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Fanen Terdoo

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Vulnerability and adaptation of rice value chains in Benue State, Nigeria

Fanen Terdoo

Department of Geography and Regional Planning,
Federal University Dutsin-Ma,
P.M.B. 5001 Katsina State, Nigeria
Email: fanenterdoo@gmail.com

Abstract: This study provides a synchronic baseline assessment of the complexities of the rice value chains (RVCs) in Benue State, Nigeria. Data sets were drawn from face-to-face (n = 72) interviews with RVCs' actors (growers, millers, and traders) in three study areas. The vulnerability scoping diagrams (VSDs) were applied to help examine the components of RVCs actors' exposure, sensitivity, and adaptation practices in detail. The results highlighted uneven vulnerabilities among the RVCs' actors based on geographical location, cropping, milling, market system, and spatio-temporal dynamics. In addition to uncovering specific interactions of the effects of vulnerability with the downstream components of the RVCs, this study found several adaptation practices that were not only characterised by trade-offs and uncertainties but resulted in maladaptation outcomes that increased vulnerability. This study emphasises the importance of taking into account the effects of multiple interactions of vulnerability with actors along the chain when developing vulnerability reduction and resilience-building strategies.

Keywords: multiple exposures; maladaptation; vulnerability scoping diagram; VSD; socio-ecological systems; SES; West Africa; Nigeria.

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Biographical notes: Fanen Terdoo currently works in the Department of Geography and Regional Planning, Federal University Dutsin-Ma, Katsina State, Nigeria. His research focuses on vulnerability, adaptation, and resilience of agri-food systems and livelihoods to global change, with a particular focus on northern Nigeria.

1 Introduction

The rice value chains (RVCs) are vital to Nigeria's economy in many ways. First, in terms of food culture, rice is considered the most important dietary staple in the Nigerian diet, accounting for 10.5% of total calorie consumption, ahead of maize, yams and cassava (Gyimah-Brempong and Kuku-Shittu, 2016). Nigeria also has the highest per capita rice consumption (33.94 kg per year) in Africa, with rice accounting for almost 6% of household expenditure (Durand-Morat and Chavez, 2021; Johnson et al., 2013). Second, being an important cash crop, RVCs' operations and processes such as rice farming, milling, distribution, selling, and trading produce more jobs and money for a

larger population of Nigerians than any other cash crop (Cadoni and Angelucci, 2013; FAO, 2018).

Despite the strategic roles of the RVCs in food security and the economy, the annual rice production and processing have grown at a slower pace of 1.8% during the past decades, while consumption has increased at a faster rate of 2.8%, resulting in a 5.0% increase in rice importation (Durand-Morat and Chavez, 2021; Johnson and Dorosh, 2017). Existing research has linked the issue to vulnerability, particularly its exposure and sensitivity to, and limited adaptation of RVCs' operations (such as growing, milling, distribution and trading) to multiple climatic, economic and market pressures (Bosello et al., 2017; Demont and Ndour, 2014; Johnson and Dorosh, 2017; Matthew et al., 2015; Okodua, 2018). Thus, in many states, extreme weather events, such as temperature anomalies, flooding, rainwater shortages, and changes in onset and cessation of rainfall, amongst others, have been observed, and impacts spread across all parts of the RVCs, including other sectors of the economy (Bosello et al., 2017; Enete et al., 2012; Matthew et al., 2015; Nwalieji and Uzuegbunam, 2012; Onyeneke, 2021). In addition to the pressures imposed by climate change and variability (CCV), RVCs in Nigeria and West Africa have been exposed to economic pressures, such as volatile markets; frequent, stark, and unexpected changes in agricultural policy; poor milling technology and infrastructure; and international competition (Demont, 2013; Johnson et al., 2013; Terdoo and Feola, 2016; Tondel et al., 2020; Nyantakyi-Frimpong and Bezner-Kerr, 2015).

The implication is, that to adapt and build resilience in the RVCs, which will ensure the continued, secured provision of the national staple and the income it generates, a holistic process is needed which goes beyond current, single, haphazard policies (Tondel et al., 2020). Such a process must consider the entire RVCs and the interaction of factors that combine to increase the complexities of the system and put it under pressure (Moseley and Battersby, 2020; Tendall et al., 2015). This is important, given the complex socio-ecological dynamics that characterise the RVCs' system when pressures (e.g., CCV, poor market prices) or part of the chains (e.g., milling, trading) are addressed in isolation and in a short time, because they can obscure and conceal visualisation of the interaction of the effects of vulnerability along with the downstream parts of the chain as the effects of pressures on one component interact or transmit through the entire RVCs' system, hence compounding the vulnerability of the RVCs (Leichenko and O'Brien, 2008; Stave and Kopainsky, 2015). Secondly, they may result in maladaptive outcomes-situations in which a well-intended practice employed to reduce exposure and sensitivity instead increased them (Schipper, 2020; Work et al., 2019). This can result in piecemeal bits of knowledge on parts of the system rather than knowledge about the system as a whole, which limits holistic and comprehensive adaptation approaches and increases uncertainties and maladaptive outcomes that ultimately amplify vulnerability.

Despite the foregoing, little is known about the impacts of multiple, simultaneous pressures or their interactions on RVCs, the effects of CCV, and market dynamics on parts of the value chain other than production (e.g., rice milling and trading) in Nigeria (Terdoo, 2019), or the forms and extent to which different adaptive practices employed by different actors (e.g., growers, millers and traders) become maladaptive and thereby hinder or enhance the resilience of RVCs in the face of climatic and other pressures in Nigeria (Glover and Granberg, 2021; Schipper, 2020). Such an understanding is the basis upon which evidence-based vulnerability intervention in the rice sectors of Benue State in particular and Nigeria broadly can stem from.

To address these gaps, a synchronic baseline vulnerability assessment of the complexities of RVCs in Benue State was conducted to clarify the following research questions:

1 What current pressures are the rice growers, millers, and traders exposed and sensitive to, and what adaptation practices are employed in response to such pressures?

2 Do the trend and pattern of exposure, sensitivity, and adaptation practices of different groups or classes of RVCs' actors vary geographically and concerning the choice of cropping, milling, and a market system and spatio-temporal dynamics?

3 How does the vulnerability of growers, millers, and traders in rice interact within the RVCs?

4 What are the (mal)adaptive outcomes of those practices?

5 What are the trade-offs in adaptation decision-making?

This study contributes to the debate about the impact of global change on agri-food systems broadly and food security and agricultural development in particular. It provides a context-based assessment of vulnerability and adaptation of RVCs to multiple pressures in low-income regions.

2 Theoretical and conceptual context

This study adopts a multiple exposure framework and a systematic approach to vulnerability analysis. While the multiple exposure frameworks acknowledges the complex interactions between climate change and other socio-economic processes (Belliveau et al., 2006; Leichenko and O'Brien, 2008), the system approach emphasises wholes rather than parts and interconnections as well as interrelations and complexities (Arnold and Wade, 2015; Senge, 1993; Stave and Hopper, 2007). In these frameworks, RVCs are viewed as integral parts of agri-food systems and are conceptualised as socio-ecological systems (SES) (Adger, 2006; Ericksen, 2008; Folke, 2006), which comprise a wide range of biophysical and social processes and activities leading to rice production, processing, marketing, and distribution up to the point of consumption (Tendall et al., 2015).

Vulnerability is understood as "the degree to which a system is susceptible to and is unable to cope with adverse effects" [Adger, (2006), p.269]. Operationally, vulnerability can be described as having three dimensions, namely exposure, sensitivity and adaptive capacity. Exposure and sensitivity are intimately related concepts, where exposure refers to the condition of being subject to detrimental effects, and reflects the biophysical characteristics of the pressure/stressor relative to the location and nature of the system (Füssel, 2007). Sensitivity describes the degree to which a system is affected by or responsive to pressure and is related to characteristics of the system and broader non-climatic and socio-economic or demographic factors (Smit and Pilifosova, 2001).

The vulnerability of the RVCs emerges as a result of the multiple exposures and sensitivities of a diversity of system actors (e.g., growers, millers and traders) to social and ecological processes or factors such as environmental conditions, access to resources,

markets, information, and knowledge, political, culture and governance (Darnhofer, 2010; Tendall et al., 2015; Thomas et al., 2019; Vermeulen et al., 2012; Zossou et al., 2009). As well as their inability to adapt to these pressures, which may be due to their limited or differential capacities and access to resources and safety nets, this is also the reason for differential vulnerabilities being highlighted in a growing number of studies across SSA (Antwi-agyei et al., 2017, 2018; Segnon et al., 2021; Widayati et al., 2021; Nyantakyi-Frimpong and Bezner-Kerr, 2015).

Adaptation can be described as practices that facilitate adjustments in coupled SES in response to actual or expected pressures, or their effects, which moderate harm or exploit beneficial opportunities (McCarthy et al., 2001). While adaptation responses are expected to reduce vulnerability and build resilience, when they are poorly designed and implemented they can result in maladaptation. Maladaptation is a situation that occurs when adaptive responses, instead of reducing, increase exposure and sensitivity to the pressures they originally set out to address (Schipper, 2020; Work et al., 2019).

Adaptation practices are classified as short or long-term, depending on the duration for which they are employed. They can also be viewed as planned, preventive, anticipatory, or strategic, when taken before the pressure occurs, or reactive, when the purpose is to cope with the pressure as it occurs. Similarly, others classify adaptive practices based on the form they take, e.g., technological, indigenous, behavioural, financial, or institutional; the number of people involved, e.g., autonomous or collective (Enete et al., 2012; Smit and Pilifosova, 2001); and the degree of change required, e.g., incremental or transformational (Biagini et al., 2014; Rickards and Howden, 2012). These different typologies of adaptation practices are important for this study in that they shed light on the manner and success of adaptation to current and expected pressures by rice growers, millers and traders.

3 Methods

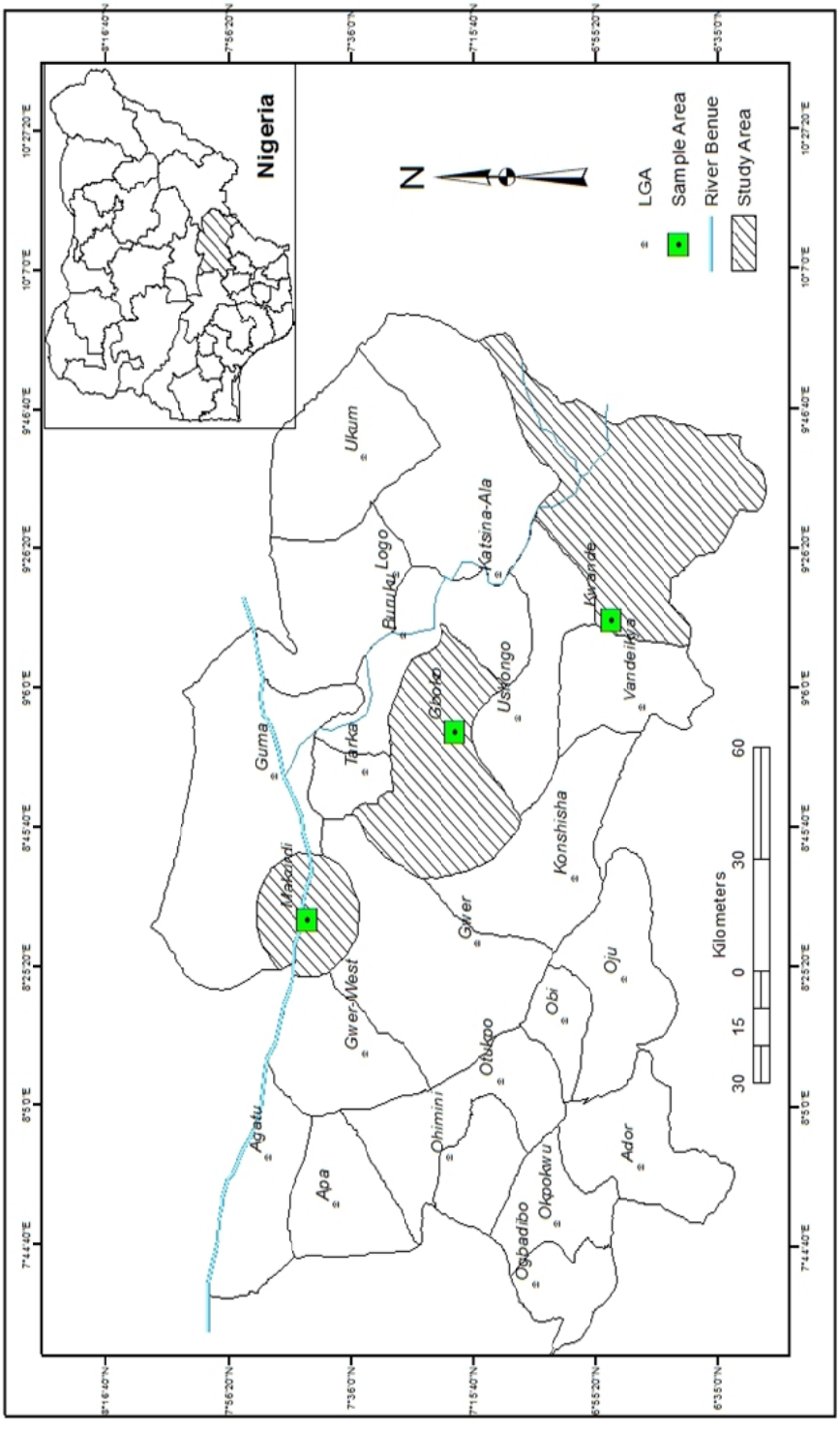
3.1 Study area

A field study was conducted in Benue State, North-Central Nigeria (Figure 1). Benue State is located in a trough-like basin, which lies between latitudes 6° 25′ N and 8° 8′ N, and between longitudes 7° 47′ E and 10° 00′ E, and has a total land area of 30,800 sq. km (National Bureau of Statistics, Nigeria, 2010).

The climate of Benue State is that of a sub-humid tropical climate, which is characterised by distinct rainy/wet and dry/harmattan seasons. The monthly distribution of rainfall varies significantly from the north to the south, with the annual total averaging between 1,200 and 1,400 mm (Ogungbenro and Morakinyo, 2014). The average temperatures range from 23°C–32°C.

The vegetation in the state is characterised by sparse grasses and numerous heterogeneous species of scattered trees (Hulu, 2010). The soils in the region (e.g., uplands and lowlands) are formed from the parent materials that originate from both sedimentary and basement complex rocks; the lowland alluvial soils of the floodplains are called ‘Fadama’ and are suitable for all-year-round cultivation, including rice growing, under wide-ranging growing systems.

Figure 1 Map of Nigeria showing Benue State and the study sites (see online version for colours)



In terms of economy, Benue State also known as the 'food basket of Nigeria', can be described as an agrarian society. Of which, well over 70% of its estimated 4,780,389 people (National Population Commission, 2006) depend on agriculture and produce, mainly grain (rice, soybeans, groundnuts, maize and millet), fruit (oranges and mangoes), vegetables (tomatoes and peppers), and tuber crops (yams, cassava and potatoes).

3.2 Background information on RVCs

Rice is grown in Nigeria under five different ecologies or systems, these are rain-fed upland (RU), rain-fed lowlands (RL) also called FADAM, irrigated (I), deep water floating (DWF) and mangrove swamp (MS) (Ezedinma, 2005; Longtau, 2003; Uduma et al., 2016). In Benue State, RL and RU are the dominant rice growing systems practised by the majority of rice growers. The geographical location of the state in a sub-humid agro-climatic zone and a trough-like basin gives it huge potential for growing rice in all the systems.

After the rice is grown and harvested, it is aggregated or assembled by village buyers (USAID, 2009). Most of these buyers are intermediaries (middlemen) and speculators (locally known as Branda), and some are agents of outsourcing rice milling companies, or of small or large rice mills. This group of actors plays a significant role in linking rice growers to millers and, as such, could manipulate the rice market, including prices. The key functions of this group of actors include buying, assembling, storing, and transporting paddy rice to the processors (i.e., the millers).

In Benue State, there are two market systems where unmilled rice aggregation or assemblage takes place. The first is the traditional open periodic market system, where rice is sold at the market square, on a particular weekday. The common characteristics, and perhaps challenges that pressure rice growers, are that formal scaling or weighing systems are not used during the selling or buying of unmilled rice, and prices are neither regulated nor controlled, resulting in growers being frequently short-changed. The second market system is the program, network, or contract market, where growers enter into an agreement with a certain buyer, miller, or company to sell their rice at the end of a harvesting season. Unlike the traditional system, this market system uses formal scaling or weighing systems, such as kilograms and tons, for selling and buying the rice, and attempts to enhance quality to match that of and so compete with imports.

The market prices of unmilled rice in Benue State are mainly a function of availability (e.g., supply), but other factors have some impact, such as rice quality, variety, and sometimes market location and distance. Prices also vary with the season in some years. Usually, the prices are low and often crash between November and December when the main season rice is being harvested. However, prices soon improve towards the end of December when the Christmas festivities set in. Then, the prices peak between May and June when stocks are completely sold out.

Lastly, rice milling (i.e., the processes or activities such as soaking, parboiling, drying and dehusking) in Benue State is carried out under either of two major milling arrangements. The first comprises small and medium-sized mills, while the second is made up of larger, modern, industrial mills run by millers who seek to enhance the quality of domestic rice to match the high quality of imported rice.

3.3 Data collection process

Although the vulnerability is dynamic, a qualitative strategy that supports a cross-sectional design with a case study element allows for data collection in different study sites and with different actors along the chain (Denscombe, 2014). Three study sites were chosen to represent areas with a well-established rice farming, milling, and trading history as well as their climatic and ecological belts. These are Makurdi in the north, Gboko in the centre, and Adikpo in Kwande in the south, respectively (Figure 1). The rationale for these choices lies in the possibility they allow differences in exposure, sensitivity, and adaptive practices of RVCs' actors to be uncovered across the geographical divides of Benue State.

Snowball sampling, a technique by which one or more participants refer the researcher to other potential participants (Schutt, 2012) was used, which enabled an exploratory sample (n = 72) to be drawn that was representative of the population rather than statistically generalisable across the three study sites, in Makurdi (n = 26), in Gboko (n = 24) and Adikpo (n = 22), respectively. The snowball sampling was particularly useful in this study as it overcame issues of trust in the field. Small landholder growers, millers, and retailers are notoriously suspicious of researchers, whom they believe to be representative of discredited government agencies. Therefore, snowball sampling enabled participant selection in a rather hostile environment by introducing the researcher via an informant, or an insider well-known to the target population, who could assure participants that the study was genuine academic research. Accordingly, 72 semi-structured interviews, each lasting approximately two hours were used to collect the data needed to populate the vulnerability scoping diagram (VSD) (Figure 2). These interviews were carried out with rice growers, millers, and traders between December 2016 and February 2017 to gain an in-depth understanding of the dynamics that make the RVCs' system vulnerable. The interviews were recorded using a digital voice recorder with the agreement of the participant as enshrined in social research ethics (Denscombe, 2014). In addition, notes were taken during the interviews.

The interview guide was organised into four sections. Questions in the first section aimed to understand the background of individual participants, their rice farming, milling, and trading activities, and the challenges they faced in carrying out their respective activities. The remaining sections focused on understanding exposure, sensitivity, and adaptive practices, respectively, in the face of economic and climatic pressures. In this study, interview questions about the challenges (hazards) faced by participants were left open to invite discussion about different types of pressures, and their interactions, rather than to suggest or limit the focus on those related to climate and markets. This was an important step in gaining a broad, holistic perspective on RVCs' system structure and recent pressures to which participants along the chain are exposed and sensitive (Terdoo and Feola, 2021).

Accordingly, participants were asked to share their experience of extreme events, and how they reacted and/or responded to such pressures over the past 5–10 years. This time frame was important to capture not only operational (i.e., daily) and tactical (i.e., seasonal) adaptation practices, but also longer-term ones (Barrett et al., 2017; Risbey et al., 1999). While this is a cross-sectional study and focuses on activities and processes such as growing, milling, and trading that tend to vary on a seasonal basis (i.e., one year), the exposure, sensitivity, and adaptive practices depend on barriers and facilitating factors that build up in a longer time frame.

3.4 Data analytical framework

After interview transcriptions were completed, a computer-assisted qualitative data analysis software, NVivo 11, was used to code the data. Content analysis was used to identify emergent themes and patterns and the underlying meaning in the data (Denscombe, 2014). Codes were generated progressively and adjusted or combined as the analysis of the interview transcripts proceeded. Moreover, codes thought irrelevant to the emergent themes were eliminated until the final lists of codes for each question were generated.

Then, all the codes were categorised following the themes of exposure, sensitivity, and adaptation practices, which correspond to the three dimensions of vulnerability. Thus, pressures were analysed (e.g., coded) topically, depending on their main driver (e.g., CCV, non-CCV). For example, every reference made to various sources of water stress to rice plants (e.g., droughts, early cessation of rainfall, dry spells, etc.) was considered as one group, which is broadly described as *water shortages*. In the same vein, every reference to excess water (e.g., too much rainwater, etc.) was described as *flooding*.

A VSD framework developed by Polsky et al. (2007) was applied for the visualisation and comparison of vulnerability assessments performed at different study sites for different value chain actors. The framework is fitting for this study because it is consistent with the vulnerability definition used, and it applies to SES, including agricultural systems (Polsky et al., 2007; Schröter et al., 2005). For example, the VSD framework has been insightfully applied in several vulnerability assessments, including water community systems (Howe et al., 2013; Polsky et al., 2007), coastal tourism (Moreno and Becken, 2009), winegrowing industries (Nicholas and Durham, 2012), and commercial fisheries management (Tuler et al., 2013).

To scope vulnerability using VSD (Polsky et al., 2007) highlighted five research elements that must be specified. These include:

1 the hazard and the associated outcome(s) of interest

2 the exposure unit

3 dimensions

4 components

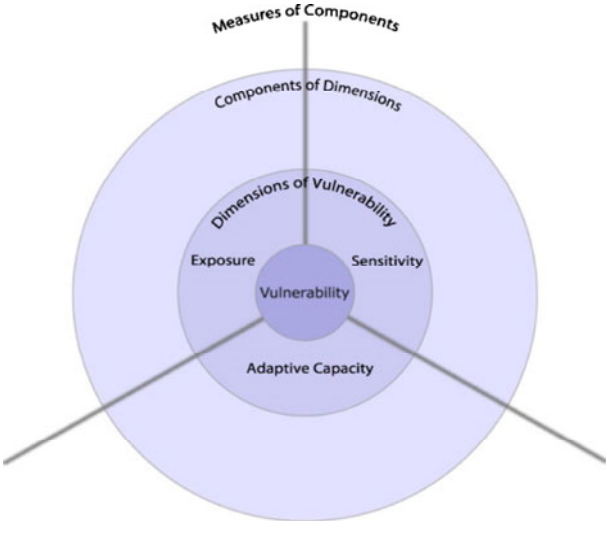
5 measures of the vulnerability process in question.

Figure 2 presents the template of the VSD. The vulnerability of the system in question is represented at the centre of the diagram. In the centre ring, vulnerability is divided into three fundamental dimensions: exposure, sensitivity and adaptive capacity. The next ring represents the components of those dimensions or the features on which they are evaluated. The final, outer ring highlights the measures of the components, i.e., the observable characteristics of each of the three dimensions.

The analysis of data with the aid of VSDs was complemented by an examination of exposure as well as sensitivity and adaptation to pressures based on the socio-demographic characteristics (SDCs) of the RVCs' actors, namely: gender, age, educational level, income class, farm size, labour access, and the number of years engaged as RVCs' actors (e.g., grower, miller and trader). Except for variability based on types of RVCs' actors, the result revealed no significant difference suggesting

vulnerability cuts across social-demographic characteristics of the respondents. In the following sections, the results of the analyses of data are presented and the possible entry points for the initiation of vulnerability reduction or resilience-building interventions are discussed.

Figure 2 General form of the VSD (see online version for colours)



Note: Pressures and exposure unit unspecified.

Source: Adapted from Polsky et al. (2007)

4 Results

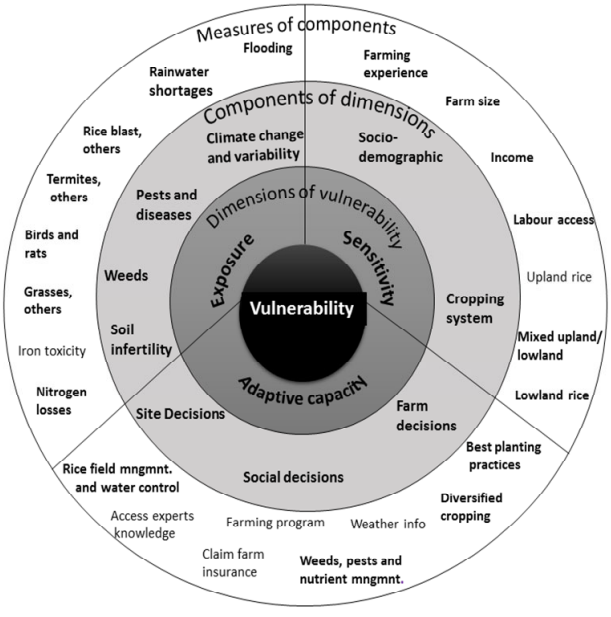
Here, the study's findings are presented as follows: first, current exposure and sensitivity, and adaptation practices are documented. Second, variability in vulnerability (i.e., exposures and sensitivities and adaptability) of RVCs' actors based on: geographical location, choice of cropping, milling and market system, and actor types as well as spatio-temporal dynamics is explored. Third, the interactions of the effects of vulnerability are presented. While in the fourth section, the maladaptive outcomes of current adaptation practices are unpacked. Then, uncertainties in growing, milling, and trading rice and trade-offs in adaptation decision-making are discussed in the fifth and sixth subsections. Lastly, a discussion and conclusions are presented.

4.1 Current exposures and sensitivities of the RVCs to pressures

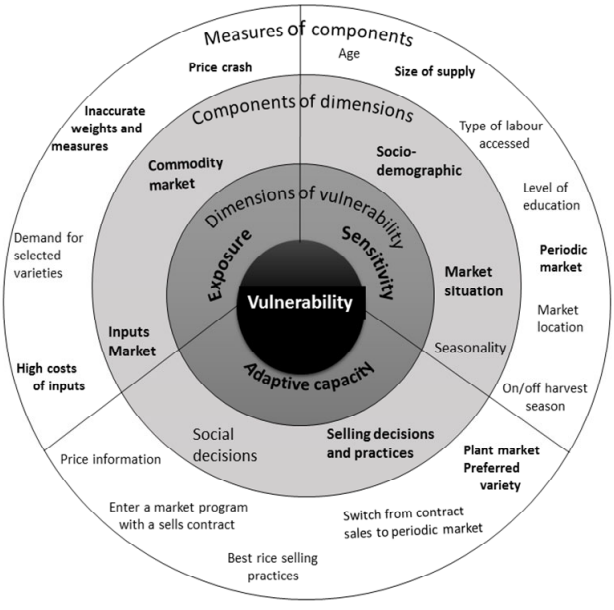
The VSDs [Figures 3(a)–3(d)] document the current pressures and sensitivities along the RVCs in Benue State. On the one hand, the VCD [Figure 3(a)] shows that 33.3% of rice growers are exposed and sensitive to recurring CCV-related pressures such as flooding and rainwater shortages, in addition to weed infestations, disease, pests and soil infertility. On the other hand, the VCD [Figure 3(b)] reveals that growers were further exposed and sensitive to market pressures from many sources, including price crashes,

high cost of inputs, use of inaccurate weights and measures, and market demand for selected varieties.

Figure 3 VSD for (a) growers to CCV-related, (b) market pressures, (c) millers and (d) traders in Makurdi, Gboko, and Adikpo, Benue State, Nigeria



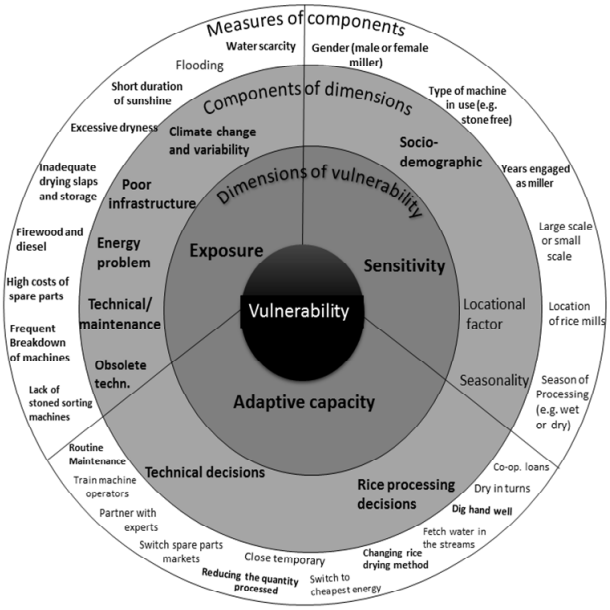
(a)



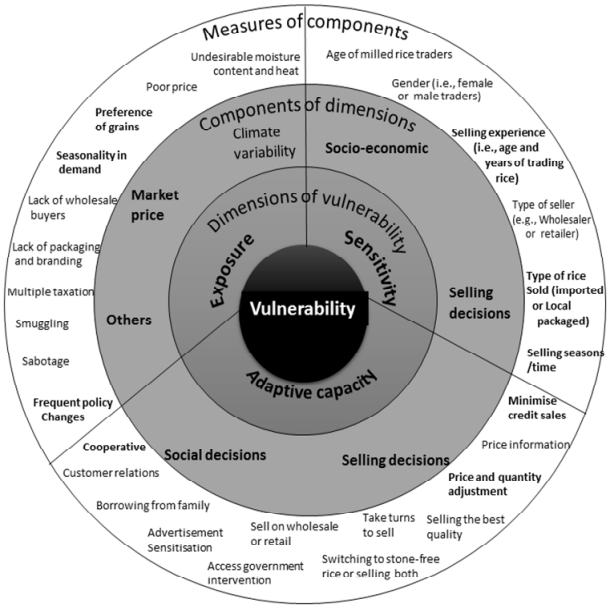
(b)

Notes: Factors highlighted in bold were mentioned by at least 33% of rice growers.

Figure 3 VSD for (a) growers to CCV-related, (b) market pressures, (c) millers and (d) traders in Makurdi, Gboko, and Adikpo, Benue State, Nigeria (continued)



(c)



(d)

Notes: Factors highlighted in bold were mentioned by at least 33% of rice growers.

In contrast to growers, rice millers [Figure 3(c)] and traders [Figure 3(d)], were more exposed and sensitive to economic/market pressures than to prolonged wet conditions,

high moisture contents, excess dryness, and water scarcity, the effects of which may have been exacerbated by CCV. The economic/market pressures, i.e., poor milling technology and infrastructure, price volatility, and trade liberalisation, both contribute to poor quality of domestic rice, and subsequently, to frequent price crashes.

Lastly, the VSDs equally examine the current adaptive practices of RVCs' actors [Figures 3(a)–3(d)]. The results show that rice growers in Benue State employed both reactive and tactical practices, both in the long and the short-term, in response to the pressures of CCV and agricultural markets.

4.2 Variability in exposures and sensitivities, and adaptability of RVCs' actors to multiple pressures

The pattern of variability in exposures, sensitivities, and adaptive practices of RVCs' actors (i.e., growers, millers and traders) to pressures across the study sites was explored. The analyses of results revealed three factors with which to compare the existing differences between the three study sites, and therefore highlight uneven vulnerabilities. These include:

1 their geographical location, in either Makurdi, Gboko, or Adikpo, and choice of cropping, milling, and market system (i.e., rainfed upland or lowland, or mixed and double or triple cropping)

2 their spatio-temporal dynamics (e.g., planting, milling or processing and selling season).

These results are presented in the subsections that follow.

4.2.1 Variability based on geographical location, choice of cropping, milling and market system and actor types

Concerning variability according to geographic location, the study revealed uneven exposure and sensitivity, and the spread of promising adaptive practices across the different sites, particularly between Makurdi and the other two sites, and among actor types (e.g., small and medium or large landholders, millers and traders) (Table 1). In particular, the results showed that growers, millers, and traders in Makurdi were more exposed and sensitive to flooding. Given the geographical context of the region, the rice fields in the area and rice mills in Wurukum and Wadata are situated in a low-lying topography and within the floodplains of the Benue River, so they can meet the water demand for growing, parboiling and milling rice. However, this exposes rice production activities in the area to recurrent flooding, which often disrupts RVCs' processes (e.g., ploughing, harvesting, soaking, parboiling and drying).

In contrast to Makurdi, growers and millers in Gboko and Adikpo were more exposed and sensitive to rainwater shortages (Table 1). Their sensitivity to water shortages, especially seasonal drought was more attributed to their choice of cropping, milling, and market system than to their geographical context (e.g., a hilly-type and gently undulating relief of the areas). For example, the practice of mixed cropping systems (e.g., upland, double or triple cropping) and the use of artisanal parboiling and milling equipment require constant use of water, which makes the susceptibility to water shortages.

For example, in the study sites, and among the RVCs' actor types, this study showed that growers, millers, and traders who are medium/large landholders are less sensitive, more adaptable, and by extension, less vulnerable to pressures due to their ability to access promising adaptive practices, such as entering a farming support program or a rice selling network/partnership, which provides buyback agreements or contracts, weather information, expert knowledge, and farming safety nets, which include crop insurance and a formal credit system (Table 1). Conversely, most small landholder and small-size millers and traders in Makurdi, Gboko, and Adikpo were generally unaware of the existence of these practices, let alone having used any of them at any time. This explains why this group of actors in each of the study sites lacked access to the above-mentioned rice production safety nets, and thus are more sensitive, less adaptable, and ultimately more vulnerable to the combination of pressure from CCV, markets and others.

Table 1 Differences in exposure and sensitivity, and adaptation of actors across the study sites

Vulnerability	*Form of adaptation*	*Study sites*	*Makurdi*	*Gboko*	*Adikpo*
Exposure-sensitivity		Water scarcity	0	1	1
		Flooding	1	0	0
		Price crash	1	1	1
Adaptive practices	Tactical reactive	Crop insurance	1	0	0
		Farming program	1	0	0
	Strategic anticipatory	Diversified cropping (e.g., double or triple cropping)	1	0	0
		Weather information	1	0	0
		Enter a market program with a sales agreement/contract	1	0	0
	Tactical reactive	Switching from a sales contract to open (periodic) market	1	0	0
		Temporary relocation and water control during flooding	1	0	0
	Strategic anticipatory	Partner and access knowledge from experts	1	0	0
		Fetching water from streams	1	1	1
		Dig hand well	0	1	1
	Tactical reactive	Switching to stone-free milling	0	1	0
		Access government interventions	1	0	0
		Promotion, advertisement and sensitisation	1	0	0

Note: 1 denotes the presence of pressures or adaptive practices in the site, while 0 denotes their absence.

4.2.2 Variability based on spatio-temporal dynamics

Spatio-temporal dynamics, especially seasonality such as planting, harvesting, milling or processing (e.g., harmattan or rainy season) and selling season (e.g., festive seasons: Christmas and Salah and when schools are in session) plays a key role in explaining why certain actors were more or less vulnerable to certain pressures, especially CCV and

market-related ones. Thus, with regards to growers, this study showed that those who planted their rice early, particularly by July were less exposed, sensitive, and more adaptable to flooding or rainwater shortages and other pressures such as weeds, diseases, and pest infestation than growers who plant at other times of the year.

Similarly, rice traders revealed that the prices of both unmilled and milled rice on the market often reflect strong seasonality. This indicates that price variability across study sites (i.e., Makurdi, Gboko and Adikpo) is not associated with improvements in rice production *per se*, but rather with the interplay between demand and supply (e.g., peak and off-peak season supply).

As highlighted by the traders, the demand for rice consumption also defers to seasonality across the sites, as the price of rice often appreciates during festive seasons. This helps to reduce the degree of trader's sensitivity to market pressures, such as: poor prices, preferences for quality and acceptable attributes, and competition from imported rice due to high consumption demand.

Furthermore, millers identified seasonality as another factor affecting their exposure, sensitivity, and by extension, adaptation. According to them, while rice is usually milled throughout the year across the state, during these two challenging seasons (e.g., harmattan or rainy season), small millers, who depend on artisan rice milling equipment and natural methods for drying rice, are more sensitive and less adaptable to weather and CCV-related pressures than are the large millers, like MIVA rice, who use modern mechanical equipment. Certainly, getting rice parboiled and dried to the desired moisture content level for the yield of high-quality milled rice is very difficult without the use of mechanical equipment in these seasons.

4.3 Interactions of the effects of vulnerability

The analysis of data further revealed some interactions of the effects of vulnerability on the downstream components of the RVCs. These include low production of rice quantity, production of low-quality rice, and processing or milling of low-quality rice. First, the vulnerability of rice growers may result in low production of rice quantity, which is a pressure on millers and traders. The adaptive strategy of millers is often the temporary shutdown of their business. This further creates a market supply deficit that results in price spikes.

Similarly, the vulnerability of rice growers may result in the production of low-quality rice. This is a pressure on millers, who do not appear to have any adaptive strategy to respond to this pressure. This in turn results in poor grain quality which lacks attractiveness to consumers. Lastly, the vulnerability of millers may result in the milling of low-quality rice, which is a pressure on traders, who do not appear to have any adaptive strategy to respond to this pressure.

4.4 Maladaptive outcomes of current adaptation practices

The results of this study also revealed that not only do specific adaptive practices aimed at a reduction in the impact of pressures result in maladaptation outcomes which actually increased them, but they also affected the manner and ways by which the adaptive practices were employed by the various actors (Table 2). Thus, growers, millers, and traders tended to employ reactive, short-term practices, which are incapable of offsetting the magnitude of abrupt pressures (e.g., flooding, rainwater shortages, price crashes).

Table 2 Growers, millers and milled rice traders maladaptation

Actor	*Pressures exposed and sensitive to*	*Adaptive practice employed*	*Maladaptive outcome of adaptive practice employed*
Growers	CCV (e.g., floods, rainwater shortages)	Planting early	Rice planted early may experience water shortages during the growing season if there is false start of rainfall or flooding if the rainy season extends beyond rice maturing dates.
		Selection of well-watered fields	Well-watered rice fields are easily flooded.
		Avoid flood prone fields	Rice fields not prone to floods water such as upland rice fields are susceptible to rainwater shortages.
		Water control techniques (e.g., digging of ridges or dykes, and construction of water channels)	Exacerbates water shortages in the off-peak rainfall seasons, and during prolonged dry spells, this practice may create artificial water scarcity by starving surrounding rice fields of water.
		Plant pressure (i.e., water stress) withstanding rice varieties such 52 (OC) and 44 (sipi)	May be less preferred by customers and therefore lower priced on the market.
	Markets (e.g., poor price, preference)	A switch in type of market, e.g., from programme/contract sales to periodic market	Growers who switch market type to sell at higher prices, but instead selling under inaccurate weights and measures experience even more loss of income.
	CCV and market	Purchase of crop insurance	Not being paid when experiencing crop failures.
Millers	Floods	Reduction in the quantity and frequency of rice parboiled	Millers who embark on this strategy may experience a reduction in income.
	Markets	Changing spare parts market	The changing market could reduce costs but increase the chances of buying substandard parts.
Traders		Credit sales	Buyers default on a credit sales agreement and this becomes a source of income loss.
		Retail selling (i.e., small quantities)	Selling in small quantities (retailing) gives traders a higher profit in the event of sudden changes in price, retailers are often the worst affected.
All actors (growers, millers and traders)	Price crashes Market preference	Planting, milling, and trading customers preferred rice varieties such 52 (OC) and 44 (sipi)	Such varieties may be less tolerant to pressures such as water stress (i.e., flooding and water scarcity).

Water management measures to prevent flooding of rice fields can be helpful in peak floods when the flooding of rice fields is recurrent but are problematic during dry spells and off-peak rainfall seasons (usually towards the end of October onwards). For example, the expensive construction of embankments and obstructions can create artificial water scarcity by starving surrounding rice fields of water. This further exacerbates water shortages as the available water flows only to fields with well-constructed water channels.

Moreover, according to growers, early/careful timing of planting helps growers adapt to climate variability by preventing losses during a false start to rainfall. However, there are certain farming seasons when it can be detrimental and therefore maladaptive. For example, in situations where the rice matures for harvest in September and early October because it was planted early, the rice is likely to be washed away by flood water. Despite this, planting early, particularly by July, often helps growers manage flooding, as the rice planted before, or by, this period usually grows to such heights that in the event of flooding it can survive the pressure, especially if the floodwater recedes after a few weeks

Another example of adaptation practice with a maladaptive outcome reported is credit sales (Table 2). It is a situation where regular customers take a certain quantity of rice, either without any payment, or after a deposit is paid, at which point an agreement is signed that payment will be made in the future, or periodically. During seasons of low demand, milled rice traders carry out credit sales to offset very low-quality rice that is liable to decompose and/or discolour if left in storage for a long time. Credit sales go some way to help rice traders reduce income losses owing to poor milling quality and prices. But there are certain seasons and conditions when this becomes a source of income loss, and thus becomes a further pressure to which rice traders are exposed. For example, the off-harvesting season when the peak supply season is over and prices have gone up is often a time when buyers default on a credit sales agreement and do so repeatedly.

Furthermore, rice traders have reported the practice of selling either on a retail (i.e., small quantities) or wholesale (i.e., large quantities) basis to cope with frequent price crashes. For example, some wholesalers reported selling in small quantities (retailing) because doing so gives them a higher profit. However, in the event of sudden changes in price, which they frequently experience, retailers are often the worst affected (Table 2).

4.5 Uncertainties in growing, milling and trading rice

In this specific case, actors along the RVCs reported that they were uncertain not only about the future effects of climate change and its variability on rice production and agricultural markets, but also about how changes in rice production policies (e.g., public support for inputs and subsidies), and trade policies (e.g., liberalisation or protectionism) might shape the rice sector in the future. In other words, RVCs' actors operate in a dynamic environment not only because of CCV and markets but also politically and institutionally, which is challenging for rice growers, millers and traders.

For rice millers, uncertainties in electricity supply: in terms of energy problems, electricity supply is a major challenge in Benue State. As a result, most rice millers depend on firewood and diesel as sources of energy for steaming, boiling and milling. Among the three sites, Adikpo and Gboko rice mills are not well connected to the national grid and do not have well-functioning electricity transformers, however, in

Makurdi, the Wurukum and Wadata rice mills have good electricity connections. In addition, the available electric power is not sufficient for the needs of the mills, and therefore it is usually rationed, this then creates uncertainties about when millers will have electricity to power their milling machines.

Furthermore, millers equally reported uncertainties in exchange rates which in turn create uncertainty in accessing new spare parts. The import of spare parts is the only option rice millers have to resolve the pressure created by frequent breakdowns of their milling machines, but this also has its challenges, especially the high costs and currency issues which have been highlighted as challenges to the purchase of quality farm inputs above.

In addition, rice traders across the study sites have reported exposure to frequent changes in rice trade policies by the Nigerian Government, a situation that makes investment in the rice business uncertain. According to the traders, changes have been from an open trade policy (i.e., an unbanned, liberalised rice market), to a protectionist policy (i.e., imposition of bans and tariffs), and vice versa. According to one rice trader, each of these policy goals has its advantages and disadvantages, either in the long or short-term. For example, an open, liberalised rice trade policy has the short-term advantage of bringing down the price of rice on the market in the country due to increased annual rice imports.

However, in the long-term, the locally produced rice is consistently outcompeted due to low milling quality, and hence investment in the sector is further reduced over time and more rice growers, millers, and traders are forced out of the rice business. On the other hand, a protectionist rice trade policy pushes prices up in the short-term, but in the long-term serves as an incentive for investment in the sector that will stabilise prices. What this means is that there are not only uncertainties but trade-offs between what policies pathway the government chooses dependent on the development priorities set for the rice sector in a specific country.

4.6 Trade-offs in adaptation decision-making

In this specific case which involves Benue State, this study showed that avoiding maladaptive outcomes and continuing to grow, process, or mill and market rice in the face of uncertainties required navigation of trade-offs in decision-making between one practice and another. For example, planting a variety preferred by buyers is a strategic practice adopted at the time of planning to grow rice. The practice helps growers respond to price crashes which are a result of demand for selected rice varieties, such as FARO 52 (OC) and 44 (sipi) which have a distinctive grain quality (i.e., long and slender), and also their good cooking quality means these varieties are highly preferred by consumers. As these varieties enjoy better prices from consumers, millers pay more for them. However, there is often a trade-off between market-preferred varieties and pressure-resistant or tolerant varieties, depending on the rice fields. For example, planting such rice variety (i.e., FARO 44) in heavily flooded or water-logged rice fields may result in significant losses as it is less tolerant to floodwater than other varieties. Consequently, growers using well-watered rice fields may have to make the decision to plant a variety which accommodates a flooded ecosystem, but which may have low market demand due to its inferior grain quality (short grains); or growers using a less-watered rice field may

have to make the decision to plant a variety that tolerates water stress, but which provides a lower yield.

Furthermore, this study reveals that trade-offs are not limited to farming decisions alone, but extend to market decisions, such as: changing the selling location (marketplace) to attract more income, but incurring additional expenses which include higher transportation costs; or, selling on the periodic market where third party influences (middlemen) exist; or, selling to a program, or to networked buyers, using a sales contract or buy back program where growers feel prices do not reflect the higher prices on the periodic market during the off season.

Rice millers also reported some sort of trade-offs between quality and quantity of milled rice. For example, during the peak rainfall period, when managing moisture content in parboiled rice becomes more challenging owing to uncertainties in weather and the use of artisanal equipment, there is a trade-off between the quantity of rice milled and the end quality of that milled rice. As a result, millers seeking better rice quality often reduce the quantity they normally process in order to manage moisture contents, this means the quality of the rice they process is not compromised, even though it also means their income is reduced.

Moreover, due to poor prices and the low market demand for domestic milled rice, traders seeking to boost their income revealed that they often have to trade-off between wholesaling (selling in large quantities, but at lower prices) and retailing (selling to households in small quantities at higher prices). Based on the foregoing discussion, a context-specific understanding of how rice millers and traders make management decisions in the face of uncertainties and trade-offs might shed more light on their responses to multiple pressures. Such understanding may be helpful to the responses made to pressures, currently and in the future. The existence of trade-offs between certain adaptation practices clearly shows that some, such as those discussed above, reduce vulnerability in the short-term, but in the long-term, they increase it, a situation which results in maladaptation.

5 Discussion

The results of the study revealed a number of important issues in respect of the vulnerability and adaptation of RVCs to multiple pressures in Benue State, Nigeria. First, the VSDs document a diversity of pressures (e.g., rainwater shortages, flooding and poor market prices) which actors along the chain are exposed and sensitive to, and the adaptation practices they currently employed in response to such pressures. The results further highlight the uneven distribution of vulnerabilities, interactions of the effects of vulnerability, the maladaptive outcomes of current adaptation practices, and the trade-offs to adapting to pressures in the study area. Both results on the diversity of pressures and uneven distribution of vulnerability are in agreement with studies on differential vulnerability (Antwi-agyei et al., 2017, 2018; Segnon et al., 2021; Widayati et al., 2021), which emphasise that actors' exposure, sensitivity, and adaptation to pressures vary depending on their situations and capacities, including access to information, resources and social capital (e.g., access to means of production and markets) (Thomas et al., 2019). However, in the specific case of Benue State, this study has shown that, apart from looking at the differential vulnerability on the basis of geographical location, choice of cropping, milling, and market system, and actor types, it is important to look at

spatio-temporal dynamics (e.g., time and season), especially the seasonal interplay (e.g., growing, milling and selling seasons) as it affects not only the RVCs' activities but the degree and intensity of their exposure and sensitivity to pressures as well as the adoption of promising adaptation practices. This is important because existing studies have shown that adaptation actions can become maladaptive over time (Glover and Granberg, 2021; Schipper 2020; Work et al., 2019).

In addition, the results of the downstream interactions of the effects of vulnerability along the RVCs explored how grower vulnerability affects millers and traders, i.e., pivotal issues relating not just to the connections between growers, millers, and traders but also shed light on pressures and the knock-on effects of changes in one part/component on the other actors and components in the value chain. As other studies have shown, such connections and knock-on effects of changes along the RVCs' components overtime may be the reasons for increased cases of maladaptation in the SSA (Antwi-agyei et al., 2017, 2018; Segnon et al., 2021; Schipper, 2020).

In general, the results of this study demonstrate the importance of paying close attention not just to CCV but also to agricultural market dynamics in gaining a holistic understanding of the vulnerability of the RVCs and in the construction of comprehensive vulnerability reduction and resilience-building interventions in SSA. As shown by Nyantakyi-Frimpong and Bezner-Kerr (2015), many farmers do not worry about CCV; while intra-household property rights, liberalised markets, and insecure land access is more critical pressures for the farming sector in Ghana. This re-echoes the need for the adoption of multiple pressures and system approaches in framing vulnerability assessments in SSA.

6 Conclusions

This study has filled a knowledge gap about agricultural vulnerability and currently adopted adaptation practices in Nigeria. By focussing on key agricultural produce – rice – this study has specifically uncovered that uneven or differential vulnerabilities are a function of geographical location, choice of cropping, milling, and market system, actor types, and also spatio-temporal dynamics in the rice growing and selling seasons. The analysis of data further revealed a number of interactions in the effects of vulnerability on the downstream components of the RVCs. In addition to providing a list of diversities of pressure and common reactive, short-term adaptive practices often employed in Benue State, this study also uncovered some adaptive practices characterised by trade-offs and uncertainties, instead of reducing growers', millers', and traders' vulnerability to pressures, actually resulted in maladaptation outcomes that increased them. As these practices were often inadequate to offset the magnitude of recent pressures and which tend to occur rapidly and on a large-scale (e.g., flooding and price crashes).

Therefore in sum, this study revealed the complexities of RVCs in Benue State, Nigeria. Secondly, the study sheds light not just on the sources of vulnerability, but also on the perceived weaknesses and strengths of current adaptation practices employed in response to pressures. At a theoretical level, this study has shown that it is crucial to use a system approach in vulnerability analysis – here illustrated by the concept of value chain. This has been a limitation of past research which has largely investigated production (farming) but overlooked other parts and actors of agri-food systems (e.g., traders,

processors). This study shows that a system approach is crucial to understand the vulnerability tensions, spillovers, as well as possible synergies across subsystems.

Accordingly, this study suggests that future vulnerability research evaluates the trade-offs between the adoption of certain adaptation practices over others, including the costs of implementing those practices by different actor groups (e.g., small, medium, or large landholders or size millers), and that whether trade-offs and costs really do form the bedrock of adaptation practices employed by actors along the chain in response to CCV and the agricultural markets in the low-income regions.

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