variations of the early analysis carried out by the Food and Agriculture Organization in Palestine (see Alinovi, Mane, & Romano, 2008) and Kenya (Alinovi, d'Errico, Maine, & Romano, 2010). Over the past

[1]The highest level of consensus on a definition of resilience was reached by the Food Security Information Network's 20 member Resilience Measurement Technical Working Group (RMTWG). The RMTWG defined resilience as "....a capacity that ensures stressors and shocks do not have long-lasting adverse development consequences" (see Constas et al., 2014 a,b).

year, however, a number of additional measurement models have developed and subjected to empirical testing. Within the last year alone, four empirical studies have been issued (see, Alfani, Dabalaen, Fisker, & Molini, 2015; FAO, 2015; Kimetrica, 2015; Smith et al., 2015). What are the notable features or the measurement approaches that each study has used to measure resilience? To what extent it is possible to develop and apply a set of standardized review criteria to document the measurement of emerging and future empirical studies of resilience? In what ways do the various measurement methodologies help stakeholders, such as program implementers and policy makers, understand the set of dynamics that account for varied states of wellbeing following exposure to a risk-laden event? Drawing attention to questions of this kind for resilience measurement will assist in making resilience measurement more transparent and help consumers of resilience measures, and consumers of resilience-focused studies, understand the details of measurement methodologies.

The present study was conducted to both document the methodological features of a small sample of recent empirical studies of resilience and to demonstrate the value of a systematic review approach, which may support efforts to track progress on resilience measurement. The overarching motivation for the present project was to create a transparent, readily accessible review framework that could support the ongoing documentation of methodologies used in connection with resilience measurement. The goal of the work was therefore more descriptive than it was critical or evaluative. The description of measurement approaches was designed to address four *focal questions:*

1. **Conceptual Presentation of resilience:** How is resilience defined and presented as part of a causal proposition important for welfare outcomes?

2. **Study features:** What are basic study characteristics (e.g., countries, sample size, data sources) in which resilience measurement has been undertaken?

3. **Focus of resilience indicators:** What are the types and properties of indicators that have been used to measure resilience?

4. **Analytical procedures:** What is nature of the analytical procedures that have been used to construct variable and estimate relationships?

The specific information documented for each focal question is detailed below in the methods section of the briefing.

Following this introduction, the rest of this study is organized into three additional sections. The first section describes the technical background for the present paper. The second section describes the methodology used to conduct the review. This third section presents the results of the review. To aid accessibility and comparability, the results are presented as a series of tables with brief commentaries. The conclusion section suggests additional steps that may be taken to support the ongoing efforts to promote and conduct systematic reviews of resilience measurement.

2

Technical Background: Foundations for the Review

The framework used to structure the present review was based on guidance provided by the Resilience Measurement Technical Working Group (RMTWG) (see Constas et al., 2014b). The initial guidance provided by the RMTWG resilience measurement was subsequently codified to support the Classification of Indicator for Resilience Analysis (CIRA) project, a project that was designed to categorize secondary data sets in terms of their potential for resilience analysis (see Constas, Upton, Knippenberg, & Downie, 2016). Building on the work of the RMTWG, the approach applied in the CIRA project constituted a review of indicators organized by a set of focal indicators which demonstrated sensitivity to properties and characteristics of the same. The focus of indicators highlights the importance of measuring wellbeing or welfare outcomes, shocks and stressors and resilience capacities. The approach designed to examine the properties of indicators highlights the need to include subjective and objective measures, quantitative and qualitative data and emphasizes the importance of collecting data which allows one to examine change over time at multiple scales (e.g., households and communities).

3 Review Methodology: Systematic Review of Resilience Measures

The idea behind systematic reviews (see Higgins & Green, 2008; Torgerson, 2003), as opposed to freely structured narrative reviews, is to treat each study as a unit of analysis. Specific details are collected from each unit or study, and in a systematic review, the process for capturing and presenting these details from each study is standardized. The type of information collected is based on an explicitly stated set of questions, such as the above noted focal questions, that serve an identifiable research goal. The goal of the present review is to document the key features of measurement methodologies found in a sample of studies focused on resilience. A description of how the systematic review of resilience methodologies follows.

STUDIES SELECTED FOR REVIEW

Although resilience is a relatively new analytical approach for those who seek to understand how households and communities can anticipate and respond to shocks, several measurement approaches have emerged as salient and influential. Under the direction of the Technical Consortium for Building Resilience in the Horn of Africa, three measurement approaches were identified as being widely recognized in the Horn of Africa and/or for the Sahel (FAO, 2015; Kimetrica, 2015; Smith et al., 2015).

The FAO study represents an updated version of a tradition of work on resilience measurement that has long been a part of FAO's portfolio of work on resilience (see Alinovi et al., 2008). The approach developed by FAO, referred to as Resilience Index Measurement and Analysis (RIMA), is notable because it represents the longest standing approach to resilience measurement and because it has been used to measure resilience dynamics in more than 10 countries, both from sub-Saharan Africa and from the middle-east. The study by Kimetrica (2015) has recently garnered attention because of the way it makes use of a wide of array of secondary data sources. The study by Smith et al. (2015) and Smith & Frankenberger (2015) is one of the few studies to engage in primary data collection with custom made measurement modules specially designed for resilience analysis. A fourth study (Alfani, et al., 2015) was added because it was viewed as representing an innovative approach to constructing a counterfactual condition, one that might permit the kind of inference required for impact evaluation. These four studies comprised the corpus of the review. While not meant to be an exhaustive listing of work on resilience, the four studies provide

a reasonable representation of the recent work on resilience measurement. The need to perform a more comprehensive review is considered in the conclusion section of the paper.

FOCUS OF REVIEW AND REVIEW PROCEDURES

For the present review, the kind of data or information collected reflects the logic of measurement. Information collected therefore begins with questions about the intended content of measures (i.e., construct definition), proceeds to questions about the operationalization (focus of indicators), and also includes questions about the structure of studies (i.e., study features), and analytical procedures.

Expanding on the above stated focal questions, the information collected from each study follows the below scheme. The sub-bullets specifiy the content that was searched for and extracted from each study.

- **Conceptual Presentation of Resilience:** How is resilience defined and presented as part of a causal proposition important for welfare outcomes?

    - Stated definition of resilience
    - Components or types of resilience noted
    - Basis identity as predictor or predicted variable
    - Causal proposition that locates resilience in a cause and effect relationship

- **Focus of resilience indicators**: What are the types and properties of indicators that have been used to measure resilience?

    - Shocks and stressors
    - Wellbeing outcomes
    - Shock and stressor mediators (e.g., resilience capacities)
    - Properties of measurement – temporal, objective, subjective, qualitative

- **Study design features**: What are the basic study characteristics (e.g., countries, sample size, data sources) in which resilience measurement has been undertaken?

    - Study location
    - Dates of data collection
    - Sample size
    - Data sources- primary or secondary

- **Analytical procedures:** What is nature of the analytical procedures that have been used to construct variable and estimate relationships?

    - Estimation procedures used for variable construction
    - Estimation procedures used for relationships
    - Opportunity to study resilience dynamics (e.g., shock X wellbeing

interactions, change of wellbeing over time)
- Inferences drawn about resilience in connection with a sample of models from the studies reviewed.

Each study was reviewed by at least two reviewers and details related to the focal question and sub-categories were entered into a series of tables. As noted above, the review was designed to produce a descriptive summary of resilience measurement and demonstrate the potential value of building a database that increase the transparency, accessibility, and comparability of resilience focused measurement methodologies.

4 Findings

Tables 1 through 4 present the findings according to the focal questions and sub-categories contained within each question.

Conceptual Presentation. Consistent with classical measurement theory (Crocker & Algina, 2006; Nunally & Bernstein, 1994), the first stage of measurement involves the definition of the construct to be measured. With measurement theory as a point of reference, the objective of the *conceptual presentation* portion of the analysis was to document, for each of the studies, how resilience was defined and to discern the purpose that resilience served in a measurement framework. The definition portion of the review provided a verbatim restatement of the definition of resilience supplied by the author. An attempt was also made to discern components or types of resilience that were expressed, either conceptually or operationally, as part of the definition. The following excerpts from definitions, highlight key aspects of the definition of resilience offered in each of the studies that were reviewed:

- "Manage change" (Alfani et al., 2015)
- "Avoidance of adverse development consequences" (FAO, 2015)
- "Speed of recovery" (Kimetrica, 2015)
- "Mitigate, adapt to, and recover from shocks and stresses (Smith et al., 2015; Smith & Frankenberger, 2015)

What is notable, here, is that the definitions provided in the articles all highlight the importance of understanding the dynamics that account for varied states of wellbeing following shocks.

The second part of the conceptual presentation sought to identify the purpose that resilience served as part of a relationship to be measured. Here, the aim was to discern the functional identity of resilience and to employ language that expressed how resilience was located in causal chain that might be explored in empirical terms.

- Resilience is a predictor variable (Alfani et al., 2015)
- Resilience is a variable to be predicted and a predictor variable (FAO, 2015)
- Resilience is a predicted variable (Kimetrica, 2015)
- Resilience is a variable to be predicted and a predictor variable (Smith et al., 2015; Smith & Frankenberger, 2015)

Another key aspect of how resilience is presented as a foundation for building a measurement approach concerns the use of resilience as part of a casual proposition that suggests a way to operationalize research. Brief statements that represent (not verbatim quotes, in this case) the kinds of casual propositions tested within each of papers reviewed are as follows:

- Resilient households maintain consumption (Alfani et al., 2015)
- Four pillars are indicators of resilience (FAO, 2015)
- Adaptation strategies reduce the effects of shocks (Kimetrica, 2015)
- Resilience capacities mediate the effect of shocks (Smith et al., 2015)

Table 1 provides an overall summary of the conceptual representation of resilience across the six papers.

Table 1: Conceptual Presentation of Resilience

STUDY	DEFINITION OF RESILIENCE	MEASUREMENT PURPOSE
Alfani et al., 2015.	**Definition** • "... the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses - such as earthquakes, drought or violent conflict - without compromising their long-term prospects" (DFID, 2011) **Components or Types** • Communal risk pooling • Accumulating and drawing down on own assets	**Functional Identity** • Predictor variable **Causal Proposition** • Households that are resilient are able to maintain consumption levels (or quickly recover) when faced with shocks.
FAO, 2015.	**Definition** • "... a capacity that ensures stressors and shocks do not have long-lasting adverse development consequences" (RMTWG, 2014) **Components or Types** • Access to basic services, assets, social networks, adaptive capacity (presented as pillars)	**Functional Identity** • Predicted variable, and predictor variable **Causal proposition** • Resilience is composed of four pillars where a combination of weighted pillars represent resilience
Kimetrica, 2015.	**Definition** • "...we define and measure resilience as the speed of recovery after a shock" (Kimetrica, 2015, p.6) **Components or Types** • Climate resilience • Weather resilience	**Functional Identity** • Predicted variable **Causal proposition** • Adaptation strategies can reduce the effect of drought
Smith et al., 2015; Smith & Frankenberger, 2015.	**Definition** • "... the ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth."(USAID, 2012) **Components or Types** • Absorbtive capacity • Adaptive capacity • Transformative capacity	**Functional Identity** • Predictor and predicted variable **Causal proposition** • The effects that shocks have on wellbeing can be mediated by a measurable set of *resilience* capacities

Study Design Features. Details on basic study features summarize the contexts, sample, and data sources for each of the studies in which resilience measures were taken. As this information is self-explanatory, a summary of study design features is presented in Table 2.

Table 2: Study Design Features

STUDY	LOCATION AND DATE(S) OF DATA COLLECTION	SAMPLE CHARACTERISTICS	DATA SOURCE
Alfani et al., 2015.	**Burkina Faso** • 2003 • 2009/2010 **Northern Nigeria** • 2010/2011 • 2012/2013 **Niger** • 2007 **Senegal** (excluding Agadez) • 2005, 2006	**Burkina Faso** • N = 8,510, 2003 • N = 8,470, 2012/2013 **Northern Nigeria** • N = 5,000 **Niger** • N = 5,669 **Senegal** • N = 4,562 (ESAM2)+ 10,780 (ESPS1)	**Primary** • NA **Secondary – Burkina Faso** • Survey-based Harmonized Indicators Program • Enquête Burkinabé sur les Conditions de Vie des Ménages **Secondary – Nigeria** • General Household Survey **Secondary – Niger** • Enquête nationale sure le Budget et la Consommation **Secondary – Senegal** • Enquête Sénégalaise Auprès des Ménages • Enquête de Suivie de la Pauvreté au Sénégal
FAO, 2015.	**Uganda** • Urban-rural • Regional coverage **Dates** • 2010, 2011, 2012	**Sample size** • N = 3,200 (baseline year) with replacement for subsequent years	**Primary Data** • NA **Secondary** • Living Standards Measurement Survey, Integrated Survey on Agriculture (LSMS-ISA)
Smith et al., 2015; Smith & Frankenberger, 2015.	**Ethiopia** • Jijiga • Borena **Dates** • 2014 (baseline) • 2015 (IMS)	**Sample strata** • Pastoralist • Agropastoralist • Non-pastoralist **Sample size** • N = baseline • N = 400 (interim monitoring survey)	**Primary Data** • HH surveys **Secondary Data** • Normalized Difference Vegetation Index • Standardized Precipitation Index • Soil Moisture Index
Kimetrica, 2015.	**Ethiopia** • 2012, LSMS • 2005, 2012, ENBCCA • 1994, 1999, 2004, 2009, ERHS	**Sample size** • N = 3684 – LSMS-E • ENBCCA • N = 1888 – ENBCCA • N = 4945 – ERHS *Analysis run separately on each sample*	**Primary Data** • NA **Secondary Data** • Ethiopia Living Standards Measurement Study (LSMS-E) • Ethiopian Nile Basin Climate Change Adaptation Dataset (ENBCCA) • Ethiopian Rural Household Survey (ERHS) • Standard precipitation evapotranspiration index (SPEI)

Focus of Resilience Indicators. The focus of the indicators used to measure resilience revealed a fair amount of variation across the studies reviewed. The studies conducted by Alfani et al. (2015) and Kimetrica (2015) relied on drought related indicators and used only objective indicators of shocks. The studies conducted by FAO (2015) and Smith et al. (2015) and Smith & Frankenberger (2015) had a broader range of shock indicators. The study conducted by Smith et al. (2015) and Smith & Frankenberger (2015) was further distinguished by its inclusion of both high subjective measures of shocks and stressors. Smith & Frankenberger (2015), as part of an interim monitoring survey (IMS), also made use of high frequency data collection (six rounds of monthly data). FAO had the next most frequent data collection with three rounds of data. FAO also made use of geographic information system (Africa Rainfall Climiatology, Version 2 - ARC2) data for weather shocks and considered data on political conflict (Armed Conflict Location and Event Data Project - ACLED). Both Alfani et al. (2015) and Kimetrica (2015) had two rounds of data collection. Wellbeing indicators cited across all studies reviewed, used one of several types of food security or food insecurity score scales to measure food security such as the Household Food Insecurity Assessment Scale or the Household Hunger Score, Household Dietary Diversity Score, or the other standardized food consumption score.

Questions about how best to explain variations in wellbeing following exposure to some shock are commonly answered in terms of demographic (e.g., age, education levels, family composition) and economic factors (e.g., asset holdings), livelihood types, and access to services. These types of indicators were used as shock/stressor mediators by Alfani et al. (2015), FAO (2015), and Kimetrica (2015).

The idea that shocks and stressors can be mediated by an identifiable set of resilience capacities found in households and/or communities is relatively new, one that was only recently developed by the Resilience Measurement Technical Working Group (see Constas et al., 2014 b). For two of the studies, key elements included as part of resilience capacities move beyond demographic and economic factors to include human capital and social networks. Using factor analysis and structural equation modelling, FAO (2015) constructed a variable for social networks and included that variable in its resilience analysis. Drawing on the work of Aldrich (2012), the study conducted by Smith et al. (2015) and Smith & Frankenberger (2015) used principal component analysis (PCA) to examine resilience capacity as a construct comprised of three types of capacities. The Smith et al. (2015) and Smith & Frankenberger (2015) study included indicators related to absorptive capacities (seven indicators), adaptive capacities (seven indicators), and transformative capacities (eight indicators), all of which were observed at the household (HH) level. In addition, this study included a collection of five indicators to measure community resilience and an index to measure community disaster risk reduction (four indicators). The existence of indicators at both the community level and the household level created an opportunity to examine the multi-level, nested structure of resilience.

The review of indicators included as part of resilience measurement across the four studies reviewed is presented in Table 3.

Table 3: Emphasis of Resilience-focused Indicators

SUMMARY OF RESILIENCE-FOCUSED INDICATORS				
STUDY	**SHOCKS AND STRESSORS**	**WELLBEING OUTCOMES**	**SHOCK/STRESSOR MEDIATORS**	**PROPERTIES OF INDICATORS**
Alfani et al., 2015.	• Incidence below mean rainfall • Normalized difference vegetation (< 1)	**Welfare indicators** • Consumption • Weight for age, child • Weight for height	• Demographic characteristics • Education • Livelihoods • Assets • Access to basic services	**Temporal** • Two rounds of data collection, but not for all study sample **Objective** • Reported consumption for welfare • Shocks, objective only **Subjective** • NA **Qualitative** • NA
FAO, 2015.	• Weather shocks • Crop diseases • Input-output • Wage • Death-family • Theft • Conflict • Fire	**Welfare indicators** • Food Security	• Access to basic services • Assets • Social networks • Adaptive capacity	**Temporal** • Three rounds of data collection spaced annually **Objective** • Various drought indices **Subjective** • Self-reported shocks
Kimetrica, 2015.	• Drought • Access to water Resources • Soil conditions • Livestock loss	**Welfare indicators** • Food consumption	• Climate change adaptation • Socio-demographic variables • Farm characteristics • Access to services • Aid received	**Temporal** • Two rounds of data collection 5 years apart **Objective** • shocks measured through the NDVI and SPEI **Subjective** • NA
Smith et al., 2015; Smith & Frankenberger, 2015.	**Shock module** • Drought • Livestock or crop disease • Very bad harvest • Price and demand effects • Conflict and death	**Food security indicators** • Per-capita dietary energy consumption • Household Dietary Diversity Score • Household Food Insecurity Access Scale • Household Hunger Scale	**Resilience Capacities** **Absorbtive (7)** • Bonding social capital • Shock preparedness • ... **Adaptive (7)** • Linking social capital • Human capital • ... **Transformative (8)** • Bridging social capital • Linking social capital • ...	**Temporal** • Baseline, endline, and six rounds of monthly data-IMS **Objective** • Various drought indices **Subjective** • Perceptions of shocks • Projection of future wellbeing **Scalar** • HH and community level indicators **Qualitative** • Key-informant interviews • Focus group discussions

Focus on Analytical Procedures. The type of variable construction procedures used to measure resilience depends on assumptions one holds about the variables estimated. If one assumes that indicators and the creation of variables (comprised of indicators) are latent and multi-dimensional, the preferred variable construction process is factor analysis or PCA. Both factor analysis and PCA data reduction techniques allow one to identify components that represent how data are structured. While factor analysis is driven by a priori theory that provides direction on how indicators might be clustered, PCA is more closely tied to empirical patterns found in the data and uses a theory to suggest how indicators might be clustered in coherent groupings or components.

By exploring both the multi-dimensional (both FAO, 2015; Smith et al., 2015) and the latent structure of resilience (FAO, 2015), the work of FAO (2015) and Smith et al. (2015) stands apart from that of Alfani et al. (2015) and Kimetrica (2015). Neither Alfani et al. (2015) nor Kimetrica (2015) constructed variables using statistical techniques based in psychometrics.

To test relationships among resilience-focused variables (i.e., shocks, wellbeing states, and predictor variables which may or not include resilience capacities), all studies make use of regression based models. The FAO (2015) study and the Alfani et al. (2015) study, however, move their analysis in a direction that may permit plausible causal inference. Building on descriptive analyses generated associated with structural equation modelling, FAO (2015) used logit and probit procedures to examine plausible causal relationships among resilience variables. Alfani et al. (2015) attempts to construct an empirical warrant for making causal claims by simulating a counterfactual that helps predict the probability of being resilient.

The main objective of resilience measurement is to analyze three kinds of dynamics. Listed according to increasing levels of complexity or perhaps completeness, the three types of dynamics focus on:

1. *Type 1 Resilience Dynamics* - dynamic between shocks exposure and wellbeing,
2. *Type 2 Resilience Dynamics* - dynamics among shock exposure, wellbeing, and capacities
3. *Type 3 Resilience Dynamics* - dynamics among shock exposure, wellbeing, capacities, and path or time dependence.

The opportunity to estimate these three dynamics, which are highlighted in the guidelines of the Resilience Measurement Technical Working Group (see Constas et al., 2014 a, b), depends on the availability of certain kinds of indicators that have certain types of properties (see Table 3 above). The study by Smith et al. (2015) will eventually include a baseline and endline, augmented by a high frequency interim monitoring survey.[2] This design, combined with a detailed modules on shocks, wellbeing, and resilience capacities creates the conditions for examining all three types of dynamics. The same can be said of the FAO study, though the array of resilience capacities is not as extensive as that found in Smith et al. (2015); Smith et al., had a resilience capacity subscales focused on absorptive, adaptive, and transformative capacaties. The study by Alfani et al. (2015), with two rounds of data collection, will permit some analysis of path dynamics, but owing to the limited data on resilience capacities, the empirical

[2] It should be noted that other studies conducted by FAO (e.g., Somalia) have used a design similar to the one employed by Smith et al. (2015). The design and findings reported here are restricted to FAO (2015).

conditions necessary for comprehensive reliance analysis (Type 3 above) are not present. With two waves of data, the Kimetrica study (2015) also allows analysis of path dependencies but the inclusion of limited resilience capacities prevents comprehensive resilience analysis. The analysis itself, however, was based on cross-sectional analysis. This means the ability to draw credible inferences about change over time is necessarily limited. Table 4 presents an overview of the types of analytical procedures used in the studies that were reviewed.

Table 4: Summary of Analytical Procedures

STUDY	PROCEDURES TO CONSTRUCT RESILIENCE VARIABLES AND TEST RELATIONSHIPS	ANALYSES FOCUSED ON RESILIENCE DYNAMICS
Alfani et al., 2015.	**Estimation for Variable Construction** • Simple computation • Relationships • Ordinary least squares regression • Compare actual and counterfactual welfare to benchmark	**Shock X Wellbeing** • Yes **Shock X Capacity X Wellbeing** • Yes, limited – but possible in terms of observable covariates and their impact on the counterfactual **Analysis of path/time Dynamics** • No
FAO, 2015.	**Estimation for Variable Construction** • Factor Analysis – latent variables • Structural equation models **Estimation of Relationships** • Multinomial logit models • Bi-variate probit models	**Shock X Wellbeing** • Yes **Shock X Capacity X Wellbeing** • No **Analysis of path/time Dynamics** • Three periods of data collection • Transition matrices to measure inter-temporal changes in resilience capacity
Kimetrica, 2015.	**Estimation for variable Construction** • Simple computation **Estimation of Relationships** • Ordinary least squares regression • Distributed lag non-linear model (DLNM)	**Shock X Wellbeing** • Yes **Shock X Capacity X Wellbeing** • Yes, using adaptation as a capacity **Analysis of path/time Dynamics** • Yes, using a DLNM model with pre-determined parameters
Smith et al., 2015; Smith & Frankenberger, 2015.	**Estimation for Variable Construction** • Principal/polychoric component analysis **Estimation for Examining Relationships** • Multivariate regression • Propensity score matching • Double difference estimation • Fixed effects and random effects	**Shock X Wellbeing** • Yes **Shock X Capacity X Wellbeing** • Yes **Analysis of path/time Dynamics** • Yes, IMS study has six rounds of monthly data collection and triggers

To add a more profound level of documentation related to the models that were used to estimate resilience, inferences that were most focused on resilience were located in each of the studies. Table 5 presents these inferences, along with associated models with key terms defined.

Table 5: Overview of Resilience-focused Inferences and Associated Models

TYPE OF MODEL	RESILIENCE-FOCUSED INFERENCES AND ASSOCIATED MODELS	KEY TERMS
Alfani et al., 2015.		
Ordinary least squares	**Inference:** Uses counterfactual estimation techniques to classify households as chronically poor, resilient, or non-resilient. **Model:** $\bar{C}_i \leq \bar{C}^{s}_{it}, \bar{C}_i \leq \bar{C}^{ns}_{it}$ where $\bar{C}_i$ is the permanent welfare measure estimated as $C_{it} = a + \beta X_{it} + v_{it}$	*s, ns* – shock or non shock depending on rainfall in previous period *C* – welfare (consumption, child nutrition) X – household demographics
Kimetrica et al., 2015.		
Ordinary least squares & distributed lag non-linear model	**Inference:** Estimates resilience as speed of recovery from a particular weather shock ("share of time before a next shock is expected to strike spent not recovering"). **Model:** $R_{W,i}(s_1) = 1 - \frac{1}{4} \sum_{2}^{12} I(V^{1}_{W,i,t}(s_1) > 0)$	$V^{1}_{W,i,t}(s_1)$ – weather induced poverty shortfall – percentage below the poverty line – at time t from shock s in period 1
Probability weighted average	**Inference:** Estimates climate resilience as the average speed of recovery, based on SPEI probability-weighted weather shocks. **Model:** $R_{C,i} = E_s(R_i(s))$	E_s – is the expectation operator for shock s
FAO, 2015.		
Multinomial Logit	**Inference:** Determinants of increasing probability to be in a 'more resilient' category in one year out of three (t = 1) two years (t = 2) or both t = (1, 2) **Model:** $R_{i,t} = \alpha + \beta_1 X_i + \beta_2 Z_k + \varepsilon_i$, *(implied)*	$R_{i,t}$ – Composed Resilience Indicator X_i – HH level characteristics Z_k – Community level characteristics
Bivariate probit	**Inference:** Probability of being above (or below) a particular resilience threshold conditional on level of resilience in previous period **Model:** $(R_{i,t} \lesseqgtr \bar{R}_{\square} \mid\mid R_{i,t-1} \lesseqgtr \bar{R}) = \alpha + \beta_1 X_i + \beta_2 Z_k + \varepsilon_i$ *(implied)*	$1(R_{i,t} \lesseqgtr \bar{R}_{\square})$ – indicator function for index above/below threshold X_i – HH level Z_k – community level
Smith & Frankenberger, 2015.		
Bivariate probit	**Inference:** Estimate whether or not each household maintained or increased food security **Model:** $R_{i,BL\_R1} = \alpha + \beta_1 SE_{i,BL\_R1} + \beta_2 X_{i,BL} + \varepsilon_i$,	R – resilience measure in terms of food security SE – shock exposure X HH – characteristics
Standard growth model	**Inference:** Estimate the extent to which households' resilience capacities at baseline helped protect them from the negative impacts of the drought **Model:** $Y_{i,R1} - Y_{i,BL} = \alpha + \beta_1 (SE_{i,R1} - SE_{i,BL}) + \beta_2 RC_{i,BL} + \beta_3 Y_{i,BL} + \beta_4 X_{i,BL} + \varepsilon_i$, *(5)*	$Y_{i,R1} - Y_{i,BL}$ – change in food security RC – resilience capacity SE – shock exposure

The objective of presenting further details of estimation models, as shown Table 5, was to merge the language of inference with the symbolic expressions of estimation models. While language used across studies and the specific form of estimation models varied, a good degree of convergence can be found. It is clear that all studies are trying to estimate some feature of the dynamic that explains variations in wellbeing following shocks.

5 Conclusion

The aim of the present study was to describe the basic features of a sample of methodologies that have been used to measure resilience. By posing a series of focal questions, details about how resilience is defined, operationalized, and modelled for each study were presented. The summary of methodologies also included information about the context of each study and features of study design. Based on the logic of a systematic review, the intent was to provide a detailed descriptive account of resilience measurement methodologies.

The empirical literature on resilience in development contexts is still relatively new. It is, however, now possible to document critical features of resilience measurement methodologies. As the literature grows, it will become increasingly important to track innovations and understand how principles of resilience measurement are implemented. Understanding the contents of existing resilience measures will allow researchers, evaluators, and donors to identify which measures and methods are most appropriate in different contexts while also highlighting possible synergies for improved technical performance. One of the benefits of the systematic approach to review that was employed here is that such an approach and its products (i.e., tabular summaries) may potentially help consumers of empirical work on resilience better understand the contents and technical features of resilience measurement. The other benefit to using a systematic approach, which is of critical importance, is that such an approach is more easily replicated. This study represents a first step in what could be continued as an ongoing effort to increase the transparency of resilience measurement and to do so in a way that will allow consumers of resilience studies to make informed and data-based decisions about how best to monitor and track the effectiveness of resilience investments.

In addition to satisfying the objective of making resilience measurement methodologies more accessible, the approach used here may have broader applications. First, the protocol used to capture the key features of resilience measurement can be viewed as a generalizable set of review procedures. Thus, the use of a systematic review approach, where key features of measurement methodologies are located and organized into a series of tables, can be used for other areas of measurement. The problem of opacity is not unique to resilience measurement. Various audiences who need to understand and compare measurement methodologies, across a range of topics important for development (e.g., poverty, food and nutrition security, social capital, empowerment, strength of institutions), might choose to design and implement a systematic review protocol. Second, breaking down resilience measurement methodologies into component parts can serve as a foundation for practical activities such as exploring capacity building and writing statements of work or terms of reference for resilience

measurement activities. Each of the above tables highlights the kinds of skills (e.g., sample design, indicator development, analytical modelling) and capacities that are needed for resilience measurement.

Building on the procedure and findings presented here, the logical next step is to widen the review to a broader selection of studies. Only a small number of studies on resilience measurement were examined for the purposes of this study. A more inclusive selection strategy based on a more extensive search of databases can be employed. Once a larger corpus of studies have been reviewed, it might also make sense to create a dashboard-like search tool that would help one search for studies with particular characteristics. Recalling the overarching objective of the present study, additional efforts should be made to make resilience measurement methodologies more transparent. The more progress that is made toward this effort, the better that technical and non-technical communities can judge the strengths and limitations of resilience studies and resilience-focused data.

The eventual aim of this study and other similar studies carried out by the authors[2] for the second Technical Report series for the Technical Consortium, is to produce methodologies or tools that can assist all actors (NGOs, development partners, donors, national and lower administrative level governments) carrying out or intending to carry out interventions designed to enhance the resilience of populations vulnerable to the effects of hazards such as drought and flooding. While this paper, and the aforementioned other studies are essentially proof of concept studies, they are the first step towards the application of further refined tools. As mentioned previously, a widening of the review to a broader selection of studies is necessary to further the development of such methodologies. In addition, once sufficient understanding is gained from the further analysis of more impact assessment frameworks, the development of theories of change for different projects and investments and application of the methodology for selection of different indicators for different projects, the trialing and testing of all three of these tools must be carried out involving projects, interventions and investments being implemented in the field. This trialing and testing using actual scenarios must be reiterated many times, thus eventually producing a database of information which can be used to refine the tools to the point they are ready to be applied by those who would benefit from their use. Once this has been achieved, those who seek to enhance the resilience of vulnerable communities will be able to firstly, envision a reasonably plausible relationship between their investments and projects and their intended outcomes, secondly, be assured that they are monitoring indicators which will inform sustained adherence to a productive trajectory, and thirdly, assess the impacts of their work in a manner that can offer conclusive results.

[2]Reference is made here to Report 7 – Classification of Indicators for Resilience Analysis: An Assessment of Selected Data Sources Focused on Arid and Semi-Arid Lands by Mark Constas, Joanna Upton, Erwin Knippenberg and Katie Downie and Report 10 – Building Better Connections between Theories of Change and the Empirical Demands of Evidence-Based Decisions: The Case of Kenya's Policy on Ending Drought Emergencies by Mark Constas, Tim Frankenberger, Erwin Knippenberg and Katie Downie.

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The Technical Consortium for Building Resilience in the Horn of Africa provides technical support to IGAD and member states in the Horn of Africa on evidence-based planning and regional and national investment programs, for the long-term resilience of communities living in arid and semi-arid lands. It harnesses CGIAR research and other knowledge on interventions in order to inform sustainable development in the Horn of Africa. www.technicalconsortium.org