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# A systematic review of how vulnerability of smallholder agricultural systems to changing climate is assessed in Africa

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## Abstract

The impacts of changing climate on agriculture have consequences on livelihoods and food security. Smallholder farmers, who have heterogeneous farming systems and limited resources, compounded with multiple risks, are greatly affected. There has been limited research showing how vulnerability assessments have evolved in the smallholder agricultural sector of Africa overtime. This study systematically reviewed recent publications on vulnerability studies, especially among smallholder agricultural systems, to provide an overview of current developments in theory and practice of vulnerability in Africa over the last decade. The findings indicate an increase in vulnerability assessments undertaken across Sub Saharan Africa. Despite progress made in the application of enhanced conceptual frameworks and methods, at least four important gaps exist in the assessment process namely, inadequate engagement of local perspectives and knowledge, lack of clarity in the operationalisation of vulnerability, lack of comprehensiveness of measurement criteria employed and relevance of assessment in decision support. Notwithstanding these challenges, there exist opportunities to geographically improve assessments across Africa. In order to produce knowledge to traverse projected changes in climate systems for agricultural economies and to ensure sustainable smallholder livelihoods, we suggest that future research efforts should be oriented towards providing more information to enlighten science, policy and practice for informed decision-making and evidenced based policies. This requires evaluation of adaptation capacity as a critical aspect of vulnerability assessment to provide guidance and inform effective decision-making on allocation of scarce resources (prioritization); understand trade-offs management and implementation to build understanding among stakeholders that guide possible pathways to reduce vulnerability.

## 1. Introduction

Changing climate is considered a precarious challenge facing humanity. The impacts of climate variability and change are manifested in regime changes of floods, droughts, unseasonal rains and extreme events. This creates enormous developmental challenges for developing countries and economically vulnerable communities (Morgan 2011). According to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change

(IPCC), further changes in climate is inevitable in the coming decades (IPCC 2013). The effects are forecasted to be more severe in the agriculture sector (both rain-fed and irrigated agriculture), one of the most sensitive sectors to climate change. People in developing countries whose livelihood depends mainly on agriculture and livestock production are particularly vulnerable (Panthi *et al* 2016).

Sub-Saharan Africa (SSA) has been identified as one of the most vulnerable regions to the impacts of changing climate as many areas inherently

receive unpredictable rainfall (IPCC 2014, Serdeczny *et al* 2017), which has been evident in several recent studies (Asante and Amuakwa-Mensah 2015, Angula and Kaundjua 2016). SSA's economy remains strongly dependant on agriculture relative to other regions (Livingston *et al* 2011). The sector's importance in the region is evident in its contribution to total gross domestic product (GDP). For instance in 2014, the agriculture sector in SSA contributed 15% of total GDP, which was comparatively high in the global context (OECD/FAO 2016b). It further employs more than half of the total labor force of the rural population, providing a valued livelihood for multitudes of small scale producers (OECD/FAO 2016b).

The negative effects of the changing climate severely affect smallholder and subsistence farmers due to their overreliance on natural resources compounded by factors such as widespread poverty and various socioeconomic, demographic, and policy trends such as limited production capacity and income, poor land tenure arrangements and unstable prices for commodities, all reducing their adaptive capacity (Morton 2007, Hitayezu *et al* 2014). According to Sietz *et al* (2012), smallholder livelihoods are frequently threatened by weather extremes. Recently, the severity of the 2015–16 drought across the region (an El Niño episode accompanied by exceptionally dry conditions), resulted in the lowest annual rainfall in 30 years in Ethiopia and the lowest annual rainfall since 1904 in South Africa, illustrating potentially disastrous impacts of climate change in Africa and raising concerns for food security (OECD/FAO 2016b). A recent study also highlighted that agricultural productivity in rural areas is severely affected by climate variability which elevates the vulnerability of rural households to food insecurity in Africa (Mohammed *et al* 2018). Such effects together with projected impacts of climate variability and change on the sector indicates that resilience to changing climate will likely soon be undermined within the region. To this end, better understanding vulnerability assessment of smallholders' agricultural systems, which constitute approximately 80% of all farms with livelihoods directly threatened by weather extremes (AGRA 2017), is paramount.

Vulnerability is used in a diversity of scholarly contexts including poverty and development, ecology, secure livelihoods and famine, sustainability science, land change as well as climate impacts and adaptation (Fussler 2007). Theoretical frameworks enable some level of understanding and definition of vulnerability during assessments. Disaster risk reduction (DRR) and climate change adaptation (CCA) research are common theoretical concepts dealing with vulnerability (Tánago *et al* 2016). Naumann *et al* (2014), defines DRR approach in terms of a person or group's capacity to anticipate, resist, cope with, and recover from the impact of natural or man-made hazards. Hahn *et al* (2009), observed that the field of climate vulnerability

assessment has emerged to address the need to quantify how such communities will adapt to changing environmental conditions. Research on vulnerability assessment of systems to climate variability and change has emerged in studies and in scientific reports contributing to scientific knowledge in the area (Jakpa 2015, Dumenu and Obeng 2016, Nyamwanza *et al* 2017). CCA falls under the IPCC definition of vulnerability, which is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate (IPCC 2007). While DRR aims at highlighting means for risk reduction in response to shocks, CCA looks for the most efficient way to adapt to impacts derived from climate change (Romieu *et al* 2010). Identification of determinants of vulnerability that show where, how, and why people are affected by changes in the climate system, are the main focus of vulnerability assessments (Smit and Wandel 2006, Ford and Smit 2004). The diversity of possible implications of climate change however, mean that the question of what is vulnerable varies significantly from one study to another (Preston 2012).

There has been limited research showing how vulnerability studies have evolved in the agricultural sector of Africa overtime. Yet the research agenda has seen a significant growth in interest with 70% ( $n = 25$ ) of the peer reviewed articles reviewed here being published in the last five years (from 2013–2017). Despite this increase however this research identifies vulnerability scholarship focusing on smallholders in Africa has made limited progress in empowering farmers' adaptation planning. Some recent reviews on vulnerability have been conducted from different contexts, for some examples, how human and biophysical stresses interact to affect vulnerability and problem identification (Delaney *et al* 2014, Mcdowell *et al* 2016), drought vulnerability (Tánago *et al* 2016), dynamism in vulnerability by defining risks posed by changing climate (Jurgilevich *et al* 2017), with focus ranging from Central America and Mexico (Donatti *et al* 2018), India (Singh *et al* 2016) and Canada (Ford and Pearce 2010). However, none of these studies have exclusively focused on smallholder agricultural systems nor with a specific African focus. Examining the state of the field will address this gap. There is also growing demand among stakeholders for explicit information regarding vulnerability to climate change at the local level (Preston *et al* 2011), in order to identify where efforts to strengthen adaptive capacity should be made and aid decision makers at sub-national and local levels (Bisaro *et al* 2010). This paper systematically reviews existing literature addressing Vulnerability Assessment of Smallholder Agricultural Systems (VAoSAS) in Africa, guided by the following research questions: what is the state of vulnerability assessment of smallholder agriculture in Africa (2008–2017); how has vulnerability of smallholders in Africa been conceptually and theoretically framed; what methods are used in

assessing vulnerability of smallholder farmers in Africa and what are the implications of the outcomes of vulnerability assessment for future use? This would contribute to the current dearth of studies on vulnerability assessment in the region, improve understanding and knowledge of vulnerability of smallholders as well as guide decision making to enhance climate adaptation planning and actions.

### 1.1. Definition of smallholder agricultural systems

In addition to crop production, livestock, fisheries and aquaculture contribute to the agricultural farming system in SSA. Even though the crop sector dominates total agricultural production value, accounting on average for almost 85% of total production, the remaining total value of agricultural output in the region is derived from the livestock and fishery sectors (OECD/FAO 2016b). This paper considers the vulnerability of smallholder agricultural systems whose livelihoods and well-being are climate dependent in Africa. Regional differences in scale of production, agroecological and cultural diversity exist among this population broadly referred to as subsistence, small scale or smallholder farmers. Most farmers in Africa are considered smallholders, farming on small farms, facing varying livelihood prospects depending on their assets and aspirations as well as their regional and country contexts (OECD/FAO 2016b, AGRA 2017).

In targeting small farm assistance, Hazell and Rahman (2014) classified three groups of smallholder farm households depending on scale of production and proportion of produce marketed from high to the low, namely, commercial farmers, transition farmers and subsistence farmers. An early definition of smallholders conceptualized rural producers, mainly in developing countries, as those whom employ mostly family labor and for whom farming provides the primary source of income (Cornish 1998). Barnett (1997) extended this definition to associated activities that together form a livelihood strategy where the main output is directly consumed and only a minor proportion is marketed. Smallholder farmers in SSA have been recognized as a group of little uptake of improved and introduced production technologies due to constrained resources, which involves trade-offs with other activities from which they generate their livelihood (Giller *et al* 2009). Morton (2007) also described smallholder farmers to be found on a continuum between subsistence production and crop production for the market. Morton's definition encompassed pastoralists who depend on the sale of livestock and livestock products to buy staple foods and other necessities as well as people who depend on fisheries and aquaculture enterprises. Smallholders are believed to suffer similar problems including isolation, low levels of technology, unpredictable exposure to world markets, generally of small scale, often farming under

traditional or informal tenure and in marginal or risk-prone environments (Morton 2007).

Following the forgoing definitions, in the context of this study, 'smallholder agricultural systems' is used throughout the paper to refer to a livelihood system comprising of rural populations grouped as smallholders that includes crop producers, agropastoralists and/or agrosilvopastoralists within a SSA country with limited resources of production and exposed to both climatic and non-climatic stresses. Particularly interested in rural areas was taken in this case as agricultural livelihoods are considered most sensitive to climate change impacts in rural communities which are commonly socio-economically disadvantaged hence inherently vulnerable (Singh *et al* 2017). More so, despite growth in urbanization, rural population in Africa is considered still dominant (OECD/FAO 2016b) with depopulation having significant impact in differing ways on vulnerability, and directly affecting resilience of rural livelihoods and productivity under changing climate (OECD/FAO 2016a, Livingston *et al* 2011).

## 2. Methods

### 2.1. Systematic literature review (SLR)

This study employed a SLR method to examine progress of climate vulnerability assessments conducted in SSA between 2008 and 2017 at the local level. SLR is a literature review methodology commonly used to analyse the state of knowledge related to a topic (Ford and Pearce 2010, Ford *et al* 2011). SLR is progressively being used in climate change field to assess and interpret the state of knowledge in this area and to identify directions for further research efforts (Ford and Pearce 2010, Delaney *et al* 2014, Mcdowell *et al* 2016). This study adopted the SLR approach because systematic reviews are considered more rigorous, structured and robust (Ford *et al* 2011), making it more appropriate to structure observations of emerging literatures. Another strength of SLR is its ability to identify gaps and provide information through detailed summaries of evidence found in a specific literature database, based on clearly defined research questions and methods (Tánago *et al* 2016). This study followed the criteria of systematically selecting and examining documents found in selected literature databases. We conducted the SLR following identification of literature using keywords, creation of inclusion/exclusion criteria for the selection of publications and through analysis using both descriptive and qualitative methods.

### 2.2. Data selection process

Four databases (search engines) were used in the literature search. These were Google scholar, Web of Science, JSTOR and AGRIS. These databases were chosen due to their extensive and current coverage

of interdisciplinary academic literature (Spires *et al* 2014). The time frame for the search covered publications from the 1st of January 2008 until the 31st of December 2017. This period was selected after the results from an initial search for the period 1998–2017 showed that the period between 2008–2017 accounted for more than 85% of the overall results. In addition, most global information on seminal vulnerability studies prior to 2008 is summarized in the annotated bibliography of agricultural vulnerability to climate change by Barsley *et al* (2013). Therefore, review of the last decade suitably provides for reflection on significant trends and progress made in VAoSAS in Africa. The terms used in searching for relevant articles were [Climat\*] [‘Vulnerability \* assessment’ OR adaptation] [Africa]. The process was iterative allowing for different keywords to be explored. [‘Smallholder’ OR ‘agriculture’] in the search terms yielded very limited results. [‘Adaptation’] was included to ensure that all studies on adaptation capturing vulnerability assessment, as an aspect of study was not missed. Even though the final search terms were quite broad, the results followed strict inclusion/exclusion criteria for the selection of relevant studies that dealt with VAoSAS at the local level in Africa. Table 1 presents details of the inclusion/exclusion criteria used in the selection of relevant published studies.

A total of 1074 studies were identified from the four databases during the initial search (figure 1). This constituted both peer reviewed articles and gray literature (e.g. working papers, published thesis, conference proceedings, and project reports). The first stage screening removed all duplicates. Title screening followed, and all publications not directly related to the study aim were removed. Abstract and full text screening completed the next step. Figure 1 summarizes the screening process, ultimately leading to 36 studies. (Material provides complete references). It was noted that, even though studies on ‘vulnerability’ in general exist in the region, there is dearth of studies on the ‘assessment of vulnerability at the local level’, which was the main focus of this review.

Out of the 36 studies considered for in-depth review, 29 (81%) constituted peer reviewed studies and 7 (19%) were gray literature studies. Reviews of relevant gray literature has been recognized as valuable for climate change studies, especially in providing local information, policy responses, and practice that often lie outside peer reviewed journals (Singh *et al* 2017).

### 2.3. Review analysis

The selected studies were analyzed using both qualitative (thematic analysis) and quantitative (descriptive statistics) methods to explore all possible responses using the defined research questions for this study. The selected studies were coded for information and

grouped into emergent themes and categories such as geographical location of study; primary focus of study; nature of exposed hazard; conceptual framework used; dimensions of vulnerability factors used; methods employed in assessment; basis for vulnerability factors selection; subsector studied; enabler of assessment; unit of analysis; indications for adaptation options; recommendations for future studies and finally; mention of challenges constraining response to vulnerability. These categories reflect the breadth of thematic coverage as well as illustrate how vulnerability assessment has become a complex and multidimensional concept.

## 3. Results

### 3.1. State of climate VAoSAS

The majority of identified assessments were from Southern and Western Africa (figure 2) with Southern Africa having the highest share (40%). In contrast, Central and Eastern Africa indicate a dearth of vulnerability assessment research. Regional differences in the relative contribution of agricultural output in SSA seem to be reflected in the geographical distribution of vulnerability assessment identified in this review. Western and Southern Africa countries accounted for more than 80% of the total value of agricultural output in SSA (between 1990–2013), that is, 60% and 22% respectively (OECD/FAO 2016a). The predominance of vulnerability assessment found in Southern and Western Africa regions therefore depicts focus of assessments on areas contributing more to agricultural output (with greater emphases on crop production and less focus on livestock and fisheries).

A positive trend was observed in the time evolution of vulnerability assessments conducted across Africa among smallholders in the past decade. This is especially so in the last five years (from 2013–2017) where about 70% ( $n = 25$ ) of the reviewed publications could be found. In the last ten years, vulnerability assessments conducted in relation to smallholder agricultural systems in Africa are mainly (58%) focused on primary crop producers (table 2). Despite efforts taken to capture all sectors of agriculture during the literature search, few of the VAoSAS were found dealing with agropastoralists (19%) and agrosilvopastoralists (6%). Some of the subsectors studied mainly dealt with annual food crop producers and their suitable locations across the regions (e.g. cereals, roots and tubers, legumes). Perennial crops such as cocoa were studied in West and Central Africa (e.g. Ghana and Cameroon). Coffee and tea were studied in central Africa (e.g. Rwanda). Agropastoralists with pasture-based production relying on fodder availability as well as marine and inland fisheries were prominent in studies from Southern, East and Central Africa (table 2). About 17% of the studies mentioned smallholder

**Table 1.** Criteria for literature selection.

Search protocol	Inclusion criteria	Exclusion criteria
Initial database and document search	<ul style="list-style-type: none"> <li>English literature</li> <li>Local level vulnerability assessment</li> <li>Vulnerability assessment of agricultural systems/agricultural productivity</li> <li>Vulnerability and adaptation assessment</li> <li>Assessment in Sub Saharan Africa</li> <li>Single studies</li> </ul>	<ul style="list-style-type: none"> <li>Any non-English literature</li> <li>National, regional and global studies</li> <li>Vulnerability assessment of other sectors such as biodiversity, water resources, health, coastal and human settlement, hydrology, tourism, engineering (more broadly)</li> <li>Perception, impact assessment and exclusively adaptation assessment</li> <li>Anywhere else</li> <li>Duplicated studies from the different databases</li> </ul>
Review of title and abstract	<ul style="list-style-type: none"> <li>Human systems and or coupled human-environment systems</li> <li>Assessment of/with smallholder farmers</li> <li>Vulnerability to climate risk, including non-climate risk</li> </ul>	<ul style="list-style-type: none"> <li>Explicitly focused on natural systems (forest, fishes, aquatic ecosystem)</li> <li>Assessment of/with medium scale and commercial farmers</li> <li>Focused exclusively on vulnerability to non-climatic risk</li> </ul>
Full paper review	<ul style="list-style-type: none"> <li>Original studies</li> <li>Rural livelihoods and household assessment</li> <li>Subnational unit of analysis</li> <li>Vulnerability assessment of agricultural systems/agricultural productivity</li> </ul>	<ul style="list-style-type: none"> <li>Literature review or discourse analysis</li> <li>Urban and peri-urban settlement assessments</li> <li>National, regional and global level analysis</li> <li>Vulnerability assessment of other sectors</li> </ul>

production systems in general without clear indication of which specific subsector is vulnerable. Because we explicitly sought for assessments in relation to smallholders, the unit of assessment was limited at the local level, thus at the community, village, household or individual levels.

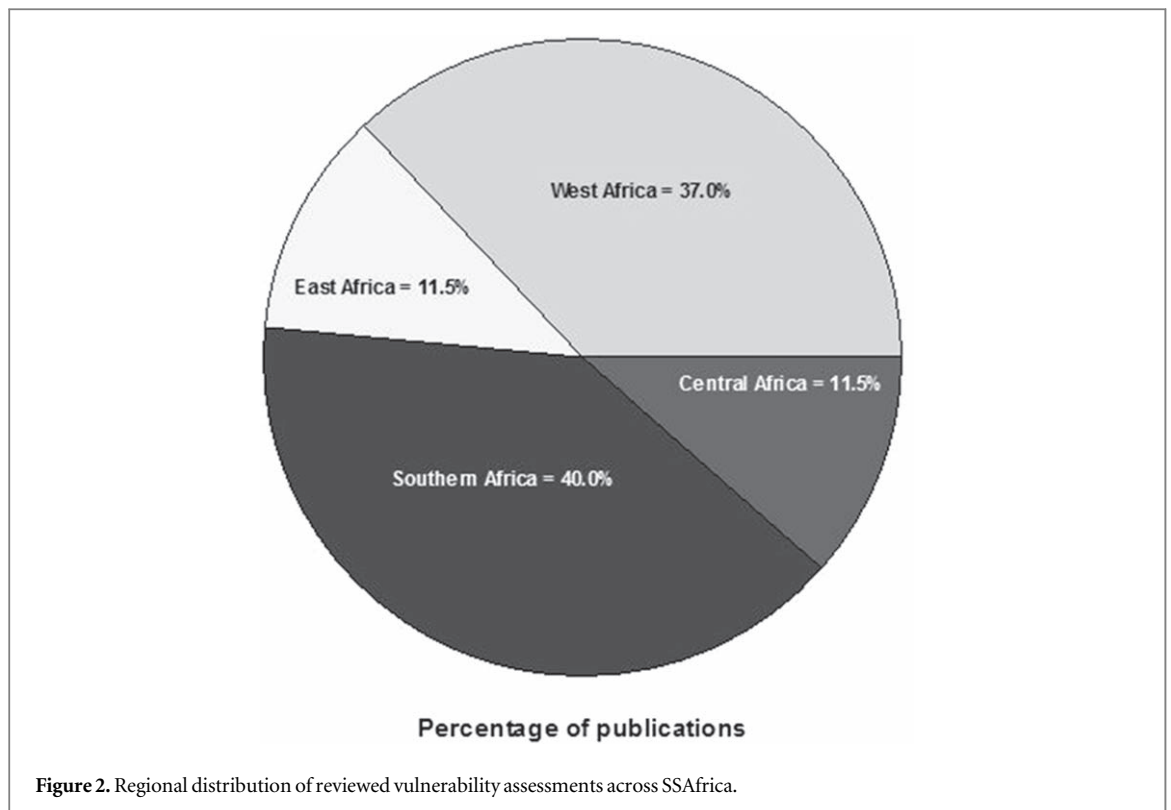
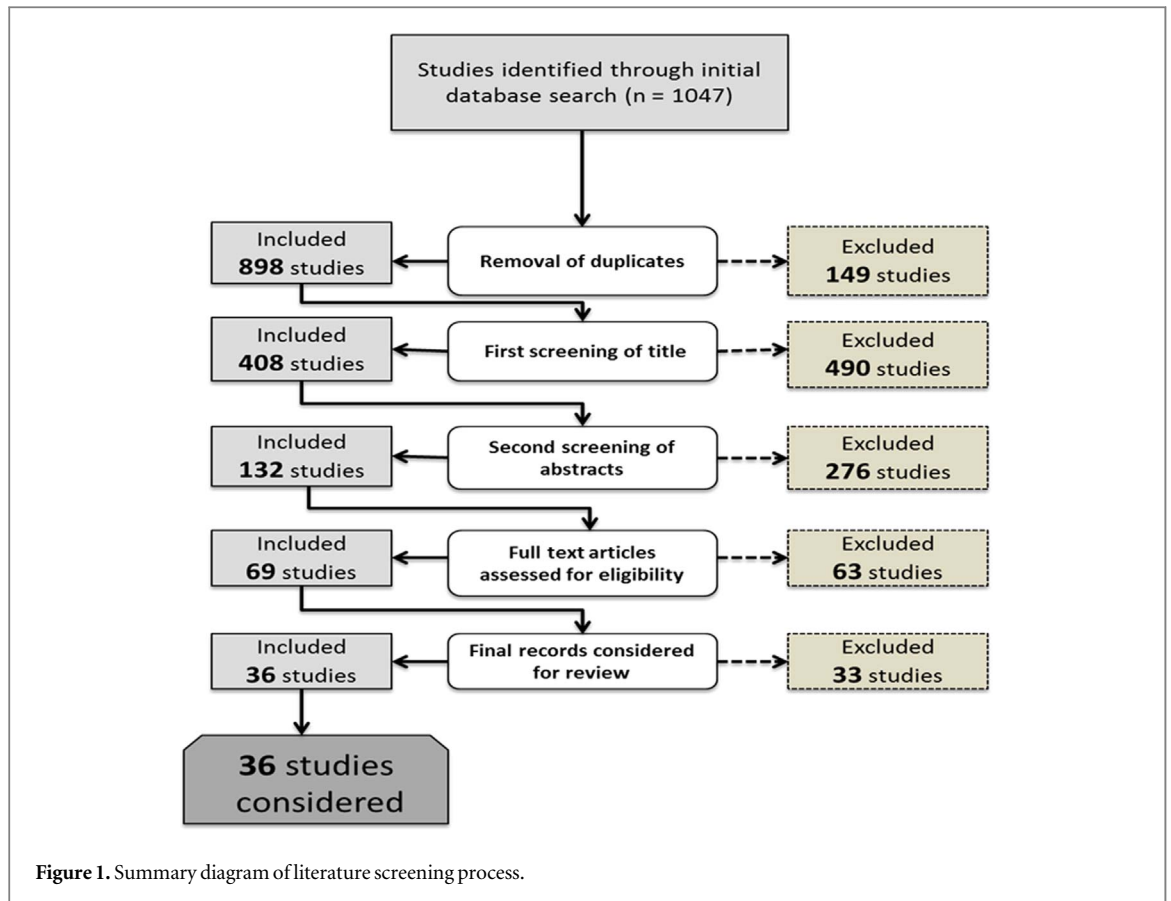
Academic researchers solely authored and led about half (50%) of assessments reviewed. Collaboration between donor funders, academic researchers (including non-university researchers), non-governmental organizations (NGOs) and government agencies also led about 44% of the findings. Few (6%) resulted solely from donor funders such as the Food and Agricultural Organization. This finding of multi-author teams encouragingly depicts the diversity of stakeholders with almost equal interests from donors, decision makers, academics and non-academics, which likely contributes towards more robust and comprehensive vulnerability research.

Due to the multidimensional nature of vulnerability, scholars of vulnerability argue assessments should be integrative to incorporate different

dimensions (e.g. social, economic, physical, environmental, and institutional) as no single measure can fully capture its complexity (Gbetibouo and Ringler 2009, Preston 2012, Tánago *et al* 2016). However, it is apparent that studies conducting VAoSAS in Africa have not adequately been integrative. Of the total vulnerability assessments reviewed, about 61% primarily focused on social assessment (assessments based mainly on socio-economic determinants) such human resources, while 39% used a combination of biophysical (climate conditions, topography, land cover, natural hazards) and social assessment (demographic, economic and social factors to assess vulnerability). None of the assessments exclusively focused on biophysical process (table 2).

### 3.2. Theoretical and conceptual framing of the vulnerability assessments

Some conceptual frameworks for expressing vulnerability across different disciplines such as the Pressure and Release model (represented by 33% of assessments), the Political Economy/Ecology model



(represented by 50% of assessments), the Resilience Model (represented by 10% of assessments) and the Expanded Vulnerability model (represented by 7% of assessments) are presented in table 3. The remaining

assessments did not make clear distinctions as to what framework is specifically guiding their analysis. Theoretical framings used, guide conceptual frameworks adopted in a study and later the

**Table 2.** Details of information on sectors/subsectors, cropping systems, location, source, unit and basis of assessment for reviewed studies.

Sector/subsector studied	Cropping system	Unit of analysis	Enabler of research		Primary basis of assessment		Country (ies) of study	Representative studies
			Individual	Project	Social	Biophysical		
Agro pastoral	N. S.	Village	✓		✓	✓	Tanzania, South Africa	Grothmann <i>et al</i> 2017
Food crops	Maize, sweet potato	Household	✓		✓		Uganda	Cooper and Wheeler 2017
N. S.	N. S.	Rural community		✓	✓	✓	Burkina Faso, Benin, Ghana	Asare-Kyei <i>et al</i> 2017
Agro pastoral	N. S.	Village	✓		✓		Chad	Okpara <i>et al</i> 2017
Food crops	Maize, rice, legume, sweet potato	Community		✓	✓		Ghana	Derbile <i>et al</i> 2016
Cash crop	Cocoa	Household		✓	✓		Ghana	Dumenu and Obeng 2016
N. S.	N. S.	Community		✓	✓	✓	Ghana	Westerhoff and Smit 2009
Fishery	Fishery	Community		✓	✓		Namibia, Angola, South Africa	Raemaekers and Sowman 2015
Agro pastoral	N. S.	Community		✓	✓		Burkina Faso	Choptiany <i>et al</i> 2017
Cash crop	Cocoa	Community		✓	✓		Cameroun	van Vliet 2010
Food crops	N. S.	District	✓		✓	✓	Kenya	Oluoko-odingo 2011
Food crops, vegetables	N. S.	Community		✓	✓		DR Congo	Bele <i>et al</i> 2014
Cash crops	Coffee, tea, cocoa	District		✓	✓		Rwanda	Pavageau <i>et al</i> 2013
Food crops	Maize, cassava	Community		✓	✓		Zimbabwe, Ghana	Mapfumo <i>et al</i> 2013
Cereals	N. S.	Household		✓	✓	✓	Ethiopia	Tesso <i>et al</i> 2012
Not specified	N. S.	Household		✓	✓	✓	Ethiopia	Deressa <i>et al</i> 2009
Agro pastoral	N. S.	Community	✓		✓		Namibia	Angula and Kaundjua 2016
Cereal, legume, root and tuber	N. S.	Community	✓		✓		Ghana	Derbile and File 2016
N. S.	N. S.	District	✓		✓	✓	Mozambique	Kienberger 2012
Cereal	Maize, sorghum	Community		✓	✓		Botswana	Molefe and Masundire 2016
Food crops	Cassava, beans	Village	✓		✓	✓	Tanzania	Sorey 2011
Food crops, fishery, horticultural crops	N. S.	Community		✓	✓	✓	Ghana	Effah 2014
Food and cash crops	N. S.	Community	✓		✓		Nigeria	Umoh <i>et al</i> 2014
Food crops	Potato, maize, beans	Village	✓		✓	✓	DR Congo, Cameroun, Equatorial Guinea	Tiani <i>et al</i> 2015
Food crops	Pearl millet, sorghum, maize cowpea	Village	✓		✓		Namibia	Hotz 2009
Food crops, horticultural crops	Rice, maize, sorghum, vegetables	Community	✓		✓		Ghana	Jakpa 2015
Agro pastoral	N. S.	Village	✓		✓	✓	Botswana	Sallu <i>et al</i> 2010
Agro pastoral	N. S.	District		✓	✓		Mozambique	Notenbaert <i>et al</i> 2013
Food crops	Maize, beans, groundnut	Household	✓		✓		Swaziland	Nkondze <i>et al</i> 2013
Agro pastoral	N. S.	Household		✓	✓		Mozambique	Ng'ang'a <i>et al</i> 2012

Table 2. (Continued.)

Sector/subsector studied	Cropping system	Unit of analysis	Enabler of research		Primary basis of assessment		Country (ies) of study	Representative studies
			Individual	Project	Social	Biophysical		
N. S.	N. S.	Household	✓		✓	✓	Ghana	Dasgupta and Baschieri 2010
Cereals	N. S.	Community		✓	✓	✓	Ghana	Etwire <i>et al</i> 2013
N. S.	N. S.	Household		✓	✓		Mozambique	Hahn <i>et al</i> 2009
Cereals	Maize	Community	✓		✓		Ghana	Antwi-Agyei <i>et al</i> 2013
Agro pastoral	N. S.	Household	✓		✓	✓	Zimbabwe	Rurinda <i>et al</i> 2014
Horticulture crops	N. S.	Household	✓		✓		Mozambique	Vilissa 2016

Note: N.S. means information was not specified in study.

**Table 3.** Conceptual frameworks with representative studies adopted in reviewed assessments.

Assessment framework	Description [source: (Adger and Nelly 1999, Turner <i>et al</i> 2003, Eakin and Luers 2006, Fussel 2007)]	Examples of analytical frameworks adopted in reviewed papers	Representative studies (reference/s) —note: six of the reviewed studies did not explicitly indicate the conceptual /analytical framework adopted hence not reported
Pressure and Release model	Applied to hazard and human ecology studies. Considers risk as an attribute of hazard and vulnerability. It synthesizes social and physical vulnerability	<ul style="list-style-type: none"> <li>• Sustainable Livelihood Approach</li> <li>• Resilience Framework</li> <li>• Integrated assessment framework</li> <li>• Vulnerability and Risk Framework</li> </ul>	<p>Westerhoff and Smit 2009</p> <p>Choptiany <i>et al</i> 2017</p> <p>Tesso <i>et al</i> 2012</p> <p>Derbile and File 2016</p> <p>Sorey 2011 Effah 2014 Umoh <i>et al</i> 2014 Etwire <i>et al</i> 2013 Hahn <i>et al</i> 2009 Rurinda <i>et al</i> 2014 Derbile <i>et al</i> 2016</p>
Political Ecology model	It is used in development, climate change and disaster risk-hazards assessment. Consists of internal social vulnerability or cross-scale social vulnerability state of being due to different exposure, impacts and capacities	<ul style="list-style-type: none"> <li>• IPCC Vulnerability to Climate Risk</li> <li>• Poverty framework</li> <li>• Sustainable Livelihood Approach</li> <li>• Moser Asset Vulnerability Framework</li> <li>• Model of Vulnerability to Poverty</li> </ul>	<p>Cooper and Wheeler 2017</p> <p>Dumenu and Obeng 2016</p> <p>Oluoko-odingo 2011</p> <p>Bele, Sonwa and Tiani 2014</p> <p>Deressa <i>et al</i> 2009 Tiani <i>et al</i> 2015 Hotz 2009 Jakpa 2015 Notenbaert <i>et al</i> 2013 Nkondze <i>et al</i> 2013 Ng'ang'a <i>et al</i> 2012 Dasgupta and Baschieri 2010 Antwi-Agyei <i>et al</i> 2013 Pavageau <i>et al</i> 2013 Grothmann <i>et al</i> 2017</p>
Resilience Model	Applied to coupled human-environment systems and considers dynamic aspects of vulnerability. Contributes to understanding the dynamics of change/transition, reorganization and capacity	<ul style="list-style-type: none"> <li>• Socio Ecological Systems Framework</li> <li>• Livelihood Trajectory Approach</li> </ul>	<p>Raemaekers and Sowman 2015</p>

Table 3. (Continued.)

Assessment framework	Description [source: (Adger and Nelly 1999, Turner <i>et al</i> 2003, Eakin and Luers 2006, Fussel 2007)]	Examples of analytical frameworks adopted in reviewed papers	Representative studies (reference/s) —note: six of the reviewed studies did not explicitly indicate the conceptual /analytical framework adopted hence not reported
		<ul style="list-style-type: none"> <li>Resilience Framework</li> </ul>	Sallu <i>et al</i> 2010
Expanded Vulnerability model	Applied to coupled human-environment systems, the vulnerability and sustainability of which are predicted on synergy between the human and biophysical subsystems as different spatiotemporal scales affect them.	<ul style="list-style-type: none"> <li>Multi-Hazard Vulnerability and Risk Assessment Framework</li> </ul>	Asare-Kyei <i>et al</i> 2017  Kienberger 2012

operationalization of vulnerability assessments (Preston 2012). It also indicates a diversity of emphases in what is deemed important within particular disciplinary approaches as well as applied contexts. This is well illustrated in the aforementioned foci of VAoSAS demonstrating both a plurality of ontological and epistemological presuppositions. VAoSAS drew their conceptual framing from concepts including Sustainable Livelihoods, Social Protection, Hazard and Human Ecology, Political Economy, Entitlement or Resource Endowment, Poverty and Development Studies (table 3). Detailed description of models, examples of analytical frameworks adopted in the reviewed papers, and their representative studies identified from the review can be found in table 3.

Studies used different definitions to build a composite index in operationalizing vulnerability. These included the risk hazard concept, socio-economic and political structures and processors, ecological resilience concept, human environmental system concept and vulnerability to poverty approach (see online supplementary material at [stacks.iop.org/ERL/13/103004/mmedia](https://stacks.iop.org/ERL/13/103004/mmedia) for details on conceptual definitions, hazards and variables for characterizing vulnerability of reviewed studies). Overall, the reviewed studies mainly assessed vulnerability of systems to climatic risks comprising of climate change, climate variability and disasters (58%). About 22% indicated vulnerability to both climatic and non-climatic risks such as climate-water conflict, food insecurity and climate change as well as poverty and climate variability. About 20% of the studies did not however indicate clearly what their system of study was vulnerable to.

### 3.3. Types of methods used in the design and analysis of VAoSAS

As vulnerability cannot be observed directly, the various analytical approaches used in operationalizing vulnerability in the 36 studies reviewed are presented in table 4. The methods most commonly used across the studies were the indicator based approach and

the participatory/qualitative methods. The indicator based approaches mainly employed proxy indicators in the construction of vulnerability indices while the participatory approaches were broadly case study based (table 4). Statistical analysis was recorded in seven of the studies reviewed using regression models and a multivariate statistical dimension reduction technique (Principal Component Analysis). Integrated/comprehensive approaches were observed in six studies combining proxy indicators, statistical and qualitative approaches (namely, Sallu *et al* 2010, Sorey 2011, Antwi-Agyei *et al* 2013, Rurinda *et al* 2014, Jakpa 2015, Angula and Kaundjua 2016). The least reported methods included model simulation and spatial mapping approaches reported in Kienberger (2012) and Asare-Kyei *et al* (2017) respectively. Data sources for assessments included both primary sources (basically through surveys using questionnaires, Focus Group Discussions [FGD] and Key Informant Interviews [KII]) and secondary sources (largely climate data from meteorological agencies in respective countries). Data sources for spatial mapping technique relied on spatial indicators like land cover, land use, road network and other landmarks with some component of build up from local knowledge. Only two studies presented differences in time scale in their assessment using primary information from census data. These were from Ghana (Dasgupta and Baschieri 2010) and Swaziland (Nkondze *et al* 2013) and concluded that the dynamic nature of vulnerability is understudied. According to Singh *et al* (2017), lack of attention paid to temporal scales during vulnerability assessments has implications on reporting differences in vulnerability over different time-scales to understand dynamism of vulnerability, especially in the context of seasonality and rural livelihoods in Africa.

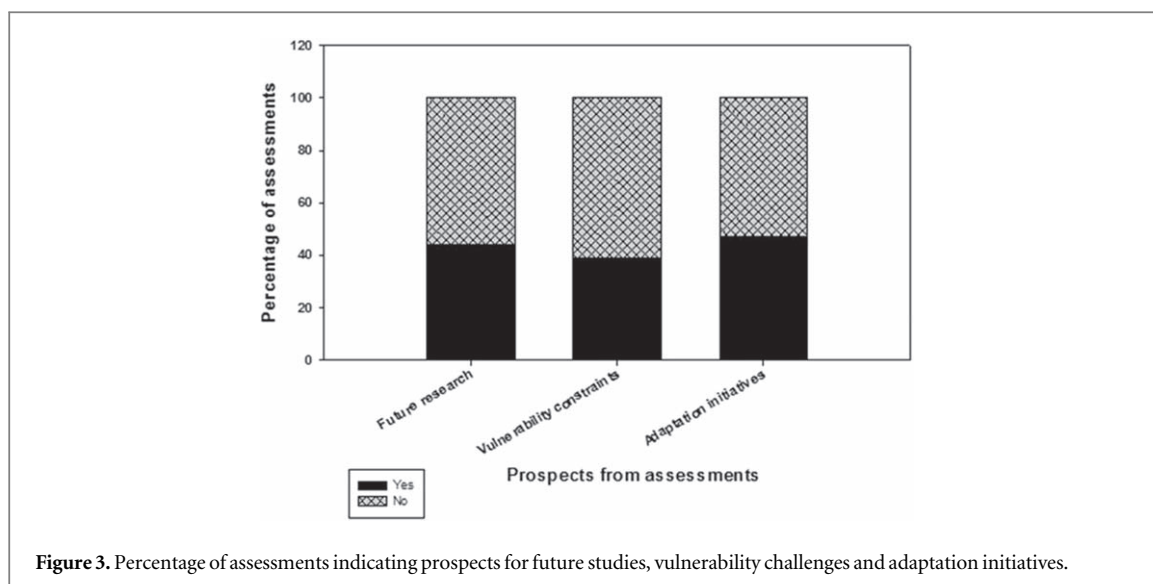
The selection of vulnerability factors influences methodological quality in the design and operationalization of vulnerability assessments (Tánago *et al* 2016). As depicted in table 3, the VAoSAS

**Table 4.** Information of sources of data and instruments used, basis of variable selection and analytical approached employed by reviewed studies.

Reference(s)	Sources of data		Data collection tools/instruments employed	Basis of variable selection		Main analytical approach for operationalizing vulnerability
	Primary	Secondary		Theory	Subjective	
Grothmann <i>et al</i> 2017	✓	✓	Focus Group Discussions (FGDs), questionnaires. interviews, stakeholders workshop, observation	✓		Statistical (logistic regression models and index computations)
Cooper and Wheeler 2017	✓		Interviews, semi structured questionnaire, FGD	✓		Indicator based (descriptive and thematic analysis)
Asare-Kyei <i>et al</i> 2017	✓		Statistical remote sensing, Geographical Information Services (GIS)	✓	✓	Spatial mapping (Remote sensing and GIS techniques and re-scaling normalization technique)
Okpara <i>et al</i> 2017	✓		Semi structured interviews, FGDs	✓	✓	Indicator based (Weighting and averaging indicators)
Derbile <i>et al</i> 2016	✓		In-depth interviews, FGDs		✓	Participatory/qualitative (Descriptive, climate learning ladder approach)
Dumenu and Obeng 2016	✓		Interviews, FGD, questionnaire	✓	✓	Indicator based (Descriptive, weighting and averaging indicators)
Westerhoff and Smit 2009	✓		Semi structured questionnaire, in-depth interviews, FGDs	✓		Indicator based (Community based analytical approach)
Raemaekers and Sowman 2015	✓		Community workshop, FGDs, Key Informant Interviews (KIIs)		✓	Participatory/qualitative (thematic and content analysis)
Choptiany <i>et al</i> 2017	✓		Multi-stakeholder workshop, structured and semi structured questionnaires	✓	✓	Indicator based (Descriptive, Self evaluation and holistic assessment of climate change resilience technique)
van Vliet 2010	✓		Questionnaires, interviews		✓	Participatory/qualitative (participatory community mapping, scoring systems, historical trend analyzes and participatory wealth ranking)
Oluoko-odingo 2011	✓	✓	Questionnaires, interviews, general observations, remote sensing techniques.	✓		Indicator based (multiple correlation and regression analysis, stepwise multiple regression analysis, principal components analysis, factor analysis, and cluster analysis)
Bele <i>et al</i> 2014	✓		FGDs, KIIs, Field observation	✓		Participatory/qualitative (Brainstorming, historical trend analysis and diagnosis)
Pavageau <i>et al</i> 2013	✓		District level workshops		✓	Participatory/qualitative (Field based farmer learning approach)
Mapfumo <i>et al</i> 2013	✓		Expert consultations, KIIs, Field-based farmer learning centers	✓	✓	Participatory/qualitative (Feedback analysis)
Tesso <i>et al</i> 2012	✓		Structured questionnaires, FGDs		✓	Statistical (Descriptive, Principal Component Analysis and probit regression model)
Deressa <i>et al</i> 2009	✓	✓	Questionnaires	✓		Statistical (descriptive, expected poverty and proxy analysis)
Angula and Kaundjua 2016	✓		FGDs, in-depth interviews, questionnaires	✓		Integrated/comprehensive (Mapping out, statistical estimations)
Derbile and File 2016	✓		KIIs, FGDs		✓	Participatory/qualitative (seasonal calendar analysis; two generational analytical framework)
Kienberger 2012	✓	✓	GIS, expert interviews	✓	✓	Model simulation (Integrated modeling using algorithms for interpolation, weighting of indicators through spatio-temporal context)
Molefe and Masundire 2016	✓		Workshop		✓	Participatory/qualitative (content analysis)
Sorey 2011	✓		FGDs, KIIs, observation	✓		

Table 4. (Continued.)

Reference(s)	Sources of data		Data collection tools/instruments employed	Basis of variable selection		Main analytical approach for operationalizing vulnerability
	Primary	Secondary		Theory	Subjective	
Effah 2014	✓	✓	Survey questionnaire, interviews	✓		Integrated/comprehensive (Resource mapping, hydro-climate characterization with percentages and mathematical formulae)
Umoh <i>et al</i> 2014	✓		Questionnaire, FGDs, In-depth interviews		✓	Statistical (linear regression analysis and descriptive statistics)
Tiani <i>et al</i> 2015	✓		FGDs, Workshops		✓	Indicator based (Mean scoring and averaging indicators)
Hotz 2009	✓		KIIs, interviews, community workshops, observation,	✓	✓	Participatory/qualitative (Profile analysis and resource mapping, interpretation of narratives, historical analysis, flows analysis)
Jakpa 2015	✓		GIS, semi-structured questionnaires, FGDs, interviews, transect walk		✓	Participatory/qualitative (Ethnographic approach and analysis)
Sallu <i>et al</i> 2010	✓	✓	GIS, oral history	✓	✓	Integrated/comprehensive (Logical analysis and separation biases and stereotypes, cross-checking, triangulating data sources, weighting and averaging indicators and GIS mapping)
Notenbaert <i>et al</i> 2013	✓		Survey questionnaire	✓		Integrated/comprehensive (in-depth livelihood trajectory mapping, thematic analysis, descriptive, multivariate statistics cluster analysis and correlations using Principal Components Analysis (PCA), Landsat images)
Nkondze <i>et al</i> 2013	✓	✓	Personal interviews, secondary sources	✓		Statistical (correlation and binary logit regression)
Ng'ang'a <i>et al</i> 2012	✓		Structured questionnaire	✓		Statistical (Descriptive statistics, multinomial logistic regression)
Dasgupta and Baschieri 2010		✓	Secondary sources using data from Living Standards Cross sectional Survey	✓		Statistical (Descriptive statistical analysis, frequencies, percentages, means and standard deviation)
Etwire <i>et al</i> 2013	✓	✓	Survey questionnaire	✓		Indicator based (Principal Component Analysis and weighting for each variable)
Hahn <i>et al</i> 2009	✓		Survey questionnaire	✓		Indicator based (Weighting and averaging indicators)
Antwi-Agyei <i>et al</i> 2013	✓		Survey questionnaire, KIIs, FGDs	✓		Indicator based (Weighting and averaging indicators)
Rurinda <i>et al</i> 2014	✓	✓	Survey questionnaire, FGDs, KIIs, community workshops, farm diaries	✓	✓	Integrated/comprehensive (content analysis, ANOVA K-means cluster analysis)
Vilissa 2016	✓	✓	Semi structured interviews, questionnaire, KIIs	✓		Integrated/comprehensive (Participatory diagnostic techniques, descriptive statistics, trend analysis)
						Participatory/qualitative (Content analysis, trend analysis)



reviewed showed that 17 studies (47%) based the selection of their vulnerability variables solely on previous studies in literature (theoretical underpinning) with modifications made in relation to location, context and data availability during assessment. Variable selections in about ten studies (28%) were exclusively subjective, based on expert and/or various stakeholders' knowledge and judgment. The remaining nine studies involved both theory and subjective processes in the selection of vulnerability factors.

### 3.4. Interpretations of the VAoSAS

According to Preston (2012), most vulnerability assessments should target identification of the problem orientation, methodological framing or enabling support to decision making. Following Preston's explanation, to identify and understand the implications of the assessments reviewed in this study, the key objective and conclusion for the reviewed studies were categorized according to the following outcomes:

- Vulnerability identification for different sub-sectors, systems, people and places.
- Contribution to complementing/enhancing/developing vulnerability assessment methods/concepts.
- Facilitation of decision-making.

Vulnerability identification and methodological contribution relate to the examination and understanding of the nature and determinants of vulnerability, as well as of the methods employed and various concepts framed for analyzing vulnerability. The last category relates to supporting decision-making for either policy or practice on adaptation. The most common outcome of the examined assessments identifies the determinants and vulnerability of sub-sectors, systems, people and places (58%) followed by

methodological contribution (25%) and decision support (17%). See online supplementary material for details of summary of outcomes and implications of vulnerability assessments from reviewed studies.

Further analysis of the results, discussion and conclusion sections of the reviewed assessments tried to link the findings of the assessments to vulnerability and adaptation planning. This helps identify the potential implications of enhancing adaptation practice on the basis of the assessments conducted. The intended end-users of vulnerability assessments include policy makers, decision makers (government and farmers) and other stakeholders (for example, researchers, community/village groups, NGOs). Among the studies reviewed, only 44% linked their findings with recommendations for future research (either into methodological aspect of assessing vulnerability; or into furthering the conceptual understanding of vulnerability or adaptation planning) (figure 3).

Only 47% of the assessments expressly reported on adaptation/coping initiatives practiced in the studied communities, with the intent to inform policy or practice. Also, 39% of the examined studies mentioned constraints hindering their study systems' response to vulnerability (figure 3).

## 4. Discussion

### 4.1. Current status of smallholder vulnerability assessment in Africa

Over the last decade, the rise in vulnerability assessments and research in Africa has begun to focus on smallholder livelihoods and communities. A steady rise in annual studies has been evident since 2013. The greater number of assessments in recent years reflects the growing awareness of the impacts of climate change on the continent. As a consequence, increasing

assessments have been conducted to identify vulnerable people as well as places to support decision-making and effectiveness of adaptation planning. Our review indicates that, assessments have particularly been focused on Western and Southern Africa. This is consistent with areas contributing the most to agricultural output in Africa. The crop sector dominates total agricultural production value (almost 85%) with the Western and Southern Africa also accounting for a comparatively large publications share across Africa (OECD/FAO 2016a). This geographical distribution highlights notable gaps for many countries from Eastern and Central Africa where livestock production is a clear contributor to agricultural output. The gap in research in these areas is potentially problematic as Eastern and Central Africa are also regarded as two of the most sensitive areas to El Niño episodes, threatening food security in the area (OECD/FAO 2016b). This trend suggests that vulnerability assessments in Africa are not necessarily driven by characteristics of inherent vulnerability, but are geospatially linked to research institution, market and productivity intelligence.

Although it is generally recognized that assessing vulnerability of particular groups enables clearer and more effective responses to be directly targeted towards them (Barsley *et al* 2013), guidance for specific subsector assessments were limited in the literature covered. More than half of the studies did not specify the exact cropping systems covered in their studies. Producers and production areas for mostly cereal, root and tuber, legume and other cash crop production without clear or detailed inclusion of other subsectors like the horticultural sector was observed. The horticultural sector however constitutes an important source of revenue for smallholder producers and provides rural households with employment opportunities in a number of countries in SSA (OECD/FAO 2016a). It is clear from the gaps noted from dearth of studies in spatial distribution and sectorial coverage that more context specific assessments should be developed and more studies on vulnerability assessments should be promoted across Africa.

Furthermore, scholarly evolution contributing to vulnerability research, has moved from assessments focused on solely biophysical or socioeconomic factors as observed in more than half of the reviewed studies (see table 2), towards a broader concept of multi-disciplinary (combining socioeconomic and biophysical factors), and multi stressors vulnerability research approaches (Luers *et al* 2003, Bisaro *et al* 2010, Delaney *et al* 2014, Devisscher *et al* 2013). The majority of studies were exclusively focused on climatic risk. Others were unclear as to what their study systems are vulnerable to, reflecting a lack of specificity and generally poor recognition of the multiplicity of stressors in shaping vulnerability among smallholders (O'Brien *et al* 2009). There is the need for future research studies to make adequate progress to invigorate all interlocking

stressors of vulnerability other than climate climatic risks or social factors.

#### 4.2. Conceptual framing and operationalisation of vulnerability among smallholders' in Africa

Political Ecology and Pressure and Release models are the most dominant theories for vulnerability studies in Africa. The theories mainly originated from CCA studies and consider states of being due to different exposure, impacts and capacities and risk as an attribute of hazard and vulnerability. Studies by scholars such as Hahn *et al* (2009) and Rurinda *et al* (2014) among the reviewed studies applying models from political ecology and sustainable livelihoods backgrounds give valuable contribution and perspectives in comparing rural livelihoods of different socio-political and economic contexts. The conceptual framings identified however spanned different disciplinary paradigms including hazard and human ecology, development, climate change and disaster risk-hazards as well as coupled human-environment studies. Notably, gender concerns were limited. The varied disciplines guided the diverse conceptual underpinning in framing and conducting VAoSAS over the past decade. Consequentially, heterogeneity in adopted conceptual frameworks is reflected in the diverse definition and operationalisation of vulnerability. With different conceptual frameworks, ranging from Sustainable Livelihoods, Social Protection, Hazard and Human Ecology, Political Economy, Entitlement or Resource Endowment, Poverty and Development Studies, definitions of vulnerability varied across the studies. There is increasing attention given to the conceptualization of vulnerability, to enhance the consensus of assessments, and to provide more adapted information (Preston *et al* 2011, Singh *et al* 2017). Our results show that studies from Africa still lack consistent framework and a clear concept guiding assessments. The 13 analytical frameworks highlighted were drawn from 13 different studies. Such progress emphasizes the increasing concern in lack of consensus regarding frameworks and the varied definitions used in constructing vulnerability assessments among scholars (Preston *et al* 2011, Delaney *et al* 2014, Tánago *et al* 2016, Singh *et al* 2017).

Climatic risks with few interactions of both climatic and non-climatic risks drove majority of the reviewed studies while some could not also exclusively indicate what is driving vulnerability of their study systems. Studies not explicitly specifying the concept underlying their assessment and/or what drives vulnerability is a limitation and reflects a general lack of systems approach to assessments. Dominance of studies taking climatic perspectives such as droughts, floods, hailstorm and strong winds, and non-climatic perspectives but related to changing climate as vulnerability drivers could however partly result from the present review focusing on climate variability and

climate change. Identifying vulnerability drivers potentially enables subsequent identification of measures to reduce that vulnerability. More generally, vulnerability constitutes the difference between the adaptive capacity of a household in response to its sensitivity and exposure to climate induced hazards. Assessments were generally conceptualized based on the systems exposure to hazards as a function of both magnitude and scope of perturbation. It involves the system it influences, as well as risk of being affected by extreme events or stressors. The main foci of such assessments were on current vulnerability, risk of present and future climatic variations and best responses to reduce present vulnerability and improve resilience to future risk. There is need for improvement in this approach with possible consideration of the recognition of how other non-climatic stressors shape vulnerability. Drivers of vulnerability inform the theoretical framings used, guides the conceptual framework adopted and later the operationalization of vulnerability assessments. Improved integration of other stressors related to demographic, economic and social factors interacting with climatic risks in assessing vulnerability is important and could contribute to the improved framing of vulnerability and to address the causes of all hazards. These need to be considered and given attention during future assessments to demonstrate the relevance of how vulnerability, other than climatic factors, can be applied for improved operationalization of vulnerability within specific concepts and context.

#### 4.3. Methods used in assessing vulnerability of smallholders in Africa

The diverse conceptual framings and definitions of vulnerability earlier noted are reflected in the variety of analytical approaches employed (see table 3). Lack of a standardized way of analyzing vulnerability data in the reviewed studies corroborates similar findings in other regions of the world (Preston *et al* 2011, Tánago *et al* 2016, Singh *et al* 2017). Six major methodological approaches employed to interpret the vulnerability of smallholder livelihoods in Africa show a dominance in the utilization of qualitative and indicative-based methods across Africa. Each of the six methods faces some level of criticism and difficulty in evaluating vulnerability. Most local level vulnerability assessments have been widely critiqued globally for not using principles of participatory design and engaging local perspectives and knowledge as important information sources during assessments (Raemaekers and Sowman 2015, Mcdowell *et al* 2016). Vulnerability assessments related to smallholder livelihoods in Africa in the last 10 years show some level of improvement in this regard however as diverse participatory approaches such as participatory community mapping, scoring systems, historical trend analyses, generational analysis and participatory

wealth ranking were evident. With regards to local level engagements however, efforts need to be further encouraged to formally consider both subjective and theoretical aspects in variable selection for assessment by incorporating local perspectives and knowledge as source of information.

Assessments based on integrated dynamic modeling and spatial approaches at the local level however is uncommon in Africa, with only two notable exceptions, Asare-Kyei *et al* (2017) and Kienberger (2012) from the studies reviewed. This underrepresentation may result in limited understanding of future vulnerability. During vulnerability assessments in Africa, limited attention is given to evaluation at temporal scales that has implications in understanding the dynamism of vulnerability across the region overtime affecting future projections. This limitation is attributed to high data requirement for model calibration and uncertainties regarding human decision-making. Set of spatial indicators constituting vulnerability units and characterizing an area considered such as land cover/land use, road network needed may not be readily available. Additionally, existing data on national census and climate for example, which includes data on education, gender, market accessibility, age, climatic variables (temperature and rainfall) among others are usually incomplete, insufficient and inconsistent geographically. There is need for more explicit and complete data for evaluating vulnerability and improve capacity of smallholders to vulnerability if assessments should rely basically on existing (secondary) and spatial data for evaluation. It implies regularly updating all relevant and available data including census and climate data. This is more relevant as increased consideration in the scientific community for both biophysical and social vulnerability has resulted in calls for a more comprehensive approach in evaluating vulnerability (O'Brien *et al* 2004, Sietz *et al* 2012). Vulnerability assessments across Africa have started to give attention to the development of comprehensive methods with efforts in applying integrated approaches using comprehensive analysis of proxy indicators, statistical and qualitative approaches and both primary and secondary data sources. This should be further promoted. That is, due to the multidimensionality of vulnerability, future studies need to develop more rigorous and replicable local and context specific variables critical for uptake at different localities across the geographical and sectoral settings for smallholder agricultural systems context.

#### 4.4. Outcome of vulnerability assessments

At the local level, understanding current vulnerability is considered a prerequisite for identifying key determinants of successful adaptation in the future (Adger 2003). Assisting households manage current climate variability by assessing their coping capacity

would be a first step in preparing for expected increases in extreme events (Notenbaert *et al* 2013). Coping and adaptation at the local level is noted to be autonomous and farmers are essentially acknowledged as the main facilitators expending their own social capital and resources (Notenbaert *et al* 2013). These arguments have practical implications for the outcome of vulnerability assessments for smallholders. Vulnerability assessments are expected to provide adequate understanding, information and practical guidance to support farmers' decision making on adaptation planning beside vulnerability identification. The main outcome of vulnerability assessments conducted among smallholder farmers in Africa for the past ten years have mainly been to identify determinants and vulnerability of sub-sectors, systems, people and places. Other studies also broadly focused on enhancing conceptualization of vulnerability and contributing to methods employed in the assessment process. The least produced outcome was directed towards facilitating decision making among stakeholders. This finding implies that vulnerability scholarship focusing on smallholders in Africa has made limited progress in empowering farmers who are the main actors of adaptation planning at the local level to informed decision making and uptake of adaptation.

Just as importantly, the relevance of vulnerability research for decision-making on adaptation planning for other key decision makers is limited (governments and policy makers). Meanwhile, various stakeholders including policy makers, researchers, community/village groups and NGOs are intended enablers and users of vulnerability assessments. This indicates that reports of African countries still not realizing their potential in climate adaptation is still pertinent (Kurukulasuriya *et al* 2006, Ndamani and Watanabe 2017). There is need for research findings from VAoSAS to improve communication and enlighten science, policy and practice for informed decision-making and evidenced based policies. Furthermore, anticipated end-users of assessments should be involved in the assessment process as earlier indicated. Similar recommendations have been at the center of recent systematic reviews of vulnerability assessments in different contexts (Tánago *et al* 2016, Mcdowell *et al* 2016, Donatti *et al* 2018).

Our study further explored the linkage between assessment outcomes and attempts to develop options for promoting resilient smallholder agricultural systems. It is important to identify how vulnerability can be reduced to direct government policies. Range of adaptation measures specified to reduce vulnerability from reviewed studies included diversification of crops and income sources, planting different crop varieties, such as better organization at local level (i.e. cooperatives) and improvement of infrastructure. These strategies could build on some adaptive measures in agricultural programmes that already exist to improve it. Assessments reviewed however showed

insufficiencies in identifying adaptation/coping measures after assessment for possible policy interventions. The same limitation applies to indicating responses constraining farmer's response to vulnerability for concrete policy and practical solutions to identified challenges. Scientists also successfully use assessments to understand general principles of a system and what can be improved from observed situations but limited recommendations for direct future research were not specified.

In order to advance the science and practice of vulnerability assessment in Africa, there is need to conduct assessments based on specific sector/sub sector for identification of explicit potential climate adaptation strategies to improve understanding and knowledge of adaptation among different smallholder agricultural systems. To give guidance and policy suggestions from vulnerability assessments however, outcomes from the process need to inform development of policies. Even though some of the studies reviewed identified various adaptation options, the effectiveness of such measures to support decision-making is not known. For instance, to inform the development of climate adaptation programmes and policies, the assessment process needs to provide information to guide and inform effective decision-making on allocation of scarce resources through prioritization for more relevant and targeted responses. Specifically, generation of information on the costs and benefits from the implementation of climate adaptation options could direct development initiatives on investment in responding to changing climate. Farmers could also benefit from such information to understand trade-offs management and implementation to build understanding and strategically pursue possible responses to reduce their vulnerability. Information on guided policy recommendations to mainstream climate adaptation into agricultural development strategies and plans also need to be highlighted in vulnerability assessments for policy actions.

## 5. Conclusions

In presenting the progress made in Africa over the last decade, this review focused on providing an overview of vulnerability assessments and how it has been conducted and interpreted among smallholder agricultural systems. Despite the growing interest in the scholarship across the region, we observed geographical and sectorial dearth in studies on VAoSAS in Africa. Particularly, East and Central Africa regions could benefit from less spatially partial and more regionally balanced VAoSAS while more assessments of sub-sectors of smallholder agriculture, such as livestock and horticulture production could be improved across the region. The role of both climatic and non-climatic stressors and their relative importance should both be considered in assessing



smallholders' vulnerability. Even though there is widespread development of methods and concepts for VAoSAS in Africa, there are still opportunities that this study highlights as target for improvement in future assessments. We suggest the engagement of greater diversity of stakeholders as participants throughout the assessment process to make it a more inclusive method. Generally, focus of smallholder climate vulnerability research is increasingly moving towards human-environment coupling system hence vulnerability estimation should also move more towards a comprehensive approach. Relativity of indices to systems studied that is used in current indicator based approach need to be enhanced and complemented to construct a reasonable indicator system. Overall, comparing the assessments reviewed on smallholder agricultural systems in Africa to current scientific knowledge on vulnerability research that is argued to have a multidimensional nature, we suggest an integrated approach to the assessment process.

At the conceptualization and methodological level, strengths observed in the literature indicate the future of vulnerability assessment in Africa requires an holistic and multidimensional approach. It needs to be integrative to avoid ambiguity in understanding the system assessed as well as comprehensive enough to understand the human and environment system relationship better. Furthermore, best practice links vulnerability assessment outputs with adaptation policy and measures regarding the relevance of assessments to end-users. The scarcity of evaluation of economic effectiveness of adaptation strategies as critical aspect of vulnerability assessment literature in Africa requires improvement in future research. This would empower exposure units to address the causes of hazard they are been exposed to; provide guidance and inform effective decision-making on allocation of scarce resources (prioritization); understand trade-offs management and implementation to build understanding among stakeholders (farmers and policy makers) to pursue possible responses to reduce vulnerability.

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