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# Mapping and Managing Livelihoods Vulnerability to Drought: A Case Study of Chivi District in Zimbabwe

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**Abstract:** The assessment of the vulnerability to drought hazards in smallholder farming systems dependent on rain-fed agriculture has recently gained global popularity, given the need to identify and prioritize climate hotspots for climate adaptation. Over the past decade, numerous studies have focused on vulnerability assessments with respect to drought and other meteorological hazards. Nonetheless, less research has focused on applying common measurement frameworks to compare vulnerability in different communities and the sources of such vulnerability. Yet, the crucial question remains: who is more vulnerable and what contributes to this vulnerability? This article is a case study for assessing the vulnerability to drought of smallholder farmers in two wards in Chivi district, Masvingo Province, Zimbabwe. This study is timely, as climate change is increasingly affecting populations dependent on rainfed agriculture. This assessment has been conducted by calculating the Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index of the Intergovernmental Panel on Climate Change (LVI-IPCC). This empirical study used data from 258 households from the two wards and triangulated it through Key Informant Interviews and Focus Group Discussions. To calculate the LVI, twenty-six subcomponents made up of seven major components, including socio-demographic variables; livelihood strategies; social capital; access to food, health, and water; and exposure to drought, were considered. To calculate the LVI-IPCC, we combined the three contributing factors of vulnerability (exposure, sensitivity, and adaptive capacity). Our results indicate that the LVI forward 14 is statistically higher than for ward 19 ($F = 21.960$; $p \leq 0.01$) due to high exposure to drought, food insecurity, and compromised social networks. Concerning the LVI-IPCC, ward 14 was significantly more vulnerable to the impacts of drought than ward 19 ($F = 7.718$; $p \leq 0.01$). Thus, reducing exposure to drought through early warning systems, building diversified agricultural systems, and social networks are of high priority to reduce the vulnerability of the farmers.

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## 1. Introduction

There is compelling evidence of the need for global agricultural productivity to increase by at least 60% by 2050 to satisfy the projected increased food demand [1]. However, a highly variable climate poses daunting challenges and uncertainties about whether this increased food demand will be satisfied [2]. The challenge in meeting food demand is expected to be particularly prevalent in Africa, one of the most climate-variability hotspot continents [3]. The overreliance on rain-fed agriculture within their farming system amplifies this challenge [4], yet the frequency and severity of droughts are rising, leading to massive food insecurities. Thus, farmers in Africa are becoming more vulnerable to the climate crisis yearly. The vulnerability of these farmers is mostly attributable to the limited access to resources necessary for adapting to a highly variable climate [5].

In Africa, the southern African region is warming up at a rate double that of the worldwide average and is a climate hotspot region [6]. Rainfall in southern Africa is highly erratic, and many areas experience frequent severe droughts [7]. The region's economy is dependent on rainfed agriculture. Therefore, these economies are at high risk of collapse due to rising global warming and climate change [8]. The confirmed projected increase in the frequency of agricultural drought and heat extremes will further worsen this vulnerability [9] and widen the gender inequalities, particularly in the agricultural sector, which is the major source of livelihood for a majority of the rural population in southern Africa [7].

The agricultural sector needs to adapt to the projected increase in the frequency and severity of droughts to shield the people's livelihoods in southern Africa from this impending crisis. Thus, devising context-specific tailor-made interventions is now critical, and there is an urgent need in the scientific community to build the capacity and resilience of the smallholder farmers, thus increasing their adaptive capacity [10]. Therefore, context-specific interventions are key because the smallholder farmers in the region are highly heterogeneous [11] with varying production levels. Some studies have also highlighted the need to understand the sources of vulnerability in different contexts, considering that climate change impacts cannot be ascribed to exposure alone [12], but rather mediated through socioeconomic security on the ground [13]. Thus, rigorous scientific inquiry is required for in-depth knowledge of climate change vulnerability metrics in the region [14] and the factors underlying the susceptibility to climate change, particularly drought.

At the same time, comparative vulnerability assessment is also indispensable [15] when applying for funding instruments such as the Green Climate Fund (GCF), the major global climate finance vehicle established through the Cancun Agreements in 2010, which must target the most vulnerable [16]. In light of this, the vulnerability assessment of smallholder farming systems to drought deserves significant research attention, as well as the targeting of hotspot areas.

Historically, adapting to a more variable climate has dominated the climate policy and research agendas [17]. This has somehow changed as substantial research has focused on a better understanding of vulnerability related to climate shocks from regional to global scales [18–20]. Notwithstanding these notable developments, to the best of our knowledge, it is now common because that vulnerability scholarship that employs consistent data collection and robust statistical analysis is extremely limited in the developing world. Such a serious fault line does not mirror the need to prioritize climate hotspot areas in adaptation programs. In addition, vulnerability studies employ different assessment protocols [20] or multiple hazards, making it extremely difficult to provide policy and practical insights for hazard-specific vulnerability [21]. It has now become the new norm for studies on vulnerability assessments to focus on one disaster type [22,23], such as drought [24] and floods [25,26]. The assessment of vulnerability concerning a specific hazard is urgent to satisfactorily deal with one of the critical vulnerability questions scientists and practitioners need to address: "Who is at risk", "why are people vulnerable or at risk", [14] and who is more vulnerable to the impacts of a specific hazard and why? Addressing these issues with stakeholders will be vital for developing context-specific resilience-building and adaptation measures [27] that are more acceptable [21]. Thus, inconsistent vulnerability assessment protocols, including an absence of hazard-specific vulnerability assessment and limited statistical analysis, are the biggest obstacles to prioritizing adaptation strategies.

Building on the livelihood vulnerability index, Hahn et al. [28] were the first to develop the LVI-IPCC and applied it to measure the vulnerability of communities in Mozambique. It is now the major authoritative and robust instrument for vulnerability assessment [29,30] and offers a credible point of entry for climate vulnerability assessments. In a subsequent study, Mudasser et al. [31] introduced a robust statistical analysis procedure for comparing vulnerability in different communities. Thus, given the "potholes" and misgivings of previous vulnerability assessment methods, this paper aims to use the LVI-IPCC protocol to map the vulnerability of smallholder farmers to drought in selected wards of Chivi district, Masvingo province, Zimbabwe, through a household (HH) survey. This study is crucial given that the Sendai Framework for Disaster Risk Reduction underscores the importance of assessing the risk posed by drought [32].

## 2. Materials and Methods

### *2.1. Study Area*

Data collection and analysis were conducted using the case of Chivi district, in Masvingo Province, Zimbabwe. Masvingo Province is located in the southern-eastern part of the country and is among the areas (including Manicaland and Matabeleland Provinces) projected to experience the highest decline (up to 10%) in annual precipitation under both the medium- and high-emission scenarios in comparison to the 1986–2005 baseline [16]. The RANDBETWEEN function in Excel was used to select the study province. Within Masvingo Province, we purposively selected Chivi district, located in south-central Zimbabwe, approximately 400 km from Harare. Chivi district is one of the climate hotspot areas in Masvingo Province, with a mean hazard index of 0.5971 [33]. Drought and dry spells (at 32.54%) make a substantial contribution to the district mean hazard index [33]. In particular, the district lies in a semi-arid region characterized by a high frequency of climate shocks, particularly drought [33]. The annual rainfall experienced in the district is less than 650 mm [34]. However, the probability that rainfall in the area exceeds 500 mm is between 60 and 80%, whereas maximum temperatures range from 28 to 30 °C [34]. In light of the harsh climatic conditions, climate-smart agricultural initiatives are key to build the resilience of farming systems. However, despite the wide promotion of these climate-smart agricultural practices, in particular Conservation Agriculture, the adoption rates have been poor and fragmented [35].

The UNDP has mapped climate hazards affecting Zimbabwe at the ward level [33]. At the same time, the Zimbabwe National Adaptation Planning (NAP) has recommended the ward as the smallest unit for adaptation planning [36]. Although it could have made sense to conduct vulnerability analysis in all the wards in the district, our budget and timeline for the study only allowed us to do two wards. Two wards (14 and 19) were selected using a simple random sampling approach. The simple random sampling technique was used again to select 210 HHs in each ward. Coincidentally, according to the key informants, wards 14 and 19 have received less climate-related research attention. Figure 1 shows the location of the wards. Wards 14 and 19 are about 30 and 70 km from Chivi Township.

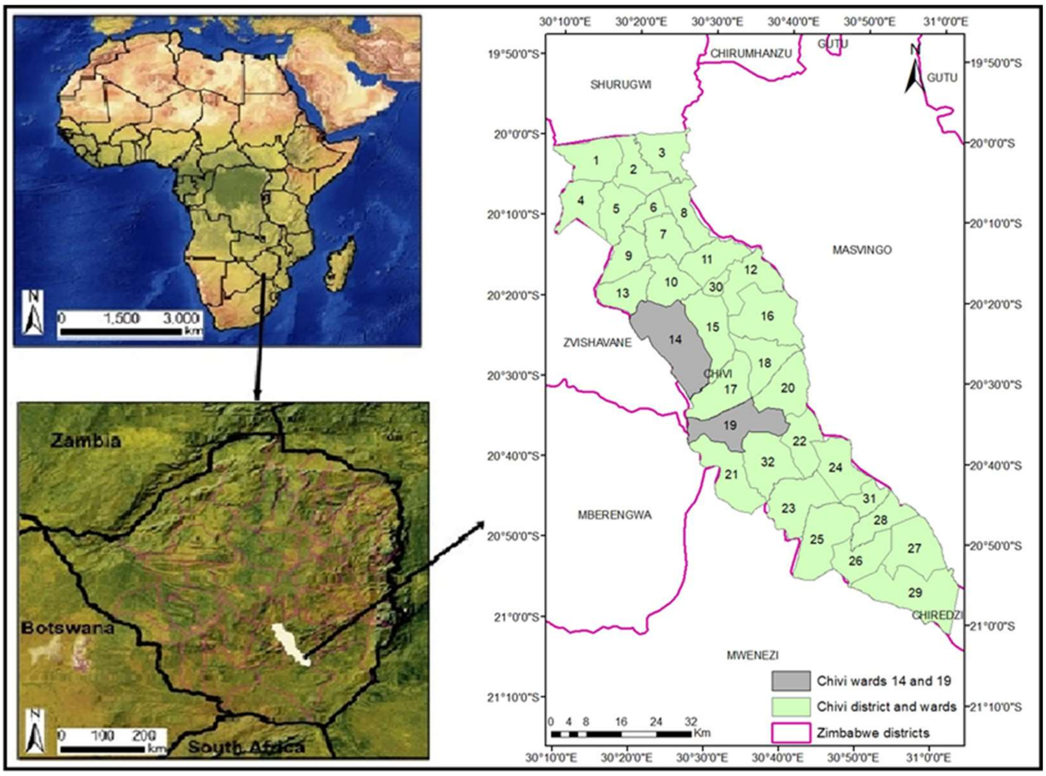


**Figure 1.** Wards 14 and 19 in the Chivi district in Zimbabwe. The background image is the natural earth-shaded relief layer for Africa and Zimbabwe, respectively.

## *2.2. Socio-Demographic Situation*

According to the 2022 population census, the Chivi district has a total population of 172,979, distributed across 32 wards. Of the total population, 54.4% are females, and the rest are males [37]. Wards 14 and 19 have a total population of 6039 and 5746, respectively. The district has a total area of 3534 km$^2$ and a population density of 47 people/km$^2$. To some extent, livestock rearing and cropping are the district's main livelihood sources [38]. Of the numerous cropping systems, *Zea mays* L, small grains *(Eleusine coracan* (L.), *Pennisetum americanum* (L.), *Sorghum bicolor* (L.), *leguminous crops (Vigna unguiculata* (L.), *Arachis hypogae* (L.), *and Voandzeia subterranea* (L.) are the main crops grown in the district [38]. However, crop yields are very low due to poor soils and perennial drought. The 2007–08 drought, the worst drought experienced in the district, resulted in low yields that left about 86% of the HHs insecure [39]. If left unattended, the drought lays a delicate foundation for adapting to climate action under Zimbabwe's National Development Strategy 1 [40]. The livelihoods of farmers in Chivi also depend on remittances and casual employment.

## *2.3. Data Collection*

The Midlands State University Research Board Ethical committee approved the study protocols in September 2021 before data collection. Within the wards, interviews were conducted with experts from AGRITEX to understand drought vulnerability better in the context of Chivi district. A comprehensive checklist of items for drought vulnerability assessment relevant to the two wards was thereafter drafted using this expert knowledge and experience. These suggested list items were validated using the knowledge of local opinion leaders in the study area. The list of suggested indicators was then used to draft the HH survey questionnaire. The questionnaire was administered to 210 HHs in each selected ward between September 2021 and November 2021. The head of the HH or any senior person in the absence of the head was asked to respond to the survey tool. Informed consent was sought from each participant before the completion of the questionnaire. Gentle social engineering was employed to glean the participants as much information as possible.

In addition to the HH questionnaire, we had one focus group discussion in each ward, where participants represented all social demographic parameters. Further, key informants from government; NGOs; and traditional, political, and religious leaders were also interviewed. The major components for measuring the LVI were the socio-demographic profile; livelihood strategies; access to food, health, and water; social networks; and exposure to drought. The major components were measured using appropriate indicators derived from the literature and expert opinion on vulnerability in the area (refer to Appendix A).

*2.4. The Livelihood Vulnerability Index and the LVI-IPCC*

The World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP) established the IPCC in 1988 to "provide policymakers with regular scientific assessments on the current state of knowledge about climate change" [41]. Amongst these issues is vulnerability assessment, defined by the IPCC as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity". Thus, according to the IPCC, vulnerability to climate change has three pivots [42]. The first is the exposure to climate-related shocks and natural hazards; the second leg is the sensitivity of the system to the climate shocks; the third is the adaptive capacity of the system in question to deal with the shocks. Both sensitivity and adaptive capacity are "internal" factors of the system, whereas sensitivity determines system resilience, and exposure to natural climate variability is the "external" factor [43]. Generally, a system with high exposure, low adaptive capacity, and high sensitivity tend to have a high vulnerability [44].

The vulnerability assessment in this research is grounded on the livelihood vulnerability framework developed by Hahn, Riederer, and Foster [28] and applied elsewhere by numerous researchers [30,45–47]. The framework employs various indicators to measure the community or HH exposure to climate variability and natural disasters. Specifically, in the context of climate change, exposure is "the nature and degree to which a system is exposed to significant climatic variations" [3] or the non-risk exposure [48]. Adaptive capacity includes the behavioral, resources, and technological adjustments to reduce potential losses and damages, take advantage of new opportunities, and/or cope with the negative impacts of climate shocks [42]. Adaptive capacity is measured using HH socio-demographic variables. Research has heightened the crucial role of increasing adaptive capacity to reduce the severity of climate impacts, particularly among smallholder farmers whose production systems are highly threatened by climate change [49]. Sensitivity to climate change mirrors the "degree to which a system is affected, either adversely or beneficially, by climate variability or change" [42]. It is assessed using the current access to food, health, and water. In the context of the present research, and in light of the place-based nature of vulnerability [50] and the current efforts by the government of Zimbabwe to develop a context-specific adaptation strategy through a participatory approach [36], we applied the bottom-up approach to probe the lived experiences of the HHs concerning the exposure, sensitivity, and adaptive capacity. The involvement of stakeholders is crucial to understanding vulnerability from first-hand experience based on the self-reviewed experiments of farmers, which are often excluded in the discourse on climate change adaptation and mitigation [51]. Moreover, the bottom-up approaches provide some credibility to the results at the smallest unit of analysis (in this case, the ward). This provides some acceptance of the co-authored locally generated adaptation strategies. This is important given that across the globe, there is a patrimony of failed imposed climate interventions [52], some of them coming from people with hidden vested interests. Further, the involvement of local communities offers a credible point of entry to garner crucial evidence on non-climatic parameters that are critical in reducing the potential impacts of climate shocks [53]. In addition, stakeholder engagement can be used to manage climate-related risk at the local level [54] and develop early warning systems that reduce the impacts of drought.

### *2.5. Calculation of the LVI and LVI-IPCC*

Major components of the LVI for Chivi district are the socio-demographic profile (SDP), livelihood strategies (LS), social network (SN), food security (FS), water security (WS), health security (HS), and exposure to drought (ETD). Each of these major components had multiple indicators. Thus, 26 subcomponents were employed in this survey, based on scholarship available on subcomponents and major components. For the ETD profile, we used a ten-year interval from 2011 to 2020, given that participants might fail to remember some events had we chosen a longer period.

All our variables were measured on different scales. Therefore, before calculating the index for each subcomponent, $Index_{nw}$ each variable was standardized using the equation used to calculate life expectancy in Human Development Index [55], as shown in Equation (1):

$$Index_{nw} = \frac{n_w - n_{min}}{n_{max} - n_{min}} \tag{1}$$

where $n_w$ is the original sub-component $n$ for ward $w$; $n_{min}$ and $n_{max}$ are the minimum and maximum values of the components.

Equation (2) was used to calculate the major component $j$ for ward $w$:

$$j_w = \frac{\sum_{i=1}^{n} Index_{nw}}{n} \tag{2}$$

where $Index_{nw}$ is the index of the subcomponent $n$ in ward $w$.

The LVI for Chivi, based on all the seven major components was calculated as follows:

$$LVI_k = \frac{\sum_{i=1}^{n} W_{Ji} J_{wi}}{W_{Ji}} = \frac{W_{SDP}SDP + W_{LS}LS + W_{SN}SN + W_{WS}WS + W_{HS}HS + W_{FS}FS + W_{ETD}ETD}{W_{SDP} + W_{LS} + W_{SN} + W_{WS} + W_{HS} + W_{FS} + W_{ETD}} \tag{3}$$

where $W_{Ji}$—is the weight of sub-component $J_i$; $J_{Ki}$ is sub-component $j$ in the ward.

Each of the IPCC contributing factors vulnerability were calculated as follows:

$$\mathrm{CF}_w = \frac{\sum_{i=1}^{n} W_{Mi} M_{wi}}{\sum_{i=1}^{n} W_{Mi}} \tag{4}$$

where $\mathrm{CF}_w$ is the IPCC defined contributing factor to either exposure, sensitivity, and adaptive capacity for the ward $w$, and $M_{wi}$ is the major component for the ward $w$, whereas $n$ represents the number of major components for each contributing factor.

Several authors, including Simane et al. [56]; Adu, Kuwornu, Anim-Somuah, and Sasaki [46]; and Hahn, Riederer, and Foster [28], have employed this approach. The $\boldsymbol{LVI - IPCC_W}$ for ward $w$ was then computed using the equation:

$$\boldsymbol{LVI - IPCC_W} = (Exposure_w - adaptive\ capacity_w) * Sensitivity_w \tag{5}$$

## 3. Results

### *3.1. A Brief Description of the Participants*

Out of the 420 total participants from both wards, only 258 HHs completed the questionnaire fully. Of the 258, 126 (49%) were female, whereas 131 (51%) were male. Regarding the literacy category, the majority of respondents, 180 (71.7%), were within the literacy group, whereas 71 participants (28.3%) were illiterate. A total of 208, representing 84.2% of the HH heads, were full-time farmers, whereas 39 (15.8%) engaged in other activities besides farming. On the other hand, 13% of the HH had at least one member working in a different community.

### *3.2. Difference between Wards for the LVI*

Table 1 shows the vulnerability indices of the sub-components of the LVI for wards 14 and 19 in the Chivi district. When compared to ward 19, the results of the seven primary components suggest that ward 14 has a significantly greater vulnerability index in the areas of livelihood strategies (F = 16.385; $p \leq 0.01$), social networks (F = 40.361; $p \leq 0.01$), food (F = 13.087; $p \leq 0.01$), and exposure to drought (F = 10.768; $p \leq 0.01$). In contrast to ward

14, ward 19 has significantly greater vulnerability scores in terms of socio-demographic profile (F = 2.758; $p \leq 0.1$) and water (F = 9.149; $p \leq 0.01$) profiles. However, there was no significant difference between the health profiles. Concurrently, ward 14 has a significantly higher LVI than ward 19 (F = 21.960; $p \leq 0.01$).

**Table 1.** Sub-components, components, and LVI of wards 14 and 19 in Chivi district.

| | Ward 14 | Ward 19 | Total Number Components in a Major Component | Test Statistics (*p*-Value) |
|---|---|---|---|---|
| **Socio-demographic profile** | **0.305** | **0.411** | **3** | **F = 2.758 $p \leq 0.1$** |
| Female HH | 0.394 | 0.609 | | |
| Illiterate HH | 0.298 | 0.264 | | |
| Dependency ratio | 0.224 | 0.360 | | |
| **Livelihood strategies** | **0.312** | **0.258** | **6** | **F = 16.385 $p \leq 0.01$** |
| Agricultural diversification index | 0.350 | 0.402 | | |
| Population dependent on rain-fed agriculture | 0.923 | 0.817 | | |
| Percentage HHs who have not changed cropping sequence | 0.310 | 0.096 | | |
| HHs who have not adopted an improved cropping system | 0.173 | 0.004 | | |
| HH with access to concessional loans | 0.014 | 0.061 | | |
| HHs with members not working in other communities | 0.100 | 0.167 | | |
| **Social networks** | **0.689** | **0.481** | **3** | **F = 40.361 $p \leq 0.01$** |
| Percentage of HHs who have gone to government or NGOs for assistance | 0.408 | 0.053 | | |
| Percentage of HH not in cooperatives | 0.908 | 0.921 | | |
| Percentage of HH without access to information | 0.679 | 0.469 | | |
| **Water** | **0.231** | **0.234** | **4** | **F = 9.149 $p \leq 0.01$** |
| Lack of access to clean water within 1km | 0.248 | 0.015 | | |
| HHs without access to safe water | 0.338 | 0.573 | | |
| Water conflicts | 0.204 | 0.192 | | |
| HHs without consistent water supply | 0.134 | 0.157 | | |
| **Health** | **0.062** | **0.117** | **2** | **F = 0.329 NS** |
| Time to a health facility | 0.083 | 0.203 | | |
| Malaria exposure | 0.04 | 0.03 | | |
| **Food** | **0.451** | **0.297** | **5** | **F = 13.087 $p \leq 0.01$** |
| Reduce expenditure during droughts | 0.943 | 0.523 | | |
| HHs with food inadequacy | 0.418 | 0.499 | | |
| HHs who do not save food | 0.270 | 0.110 | | |
| HHs who do not save seed | 0.415 | 0.088 | | |
| Crop diversification | 0.208 | 0.266 | | |
| **Exposure to drought** | **0.688** | **0.466** | **3** | **F = 10.768 $p \leq 0.01$** |
| Drought frequency | 0.524 | 0.202 | | |
| Drought warning | 0.741 | 0.522 | | |
| Drought trends | 0.80 | 0.675 | | |
| **LVI** | **0.391** | **0.323** | | **F = 21.960 $p \leq 0.01$** |

NB: NS, non-significant difference in the means of the two wards; $p \leq 0.01$, there is substantial evidence that there is difference in the mean of two wards; $p \leq 0.1$, there is little or no real evidence of differences in the means of the two wards.

### 3.2.1. Socio-Demographic Profile

The SDP had three indicators: dependency ratio, female-headed HHs, and illiterate HH head. Ward 19 had a higher dependency ratio than ward 14 (dependency ratio (ward 14) = 0.224), (dependency ratio (ward 19) = 0.36). Ward 14 has a higher illiteracy rate (0.298) than ward 19 (0.264). Ward 19 (0.609) had a higher proportion of female-headed HHs than ward 14 (0.394). Largely, ward 19 had a significantly higher vulnerability score than ward 14 with respect to the SDP (SDP (ward 14) = 0.305), SDP (ward 19) = 0.411); F = 2.758; $p \leq 0.01$). In general, female-headed HHs, with high dependency ratios and low literacy levels, struggle to adapt to the vagaries of climate change.

#### 3.2.2. Livelihood Strategies

The results for LS are presented in Table 1. The results show that ward 19 (0.402) has a higher agriculture diversification vulnerability index than ward 14 (0.350). Although the percentage of HH who rely on agriculture as a source of livelihood is high in both wards, it is higher in ward 14 (92.3%) than in ward 19 (81.7%). A higher proportion of farmers (0.31) in ward 14 were more likely to change cropping sequence than those in ward 19 (0.096). The results also show that the number of farmers who have not adopted improved cropping systems is low in both wards. However, it is slightly higher in ward 14 (0.173) compared to ward 19 (0.004). Despite having significantly low concessional loans in both wards, ward 19 (0.061) had slightly higher access to loans than ward 14 (0.014). Compared to ward 14 (0.100), a large proportion of HHs in ward 19 (0.167) had a higher proportion of individuals not working in other communities. By and large, ward 14 has a significantly higher index of livelihood strategy vulnerability score than ward 19 (LS (ward 14) = 0.312, LS (ward 19) = 0.258); F = 16.385; $p \leq 0.01$).

#### 3.2.3. Social Network

Compared to ward 14, ward 19 has a greater proportion of HHs who have gone to the government or NGOs for assistance in the last twelve months. Surprisingly, both wards have an exceptionally high score for HHs that do not have cooperative engagement, although ward 19 (0.921) has a higher score than ward 14 (0.908). Concerning information access, ward 14 (0.679) has a higher score than ward 19 (0.469) for HHs with no access to information. Largely, ward 14 has a significantly higher SN score than ward 19 (SN (ward 14) = 0.689, SN (ward 19) = 0.481); (F = 40.361; $p \leq 0.01$).

#### 3.2.4. Water Security

Concerning access to clean water within 1km, HHs in ward 14 (0.248) have a greater score than ward 19 (0.015). A higher proportion of HHs in ward 19 (0.573) has no access to safe drinking water than in ward 14 (0.338). HHs in ward 14 were likelier than in ward 19 to have more water-related conflicts. In addition, ward 19 has a higher level of risk in terms of constant water supply than ward 14. Overall, ward 19 (0.234) had a significantly higher water security vulnerability score than ward 14 (0.231); F = 9.149; $p \leq 0.01$). This could be attributed to limited access to safe water and unreliable water supply in ward 19. According to the literature, approximately 30% of the rural HHs in Zimbabwe have no access to safe water [57] or health security.

The results in Table 1 show that both wards have low vulnerability health scores. Although not statistically significant, the health score for ward 14 (0.062) is lower than that of ward 19 (0.117). On average, HHs in ward 19 (0.203) take more time to reach the nearest health facility compared to ward 14 (0.083). Both wards also have a low malaria exposure index.

#### 3.2.5. Food Security

Ward 14 (0.943) had a greater vulnerability rating regarding spending cuts during drought than ward 19 (0.523). Farmers in ward 19 (0.498) reported a higher food inadequacy vulnerability score than those in ward 14 (0.418). As expected, ward 14 (0.270) had a greater food-saving vulnerability rating than ward 19 (0.110). Similarly, ward 14 (0.415) had a higher seed-saving vulnerability index than ward 19 (0.088). Furthermore, ward 19 (0.265) had a greater vulnerability rating for crop diversification than ward 14 (0.208). In general, there was a statistically significant difference (F = 13.087; $p \leq 0.01$) in the food vulnerability index in ward 14 (0.451) than in ward 19 (0.275). This is largely attributed to higher vulnerability indices for reduced expenditure during drought, lack of food saving, and seed-saving in Ward 14.

#### 3.2.6. Exposure to Drought

Farmers in ward 14 (0.524) reported a higher score for drought frequency than those in ward 19 (0.201). Furthermore, farmers in ward 14 (0.741) have a higher vulnerability score when it comes to accessing warnings about impending drought compared to those in ward 19 (0.522). Farmers in ward 14 (0.800) reported a higher score for projected drought trends than those in ward 19 (0.675). Overall, the results indicate a statistically significant difference in exposure to drought between the two wards (F = 10.768; $p \leq 0.01$).

### *3.3. Contrasting the LVI Outcomes in the Wards*

Based on the seven major components of the LVI, ward 14 had a statistically higher LVI score than ward 19 (F = 21.960; $p \leq 0.01$). A web diagram (Figure 2), scaled from 0 (depicting low vulnerability) to 1 (depicting high vulnerability), was adopted to illustrate the factors contributing to differential vulnerabilities in the two wards. The spider web diagram shows that overall, communities in ward 19 are more vulnerable than those in 14 due to high exposure to drought, food insecurity, and compromised social networks.

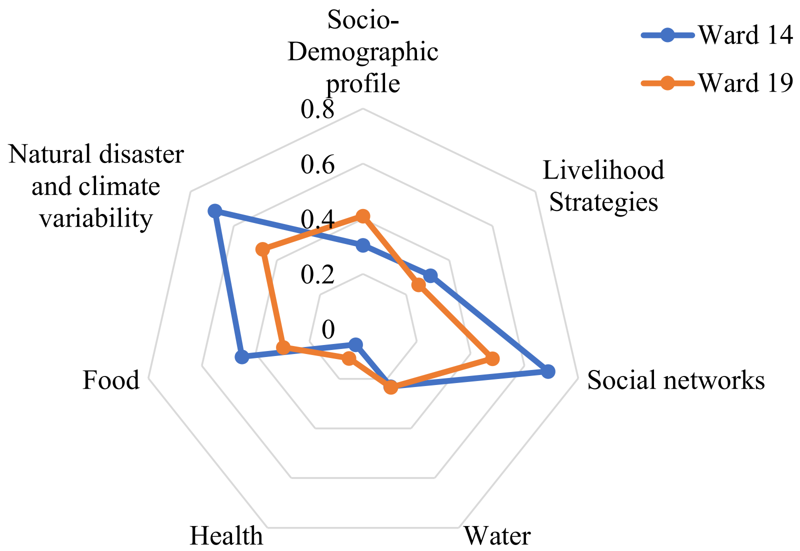


**Figure 2.** Spider diagram of the seven major components of the livelihood vulnerability index (LVI) in wards 14 and 19, Chivi district.

### *3.4. Comparison of the LVI-IPCC of the Two Wards*

Our study also employed the LVI grounded on the IPCC protocol to assess vulnerability in the two wards. The fascinating results of the LVI-IPCC for the two wards, showing exposure, sensitivity, and adaptive capacity, are shown in Table 2 and Figure 3. Although both wards have a moderate vulnerability, ward 14 was significantly more vulnerable to the impacts of climate change than ward 19. This is attributed to significantly higher sensitivity and exposure in ward 14 compared to ward 19.

**Table 2.** LVI-IPCC of ward 14 and ward 19 of Chivi district.

| | **Ward 14** | **Ward 19** | **F Statistics; *p*-Value** |
|---|---|---|---|
| Adaptive capacity | 0.435 | 0.383 | 40.361; $\boldsymbol{p \leq 0.01}$ |
| Sensitivity | 0.248 | 0.216 | 16.852; $\boldsymbol{p \leq 0.01}$ |
| Exposure | 0.688 | 0.466 | 10.768; $\boldsymbol{p \leq 0.01}$ |
| **LVI-IPCC** | 0.063 | 0.018 | 7.718; $\boldsymbol{p \leq 0.01}$ |

NB: $p \leq 0.01$, there is substantial evidence that there is difference in the mean of two wards.

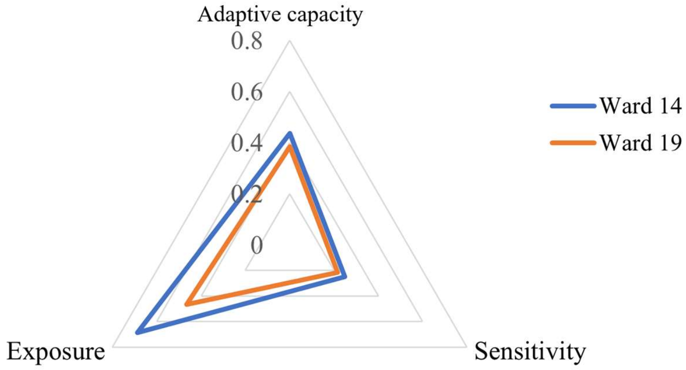


**Figure 3.** Triangle diagram for contributing factors of LVI-IPCC.

## 4. Discussion

The LVI-IPCC framework developed by Hahn, Riederer, and Foster [28] has successfully been applied to compare community vulnerability to climate change in different context [26,30]. It is better able to show the source of vulnerability to drought in different communities. The disparities in the adaptive capacities in the two wards are largely attributed to differences in HH headship (especially the proportion of female-headed HHs); the dependency ratio; the proportion of the population dependent on agriculture; changing the cropping sequence; the adoption of improved cropping systems; access to concessional loans; access to government and NGO assistance; and access to information. Additionally, the vulnerability of women to climate change has received significant research attention. Compared to male-headed HHs, female-headed HHs are more vulnerable to climate change, worsening the gender gaps between males and females [23,58,59]. This is not surprising, given that women generally have limited access to information and education [60]. However, the situation is different if women have access to information, are educated, and are employed. Similarly, de facto female-headed HHs headed by the wives of migrant workers might be different from other female-headed HHs. Thus, there is a need to disaggregate the female-headed HHs to prioritize the less fortunate women-headed HHs in climate change adaptation and resilience-building initiatives.

Regarding the dependency ratio, if a HH has a high ratio, the adaptive capacity of the HH is low [60]. Furthermore, the ratio depicts the number of people the active population needs to render support. Therefore, it is a good indicator of the community's response to numerous crises [61] and is used to measure the ratio of young <16 plus the old (65 and above) per one hundred people in the 16–64 age category.

Our study revealed that a high dependency on rain-fed agriculture contributes to high vulnerability in ward 14 compared to ward 19. However, this result did not surprise us, given the high exposure to drought in the former ward, characterized by increased drought frequency in the last decade, the lack of early warning systems, and the perception that drought frequency will increase in the future.

Changing the cropping sequence, particularly the inclusion of more drought-tolerant crops, is one of the adaptation strategies used by farmers in the semi-arid areas of Zimbabwe [62–64] that are frequently affected by drought. Some predictive models even suggest that the changes in cropping sequence, particularly if there is widespread adoption of drought-tolerant maize crops, can significantly increase crop yields and financial returns [65]. However, to effectively use the different opportunities each season provides, farmers must get a good forecast for each season to adjust cropping patterns accordingly. Unfortunately, farmers in the two wards do not receive such warnings about impending drought, as indicated by the high scores on drought warnings.

The access to concessional loans was very low in both wards. However, this did not contribute to the disparity in adaptive capacity. Research has shown that a lack of access to finance is the major barrier to climate change adaptation [66]. The availability of these loans is crucial to ensure that farmers venture into other income-generating projects [67] and other climate-resilient projects that require substantial capital investment [66]. However, the agricultural loans in Zimbabwe are currently disbursed at market rates and are very expensive. The availability of concessionary loans, which have long and flexible repayment periods and very low-interest rates, is crucial to farmers who face an increased drought risk. In our study, only a handful of farmers had access to these loans. The current climate funding landscape has not helped this situation. The Paris Agreement reiterated the need to balance financial resources allocated to adaptation and mitigation based on country-driven processes and requirements [68]. Yet, the lion's share of global finance is still skewed towards mitigation. For instance, more than 80% of climate finance has gone towards mitigation [69]. This is despite the need for increased funding for adaptation to protect the income and food security of communities in developing countries increasingly exposed to climate change vagaries. Thus, it might be prudent to prioritize mitigation practices that have adaptation co-benefits to efficiently deploy resources available for improved climate action. Fortunately, numerous agricultural practices meant to ensure smallholder farmers are more resilient to climate change have some mitigation co-benefits. Policymakers and decision-makers should advance those adaptation projects with mitigation co-benefits when advocating for climate adaptation funding. This dovetails well with the need to find innovative funding models for mitigation and adaptation, as advocated in Zimbabwe's revised Nationally Determined Contributions [70].

The water security indicator shows that ward 19 is significantly more vulnerable than ward 14 due to inadequate access to safe water and inconsistent water supplies. HHs thus tend to spend a lot of productive time fetching water.

*Limitations of the Study and Policy Implications*

Our research is not without limitations. We did not include control variables when analyzing the LVI and LVI-IPCC. For instance, we did not conduct spatial analysis of drought incidence and the distance to water sources. The knowledge of control variables could contribute to more impactful policy suggestions. Furthermore, we did not have human or animal fatalities or malnutrition data to verify our vulnerability data. Apart from this, we did not assess the impacts of exposure to drought on school attendance, given that a study in Zimbabwe has shown that exposure to drought during childhood can result in a 14% decline in lifetime earnings [71]. Thus, studies capturing losses and damages are increasingly becoming critical in vulnerability assessments in light of the need to report the loss and damage [72] linked to climate shocks. Lastly, our results are based on self-reported data from the respondents. This can provide wrong information, particularly in situations where there is something negative, given the hesitancy of people to communicate bad news, known as the MUM effect. Additionally, little has been reported about livestock in the vulnerability, despite being number two after cropping on food and income security. It could have added value, had the study reported livestock deaths and diseases under drought in addition to new and emerging pests, and other issues.

The results from our study show that vulnerability to climate change does not necessarily come from exposure alone, but from the situation obtaining on the ground. Decision-makers are key in reducing vulnerability to climate change by addressing inequalities on the ground. For instance, addressing socio-demographic and structural characteristics that affect adaptive capacity can offer a good entry point for lowering vulnerability. However, there is also a need to review the conceptual frameworks for assessing climate change-related vulnerability in the agricultural sector, given the heterogeneity of smallholder farmers and livelihood strategies in Africa and especially in Zimbabwe.

## 5. Conclusions

This work was precipitated by the increasing number of studies using different protocols and frameworks to assess climate vulnerability in different settings, thus making it difficult to compare wards, districts, and provinces at the country level. Such potholes present challenges to decision-makers and funding agencies that require vulnerability assessments to prioritize the most vulnerable communities in adaptation programming. This paper employed the LVI and LVI-IPCC to assess the vulnerability to drought in two rural wards in Chivi district, Masvingo province, Zimbabwe. The study results show that the LVI for ward 14 is higher than that of ward 19. The main contributing factors to this higher vulnerability are high exposure to drought, livelihood strategies, food insecurity, and social networks. Thus, strategies that improve livelihood strategies, social networks, and food security are required to address this vulnerability. On the other hand, both wards have moderate vulnerability based on the LVI-IPCC. This is not surprising, given the low sensitivity and moderate adaptive capacity in both wards.

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## Appendix A. Indicators Used for Measuring Major Components

**Table A1.** A structured questionnaire was developed based on information provided in Appendix A. Our questionnaire had two sections showing the demographic characteristics and a section with indicator statements.

| Three Components of the LVI-IPCC | Seven Major Components of the LVI | 26 Subcomponents of the Seven Major Components |
|---|---|---|
| Adaptive capacity | Socio-Demographic profile | % Female HHs |
| | | % Illiterate HHs |
| | | Dependency ratio |
| | Livelihood Strategies | Agricultural diversification index |
| | | % Population dependent on rain-fed agriculture |
| | | Percentage HHs who have not changed cropping sequence |
| | | % HHs who have not adopted an improved cropping system |
| | | % with Access to concessional loans |
| | | % HHs with members not working in other communities |
| | Social networks | Percentage of HHs who have gone to the government for assistance in the last twelve months |
| | | Percentage of HHs not in cooperatives |
| | | Percentage of HHs without access to information |

**Table A1.** *Cont.*

| Three Components of the LVI-IPCC | Seven Major Components of the LVI | 26 Subcomponents of the Seven Major Components |
|---|---|---|
| **Sensitivity** | **Water** | Percentage of household who do not have access to clean Lack of access to clean water within 1km |
| | | % HHs without access to safe water |
| | | % Water conflicts |
| | | % HHs without consistent water supply |
| | **Health** | Time to a health facility |
| | | Malaria exposure |
| | **Food** | Reduce expenditure during droughts |
| | | HHs with food inadequacy |
| | | HHs who do not save food |
| | | HHs who do not save seed |
| | | Crop diversification |
| | **Exposure to drought** | Average drought frequency |
| | | % Drought warning |
| | | Drought trends |

## References


1. Tilman, D.; Balzer, C.; Hill, J.; Befort, B.L. Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 20260–20264. [CrossRef]
2. Lee, M.; Gambiza, J. The adoption of conservation agriculture by smallholder farmers in southern Africa: A scoping review of barriers and enablers. *J. Rural Stud.* **2022**, *92*, 214–225. [CrossRef]
3. McCarthy, J.J.; Canziani, O.F.; Leary, N.A.; Dokken, D.J.; White, K.S. *Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2001; Volume 2.
4. Abegunde, V.O.; Sibanda, M.; Obi, A. Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability* **2019**, *12*, 195. [CrossRef]
5. Ncube, M.; Madubula, N.; Ngwenya, H.; Mthunzi, T.; Madzivhandila, T.; Zinyengere, N.; Olivier, C.; Zhou, L.; Francis, J. Climate change, household vulnerability and smart agriculture: The case of two South African provinces. *Jàmbá J. Disaster Risk Stud.* **2016**, *8*, 182. [CrossRef] [PubMed]
6. IPCC. Impacts, adaptation, and vulnerability. In *Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC: Geneva, Switzerland, 2014; Volume 1132.
7. Hachigonta, S.; Nelson, G.C.; Thomas, T.S.; Sibanda, L.M. *Southern African Agriculture and Climate Change: A Comprehensive Analysis*; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2013; Volume 3.
8. Ramirez-Villegas, J.; Ghosh, A.; Craparo, S.; Thornton, P.K.; Manvatkar, R.; Bogart, B.; Läderach, P. Climate Change and Its Impacts in Southern Africa: A Synthesis of Existing Evidence in Support of the World Food Programme's 2021 Climate Change Position Paper. In *CGIAR Research Program on Climate Change, Agriculture and Food Security Working Paper*; CGIAR: Montpellier, France, 2021. Available online: https://cgspace.cgiar.org/handle/10568/114114 (accessed on 20 October 2022).
9. Arias, P.; Bellouin, N.; Coppola, E.; Jones, R.; Krinner, G.; Marotzke, J.; Naik, V.; Palmer, M.; Plattner, G.-K.; Rogelj, J. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group 14 I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Technical Summary; IPCC: Geneva, Switzerland, 2021. Available online: https://www.ipcc.ch/report/ar6/wg1/ (accessed on 20 October 2022).
10. Donatti, C.I.; Harvey, C.A.; Martinez-Rodriguez, M.R.; Vignola, R.; Rodriguez, C.M. Vulnerability of smallholder farmers to climate change in Central America and Mexico: Current knowledge and research gaps. *Clim. Dev.* **2019**, *11*, 264–286. [CrossRef]
11. Jayne, T.S.; Mather, D.; Mghenyi, E. Principal challenges confronting smallholder agriculture in sub-Saharan Africa. *World Dev.* **2010**, *38*, 1384–1398. [CrossRef]
12. Ribot, J. Vulnerability does not just fall from the sky: Toward multi-scale pro-poor climate policy. In *Handbook on Climate Change and Human Security*; Edward Elgar Publishing: Cheltenham, UK, 2013; pp. 164–199.
13. Lahsen, M.; Ribot, J. Politics of attributing extreme events and disasters to climate change. *Wiley Interdiscip. Rev. Clim. Chang.* **2022**, *13*, e750. [CrossRef]

14. Ribot, J.C. Vulnerability before adaptation: Toward transformative climate action. *Glob. Environ. Chang.* **2011**, *21*, 1160–1162. [CrossRef]
15. Doshi, D.; Garschagen, M. Understanding adaptation finance allocation: Which factors enable or constrain vulnerable countries to access funding? *Sustainability* **2020**, *12*, 4308. [CrossRef]
16. GCF. Green Climate Fund. Available online: https://www.greenclimate.fund/ (accessed on 20 October 2022).
17. Thomas, K.; Hardy, R.D.; Lazrus, H.; Mendez, M.; Orlove, B.; Rivera-Collazo, I.; Roberts, J.T.; Rockman, M.; Warner, B.P.; Winthrop, R. Explaining differential vulnerability to climate change: A social science review. *Wiley Interdiscip. Rev. Clim. Chang.* **2019**, *10*, e565. [CrossRef]
18. Adger, W.N.; Brown, I.; Surminski, S. Advances in risk assessment for climate change adaptation policy. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* **2018**, *376*, 20180106. [CrossRef]
19. De Sherbinin, A.; Bukvic, A.; Rohat, G.; Gall, M.; McCusker, B.; Preston, B.; Apotsos, A.; Fish, C.; Kienberger, S.; Muhonda, P. Climate vulnerability mapping: A systematic review and future prospects. *Wiley Interdiscip. Rev. Clim. Chang.* **2019**, *10*, e600. [CrossRef]
20. Hagenlocher, M.; Meza, I.; Anderson, C.C.; Min, A.; Renaud, F.G.; Walz, Y.; Siebert, S.; Sebesvari, Z. Drought vulnerability and risk assessments: State of the art, persistent gaps, and research agenda. *Environ. Res. Lett.* **2019**, *14*, 083002. [CrossRef]
21. Sharma, J.; Ravindranath, N.H. Applying IPCC 2014 framework for hazard-specific vulnerability assessment under climate change. *Environ. Res. Commun.* **2019**, *1*, 051004. [CrossRef]
22. Poudel, S.; Funakawa, S.; Shinjo, H.; Mishra, B. Understanding households' livelihood vulnerability to climate change in the Lamjung district of Nepal. *Environ. Dev. Sustain.* **2020**, *22*, 8159–8182. [CrossRef]
23. Nguyen, M.-H.; Le, D.P.; Vo, T.T. Vulnerability to natural disaster and welfare effect: A case study of flood risk in Vietnam's North central region. *J. Asian Afr. Stud.* **2021**, *56*, 1879–1898. [CrossRef]
24. Meza, I.; Siebert, S.; Döll, P.; Kusche, J.; Herbert, C.; Eyshi Rezaei, E.; Nouri, H.; Gerdener, H.; Popat, E.; Frischen, J. Global-scale drought risk assessment for agricultural systems. *Nat. Hazards Earth Syst. Sci.* **2020**, *20*, 695–712. [CrossRef]
25. Hirabayashi, Y.; Mahendran, R.; Koirala, S.; Konoshima, L.; Yamazaki, D.; Watanabe, S.; Kim, H.; Kanae, S. Global flood risk under climate change. *Nat. Clim. Chang.* **2013**, *3*, 816–821. [CrossRef]
26. Yang, X.; Guo, S.; Deng, X.; Wang, W.; Xu, D. Study on Livelihood Vulnerability and Adaptation Strategies of Farmers in Areas Threatened by Different Disaster Types under Climate Change. *Agriculture* **2021**, *11*, 1088. [CrossRef]
27. Barros, V.R.; Field, C.B.; Dokken, D.J.; Mastrandrea, M.D.; Mach, K.J.; Bilir, T.E.; Chatterjee, M.; Ebi, K.L.; Estrada, Y.O.; Genova, R.C. *Climate Change 2014: Impacts, Adaptation and Vulnerability: Part B: Regional Aspects: Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2014; pp. 1–1820.
28. Hahn, M.B.; Riederer, A.M.; Foster, S.O. The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Glob. Environ. Chang.* **2009**, *19*, 74–88. [CrossRef]
29. Bhattacharjee, K.; Behera, B. Determinants of household vulnerability and adaptation to floods: Empirical evidence from the Indian State of West Bengal. *Int. J. Disaster Risk Reduct.* **2018**, *31*, 758–769. [CrossRef]
30. Huong, N.T.L.; Yao, S.; Fahad, S. Assessing household livelihood vulnerability to climate change: The case of Northwest Vietnam. *Hum. Ecol. Risk Assess. Int. J* **2019**, *25*, 1157–1175. [CrossRef]
31. Mudasser, M.; Hossain, M.Z.; Rahaman, K.R.; Ha-Mim, N.M. Investigating the climate-induced livelihood vulnerability index in coastal areas of Bangladesh. *World* **2020**, *1*, 12. [CrossRef]
32. Aitsi-Selmi, A.; Egawa, S.; Sasaki, H.; Wannous, C.; Murray, V. The Sendai framework for disaster risk reduction: Renewing the global commitment to people's resilience, health, and well-being. *Int. J. Disaster Risk Sci.* **2015**, *6*, 164–176. [CrossRef]
33. UNDP. *Mapping of Selected Hazards Affecting Rural Livelihoods in Zimbabwe—A District and Ward Analysis*; UNDP: Harare, Zimbabwe, 2015.
34. Manatsa, D.; Mushore, T.; Gwitira, T.; Wuta, M.; Chemura, A.; Shekede, M.; Mugandani, R.; Sakala, L.; Ali, L.; Masukwedza, G. *Report on Revised Agroecological Zones of Zimbabwe*; Bindura University: Bindura, Zimbabwe, 2020.
35. Nhodo, L.; Gukurume, S.; Mafongoya, O. Contestations and conflicting lifeworlds in conservation farming practices in Zimbabwe: The experiences of peasant smallholder farmers in Chivi south district in Masvingo. *Russ. J. Agric. Socio-Econ. Sci.* **2013**, *16*, 19–30. [CrossRef]
36. GoZ. *National Adaptation Plan (NAP) Roadmap for Zimbabwe*; Government of Zimbabwe Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement: Harare, Zimbabwe, 2019.
37. ZIMSTAT. *Zimbabwe Population Census, 2012*; Zimbabwe National Statistics Agency: Harare, Zimbabwe, 2012.
38. Chingarande, D.; Matondi, P. *Zimbabwe Stakeholder Mapping Report: Masvingo Province*; Research Technical Assistance Center: Washington, DC, USA, 2020.
39. Nyikahadzoi, K. *Drought Hazard Risk and Humanitarian Impact Analysis and Inventorisation of Forecast Models in Zimbabwe*; Welthungerhilfe: Harare, Zimbabwe, 2011.
40. GoZ. National Development Strategy 1. Government Printers, Zimbabwe. 2020. Available online: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC203781/#:~{}:text=The%20National%20Development%20Strategy%201,equitable%20Real%20GDP%20growth%3B%20iii (accessed on 20 October 2022).
41. IPCC. *IPCC Sixth Assessment Report (AR6): Climate Change 2022-Impacts, Adaptation and Vulnerability: Regional Factsheet Australasia*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022.

42. IPCC. Climate Change: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II. In *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2007; pp. 433–467.
43. Diana, M.N.; Chamburi, S.; Raihan, T.M.; Ashikin, A.N. Assessing local vulnerability to climate change by using Livelihood Vulnerability Index: Case study in Pahang region, Malaysia. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2019; p. 012059.
44. Rai, P.; Bajgai, Y.; Rabgyal, J.; Katwal, T.B.; Delmond, A.R. Empirical Evidence of the Livelihood Vulnerability to Climate Change Impacts: A Case of Potato-Based Mountain Farming Systems in Bhutan. *Sustainability* **2022**, *14*, 2339. [CrossRef]
45. Botero, D.G.; Salinas, A.B. *Assessing farmers' vulnerability to climate change: A case study in Karnataka, India*; Universitat Autonoma de Barcelona: Barcelona, Spain, 2013.
46. Adu, D.T.; Kuwornu, J.K.; Anim-Somuah, H.; Sasaki, N. Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo region of Ghana. *Kasetsart J. Soc. Sci.* **2018**, *39*, 22–32. [CrossRef]
47. Amuzu, J.; Kabo-Bah, A.T.; Jallow, B.P.; Yaffa, S. Households' livelihood vulnerability to climate change and climate variability: A case study of the Coastal Zone, The Gambia. *J. Environ. Earth Sci.* **2018**, *8*, 35–46.
48. Gaiha, R.; Imai, K. *Measuring Vulnerability and Poverty Estimates for Rural India*; WIDER Research Paper; The United Nations University World Institute for Development Economics Research (UNU-WIDER): Helsinki, Finliand, 2008.
49. Lemessa, S.D.; Watebaji, M.D.; Yismaw, M.A. Climate change adaptation strategies in response to food insecurity: The paradox of improved potato varieties adoption in eastern Ethiopia. *Cogent Food Agric.* **2019**, *5*, 1640835. [CrossRef]
50. Fellmann, T. The assessment of climate change-related vulnerability in the agricultural sector: Reviewing conceptual frameworks. *Build. Resil. Adapt. Clim. Chang. Agric. Sect.* **2012**, *23*, 37.
51. Theodory, T.F. Understanding the relevance of indigenous knowledge on climate change adaptation among mixed farmers in the Ngono River Basin, Tanzania. *Afr. J. Sci. Technol. Innov. Dev.* **2021**, *13*, 51–59. [CrossRef]
52. Ashburner, L.; Petrik, D.; Oettle, N.; Sithole, M.; Kgope, B. Adaptation Futures 2018 Insights from Africa. In Proceedings of the 5th International Climate Change Adaptation Conference, Cape Town, South Africa, 18–21 June 2018.
53. Malone, E.L.; Engle, N.L. Evaluating regional vulnerability to climate change: Purposes and methods. *Wiley Interdiscip. Rev. Clim. Chang.* **2011**, *2*, 462–474. [CrossRef]
54. Sekhri, S.; Kumar, P.; Fürst, C.; Pandey, R. Mountain specific multi-hazard risk management framework (MSMRMF): Assessment and mitigation of multi-hazard and climate change risk in the Indian Himalayan Region. *Ecol. Indic.* **2020**, *118*, 106700. [CrossRef]
55. UNDP. *Human Development Reports*; UNDP: New York, NY, USA, 2007.
56. Simane, B.; Zaitchik, B.F.; Foltz, J.D. Agroecosystem specific climate vulnerability analysis: Application of the livelihood vulnerability index to a tropical highland region. *Mitig. Adapt. Strateg. Glob. Chang.* **2016**, *21*, 39–65. [CrossRef]
57. ZIMSTAT. *Poverty, Income, Consumption and Expenditure Survey 2017 Report*; Zimbabwe National Statistical Agency (ZIMSTAT): Harare, Zimbabwe, 2018.
58. Sarker, M.N.I.; Wu, M.; Alam, G.M.; Shouse, R.C. Livelihood vulnerability of riverine-island dwellers in the face of natural disasters in Bangladesh. *Sustainability* **2019**, *11*, 1623. [CrossRef]
59. Tran, V.T.; An-Vo, D.-A.; Cockfield, G.; Mushtaq, S. Assessing livelihood vulnerability of minority ethnic groups to climate change: A case study from the northwest mountainous regions of Vietnam. *Sustainability* **2021**, *13*, 7106. [CrossRef]
60. Githui, N.P. *Vulnerability of Smallholder Households Livelihoods to Drought and Floods in Kinakomba Ward, Tana River County Kenya*; Pwani University: Malindi Highway, Kenya, 2021.
61. Stângă, I.; Grozavu, A. Quantifying human vulnerability in rural areas: Case study of Tutova Hills (Eastern Romania). *Nat. Hazards Earth Syst. Sci.* **2012**, *12*, 1987–2001. [CrossRef]
62. Brown, D.; Chanakira, R.R.; Chatiza, K.; Dhliwayo, M.; Dodman, D.; Masiiwa, M.; Muchadenyika, D.; Mugabe, P.; Zvigadza, S. *Climate Change Impacts, Vulnerability and Adaptation in Zimbabwe*; International Institute for Environment and Development: London, UK, 2012.
63. Mascndeke, S.; Shoko, K. Drought coping strategies and their effectiveness: The case of Ward 12 in Mberengwa District Zimbabwe. *Int. J. Soc. Sci. Stud.* **2014**, *2*, 137.
64. Frischen, J.; Meza, I.; Rupp, D.; Wietler, K.; Hagenlocher, M. Drought risk to agricultural systems in Zimbabwe: A spatial analysis of hazard, exposure, and vulnerability. *Sustainability* **2020**, *12*, 752. [CrossRef]
65. Lunduka, R.W.; Mateva, K.I.; Magorokosho, C.; Manjeru, P. Impact of adoption of drought-tolerant maize varieties on total maize production in south Eastern Zimbabwe. *Clim. Dev.* **2019**, *11*, 35–46. [CrossRef]
66. Timilsina, G.R. Financing climate change adaptation: International initiatives. *Sustainability* **2021**, *13*, 6515. [CrossRef]
67. Abdul-Razak, M.; Kruse, S. The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Clim. Risk Manag.* **2017**, *17*, 104–122. [CrossRef]
68. UN. Paris agreement. In *Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21st Session, 2015: Paris)*; HeinOnline: Getzville, NY, USA, 2015; p. 2017.
69. Thwaites, J. *Multilateral Development Bank Climate Finance in 2018: The Good, the Bad and the Urgent*; World Resources Institute: Washington, DC, USA, 2019.

70. GoZ. *Zimbabwe Revised Nationally Determined Contribution*; Government of Zimbabwe Ministry of Environment, Climate, Tourism and Hospitality Industry: Harare, Zimbabwe, 2021.
71. Alderman, H.; Hoddinott, J.; Kinsey, B. Long term consequences of early childhood malnutrition. *Oxf. Econ. Pap.* **2006**, *58*, 450–474. [CrossRef]
72. Birkmann, J.; Jamshed, A.; McMillan, J.M.; Feldmeyer, D.; Totin, E.; Solecki, W.; Ibrahim, Z.Z.; Roberts, D.; Kerr, R.B.; Poertner, H.-O. Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. *Sci. Total Environ.* **2022**, *803*, 150065. [CrossRef]