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The Influence of Socioeconomic Factors on Households' Vulnerability to Climate Change in Semiarid Towns of Mopani, South Africa

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Abstract: The changing climate and its current rate, frequency, as well as its life-threatening impacts are undoubtedly abnormal and globally worrisome. Its effects are expected to be severely different across segments of the society. It is disposed to leaving no facet of human endeavor immune, particularly in vulnerable cities of developing countries where there is dearth of empirical studies. For the context-specific nature of climate change impacts and place-based character of vulnerability, this study explores the influence of socioeconomic attributes on household vulnerability in Mopani District northeast of South Africa to provide basis for targeting, formulating, evaluating, and monitoring adaptation policies, programs, and projects. The study adopted a multistage random sampling to draw 500 households from six towns in Mopani District, Limpopo Province. Mixed methods approach was used for data collection, while Household Vulnerability Index (HVI) was estimated using principal component analysis and regressed with socioeconomic attributes. The study reveals that climate is changing with high HVI across selected towns. It further depicted that age and marital status have positive and significant relationships with HVI, while gender and educational levels have inverse and significant relationship with HVI in some towns. The study recommends the need for municipalities to partner with private sector to empower household and mainstream micro level coping strategies in urban planning across the district.

Keywords: socioeconomic; household vulnerability; climate change impacts; semi-arid towns

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1. Introduction

Climate is changing and the adduced factors to its variability include both natural but substantially human induced [1,2]. The changing climate comes with attendant negative global impacts such as increasing temperature, sea level rise, floods, etc. [3]. These consequences are manifesting in its complex interdictions, uncertainties, and competing interest among the stakeholders as well as the multigenerational nature of its challenges. It is multigenerational because it covers far beyond the lives of people currently attending to its externalities [4]. The current rate at which the climate is changing, particularly, the post 1990, is unprecedented and worrying. The increasing temperature signal is very strong for southern African region with the observed trend indicating an increase of more than 150% than the global rate [5] The "projected warming over 1990–2100 ranges between 1.4 and 2.9 °C for the central emissions scenario (1595a), while sea-level rise ranges between 20 and 86 cm . . . ", particularly for cities of developing countries [1,6] and their vulnerable population, particularly young, old, and women.

Developing countries are highly vulnerable in the region that bears the significant share of the global climate change consequences, despite their insignificant carbon footprint [7]. In the Forth Assessment Report of Intergovernmental Panel on Climate Change's

(IPCC), public concern particularly on the anthropogenic climate change currently calls for urgent attention. The character and magnitude of the change, as well as their impact on human living conditions and ecosystems, have complex relationships with human socioeconomic characteristics [8]. Africa continent like other developing regions is projected to battle with climate change adversities because of its reliance on climate-fed economies and jobs [9]. Most of these countries are becoming rapidly urbanized [10]. Coupled with this are the risks of climate-related disasters manifesting in increasing incidences and challenge of flooding, droughts, pollution, heat stress, and spatial spread of vector-borne diseases [8,11,12]. As a result of this, the urban population is particularly at a higher risk due to its concentrated densities, inadequate drainage channels, high volumes of solid wastes, and urban sprawl, occasioned by informal urbanization, as well as the occupation of risky sites, such as flood plains and impervious surfaces [13]. This phenomenon has increased the occurrences of hazards and has continually stretched and limited the capacity of local municipalities that are charged with the responsibility of responding with adaptation policies and interventions [11].

South Africa is becoming urbanized [14] and it is equally becoming highly vulnerable to climate change [15]. South Africa's urban population accounts for about 60.62% and 65.36% of the total population in 2007 and 2018, respectively, with an annual growth rate of 2.1% [16,17]. Coupled with the accelerating impacts and implications of climate change, the discernible consequences are multitudinous at varying levels of severity across the country. In a business-as-usual scenario, as envisaged, temperature is expected to be higher in the hinterland than in the coastal periphery of South Africa. The former been predicted to rise by 3 °C and the latter warmer by about 1 °C halfway the century [5]. However, by the close of the century, temperatures are projected to become warmer, respectively, by about 5 and 3 °C in the noncoastal region and coastal zone of South Africa [5,18,19]. The resultant effects of the scenario may be more devastating on the cities as well as the dwellers in the noncoastal region of South Africa, where they are currently facing with heat-related challenges, water stress, floods, and droughts.

Despite the increasing importance of the cities in the worlds social, economic, cultural, political, and environmental spheres [20], its role as a host to half of the world's population [21] coupled with the associated stress occasioned by these developments, climate change adaptation strategies, and projects focus is still mainly rural [8,22]. Current literature on vulnerability and adaptation to climate change that is urban focused is largely coastal city biased [1,23,24].

Climate has substantially altered and resulted in increasing heat episode and dwindling and unreliable rainfall in Mopani District. The transformations reflect significantly the regional climate scenarios [25,26]. These claims were further stressed in the Mopani District planning instrument (Integrated Development Plan) recognizing the changing climate and its threats on access to potable water, food security, and health effects to poverty-stricken communities [27]. The noncoastal, semiarid Mopani District is already climate sensitive and water stressed [28]. The prevalence of climatic changes has become manifested in the district as well as Limpopo Province with the potential of both direct impacts on climate-fed economic activities, including but not limited to droughts, floods, wild fire, and ancillary consequences on health, (occurrence of climate-prone diseases-such malaria, measles, typhoid fever, cholera, and diarrhea) and social systems [29,30].

Consequently, social and economic development become compromised, undermined, and even reversed by climate change extreme events with widespread paucity of physical and financial resources conspiring with abject poverty-related challenges [31,32]. This calls for well-informed vulnerability assessment from the socioeconomic lens and the strength to counter the lives disrupting tendencies of climate change extreme events, which constitute the main threats to Africa and indeed developing nations. The understanding of the impacts of climate change especially from local context and their nexus with the people's socioeconomic contents is very critical and begging for empirical attention [33].

This prompted three fundamental research questions as follows: Is climate changing in Mopani District? Can it be said that households are vulnerable to climate change in Mopani District in South Africa's semiarid (northeast) region? And can it be said that socioeconomic characteristics have influence on the Households' Vulnerability Index (HVI) across the towns and the District?

No doubt, the frequency, magnitude, and consequences of climate change differ the world over, in accordance with their peculiarities and the virtue of the people's unique individualities (socioeconomic contents) [34]. It is on this basis that this study aimed at examining the variability and trends of climatic change (rainfall and temperature) in the Mopani District and to assess the HVI as well as analyze the nexus between the HVI and socioeconomic attributes of households in the six selected towns (Tzaneen, Nkowankowa, Hoedspruit, Modjadjiskloof, Phalaborwa, and Giyani). This was intended to provide basis for targeting, formulating, evaluating, and monitoring adaptation policies, programs, and projects.

2. Materials and Methods

2.1. Description of the Study Area

Mopani District Municipality is a category C municipality. It is located in Limpopo Province, the northern-most province in South Africa (Figure 1). The district comprises of five local municipalities, namely, Greater Giyani, (district's administrative seat), Maruleng, Greater Letaba, Ba-Phalaborwa, and Greater Tzaneen. The municipality is on longitudes: 29°52′E to 31°52′E and latitudes: 23°0′S to 24°38′S, with 31°E as the central meridian. It covers 13,948.418 ha (10.2%) of the surface area of South Africa [27]

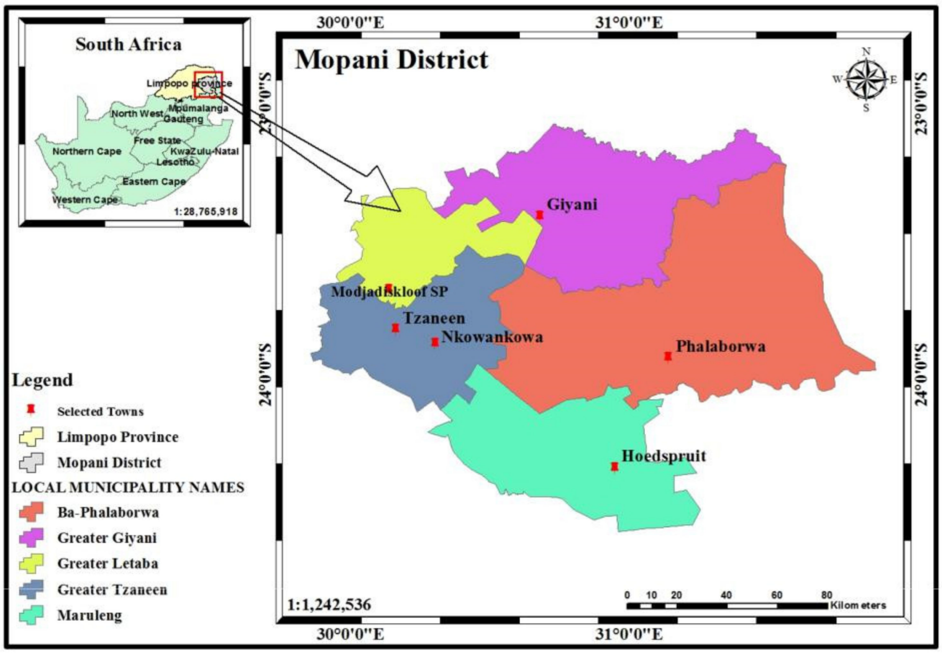

Figure 1. Mopani District showing the local municipalities and the selected towns within the context of Limpopo Province and South Africa (Source: Authors' Field Data, 2019).

Most part of Mopani District receives about 85% of its rainfall in the summer. The rainfall amount varies from the mountainous zones with about 2000 mm/annum to as low as 400 mm/annum in Kruger National Park, while the district's high mountainous zone experience on the average temperature range of 21–25 °C in the dry low veld areas of Kruger National Park [35].

The population of Mopani District is increasingly becoming susceptible to the increasing incidences of extreme climate events of floods, drought, heat waves, and the spread of climate-sensitive diseases [28–30]. These are occasioned by high rates of unemployment and poverty, limited access to resources, and high infrastructure deficit [36,37]. This justifies the need for empirical examination of household vulnerability level and its nexus with the socioeconomic contents across the selected towns in each of the local municipalities.

2.2. Methods

Several methods are available in the literature for analyzing vulnerability. The "starting point" known as disaster focused, an approach that assesses vulnerability to hazards such as flooding and heat [38], and "end point," i.e., those approaches that see and assess vulnerability as an aftermath effects of the hazards, are the two most distinct [39,40]. Adopting an isolated method comes with its attendant reservations and shortfalls [40]. Hence, this study integrates the two approaches to eradicate the shortfalls that characterize the usage of an isolated approach because of the indispensability of the two approaches [41,42].

Households' exposure sequels to the establishment of the trend of climate parameters in the study area, whereas households' duration of stay in their various places of abode signifies how long such households' have been exposed to the effects of the trending climate. These values were routed through Likert Scale of Exposure Time spent: not exposed (1) for staying for less than a year; just exposed (2) for 1–5 years of exposure; exposed (3) for >5–10 years of exposure; very exposed (4) for 11–15 years of exposure, and very much exposed (5) for >15 years of exposure.

Households' sensitivity described by the degree to which a system is affected or modified by either internally or externally induced disturbances [43]. Sensitivity was measured from data regarding households' loss of properties, fatalities, i.e., death of a family member and livestock, income that is natural resource-based, or remunerative income (Table 1). The estimation of both mean and standard deviation was conducted. The Sensitivity Index were further categorized in to three types (not sensitive, sensitive, and very sensitive).

Households' adaptive capacity is taken to be a constituent property of the several indices of livelihood assets. Adopting integrated approach [1,44] household's adaptive capacity was measured using Personal Possession Index (PPI). It is, thus, submitted that for the 0–1 scale, the calculated indicator value is more asymptotic to 1 indicates a higher adaptive capacity, but a calculated indicator asymptotic to zero (0) indicates a weak or low adaptive capacity [1]. However, these indices were further subjected to the Likert Scale of Capability as: very much capable (5) for possession of 81–100% of prescribed assets; very capable (4) for possession of 61–80% of prescribed assets; capable (3) for possession of 41–60% of prescribed assets; not capable (2) for possession of 21–40% of prescribed assets, and not capable at all (1) for possession of less than 21% of prescribed assets.

Estimating vulnerability using indicators-based approach, this study adopted the UN Habitat (2011), which indicates vulnerability as a measure of adaptive capacity, exposure, and sensitivity to climate-prone hazards. This is symbolized as:

$$Vulnerability = Exposure + Sensitivity - Adaptive\ Capacity V = E + S - AC \quad (1)$$

The Analytical Framework was to establish Household Vulnerability Index. For the population, N made up of n households, i.e., $N = hh1, hh2, hh3, \ldots, hhn$, V is a subset of v households that have some degree of vulnerability, hence having an internal vulnerability. Thus v $\leq$ n and v = 0 implies that there are no vulnerable household, and v = n implies that all households are vulnerable.

The first step witnessed the identification of key indicators (Table 1) that contribute to the vulnerability of a target system. To break down the vulnerability X into m specific dimensions of impact and give a corresponding weight $(wi, i = 1, \ldots, m)$ to each indicator, weights was assigned to these indicators rather than assigning equal weights across all indicators or using expert-based judgement [39] because of the criticism for its subjectivity and disagreements among experts [41]. This study adopted principal component analysis (PCA) following [44], as considered appropriate in a work of this nature [45]. Thus, PCA was separately ran for the selected indicators of exposure, sensitivity, and adaptive capacity to determine the magnitude of influence of each variable on the index. The loadings from the first component of the PCA was used as the weights for the indicators.

The study used both quantitative and qualitative data as guided by the hypothesized indicators (Table 1). The quantitatively measured data were, for instance, ages and duration of stay in a locality by the respondents, while housing was measured qualitatively in terms of housing condition. Making comparability of the results possible, we normalized the quantitative data normalized to 0–1 scale following [1], adopting the following equation

$$X_{ij} = \frac{X_{ij} - MinX_{ij}}{Max\ X_{ij} - MinX_{ij}}, \tag{2}$$

where X_{ij} represents the standardized indicator value i of the household j;

X_{ij} is the indicator value i that corresponds to household j;

Max and Min indicate the maximum and minimum scaled indicators' values i, respectively.

In case the standardized value is more asymptotic to 1, it will imply a higher vulnerability, and it is of low vulnerability if the value is more asymptotic to 0.

To provide broad information on the urban Households' Vulnerability Index, the mean and standard deviation of each components (exposure, sensitivity, and adaptive capacity) as well as the vulnerability were computed.

The weighting of the indicators ranges from 0 and 1, signs indicating the path in relation to other indicators for the respective indexes, with dimension values 0 = no impact and 1 = full impact. The magnitude of calculated value of the weights defines the contribution of each indicator to the value of the index.

The sum of the weighted vulnerabilities across all dimensions give the particular household's total vulnerability *Vhhi*:

$$\sum_{j=1}^{m} Xwj / \sum_{j=1}^{m} wj \ = \ Vhhi \tag{3}$$

The summation of the dimensions gives the contributions of each of the identified dimensions to vulnerability.

For the HVI, the sum of the weights is set to

$$\sum_{j=1}^{m} wj = 100 \tag{4}$$

To establish the extents of household vulnerability, several authors have adopted the Multinomial Logistic Regression Model (MLRM) but because of its limiting assumptions, that there is no order to the categories of the outcome variable (i.e., the categories are nominal), the information contained in the ordering is lost [46]. The Ordered Logit Regression Model (OLRM) on STRATA 14, an extension of the binary logic model was adopted. The choice of OLRM is informed by its ability to calculate the individual Household Vulnerability Index, the total households, as well as ordered the contributions of each hypothesized indicator [47]. In this study, the ordered dependent variable has three categories: low vulnerability, moderate vulnerability, and high vulnerability. The low vulnerability category was used as the reference category. This estimation will show, for instance, lowly vulnerable households HVI in range from 0 to 47, moderately vulnerable households HVI in range from 47.1 to 63.7, and highly vulnerable households HVI in range from 63.71 to 100.

The study used high-resolution data set from global climatic data set (temperature and rainfall) of monthly climate data based on a grid from latitudes 24.4° S to 23.3° S and 30.0° E and 31.1° E, during the period of 1958–2017 for temperature and 1958–2016 for rainfall. However, several studies like [48,49] justify this step. Table 1 summarizes the hypothesized indicators that provided guides for the evaluation of HVI.

Table 1. Hypothesized indicators and their relationship with vulnerability.

	Indicator	Component	Factor	Function/Relationship with Vulnerability	References
1	Sex	Socioeconomic	Exposure	Higher number of female populations, higher vulnerability	[1,50–54]
2	Age			Higher proportion of aged (old) and adolescents and children, higher vulnerability	
3	Education			Lower number of educated members of the household, higher vulnerability	
4	Disabilities			Higher number of members of the household with disability, higher vulnerability	
5	Marital status			Higher number of married members of the household, higher vulnerability	
6	Employment status		Adaptive capacity	Lower number of employed members of household, higher vulnerability	
7	Income			Lower number of members of household with stable income, higher vulnerability	
8	Livelihood activities	Physical		Higher total number of livelihood activities of household, lower vulnerability	
9	Personal Possession Index		Exposure	Higher Personal Possession, lower vulnerability	[55,56]
10	Housing condition		Sensitivity	Better condition of dwellings, lower vulnerability	
11	Death of family members due to climate-related disasters			Higher number of deaths of household members, higher vulnerability	
12	Number of occurrences of the five-climate change (CC)-related diseases			Higher occurrence and severity of the climate-related diseases among households, higher vulnerability	
13	Total land, houses, and other properties damaged by flood/landslides			Higher total loss of properties due to damage climate disaster by household, higher vulnerability	
14	Total damage to household source of income due to flood/landslides/drought/fire			Higher total loss of income due to damage climate disaster by household, higher vulnerability	
15	Share of natural resource-based income to total income			Higher total share of natural resource-based income to total income of household, higher vulnerability	
16	Share of non-natural based to total income			Lower total share of remunerative income to total income of household, higher vulnerability	[51,52,54,57,58]
17	Number of insurance coverage			Availability of insurance cover, lower vulnerability	
18	People graduated above secondary level			Higher number of household members graduated above Matric level, lower vulnerability	

Table 1. *Cont.*

	Indicator	Component	Factor	Function/Relationship with Vulnerability	References
19	Tools for disaster mitigation and CC mitigation	Economic		Higher available mitigation and adaptation tool, lower vulnerability	
20	Skills and experience of CC adaptation and disaster management			Higher household members with adaptation skills and experience, lower vulnerability	[1,59,60]
21	Participation in propagation, rehearsal and training for climate change disaster mitigation and adaptation, and information sharing			Higher participation in adaptation and information sharing, lower vulnerability	
22	Participation in social organization			Higher household member's participation in social organization, lower vulnerability	
23	Participation in community funds			Higher household members participation in community funding, lower vulnerability	
24	Supports from communities and relatives			Higher supports from community and relatives to household during disaster, lower vulnerability	
25 26	Topography/terrain; Temperature/rainfall	Human/social	Adaptive capacity	Flatter/lower elevation, higher vulnerability; Higher temperature, higher vulnerability	
27 28	Water availability; Water contaminated			Lower water availability, higher vulnerability; Higher contaminated water, higher vulnerability	
29	Availability/level of urban green spaces			Higher urban green space, lower vulnerability	[61–65]
30	Level of Imperviousness			Higher level of imperviousness, higher vulnerability	
31	Plot coverage/soft landscape			Higher plot coverage, higher vulnerability	
32	Household waste collection and disposal			Poor household waste collection and disposal system, higher vulnerability	
33	Availability and location of basic community infrastructures and services			Higher availability and closer basic community infrastructure and services, lower vulnerability	[53,54]

3. Results

3.1. Climate Change in Mopani District (1958–2017)

The temperature and rainfall data were analyzed by estimating the mean interannual cycle for the trend of rainfall as well as the trend of anomalies of temperature to indicate extreme cases over the District during the period of 1958–2017.

The monthly average result of analysis as contained in Figure 2 illustrates temperature trend between 1958 and 2017. From these figures, the temperature exhibits an increasing trend, rising steadily such that from about the year 2000, they have been mostly above the long-term mean. The implication of this trend is that Mopani District displayed warm temperature over the period of examination.

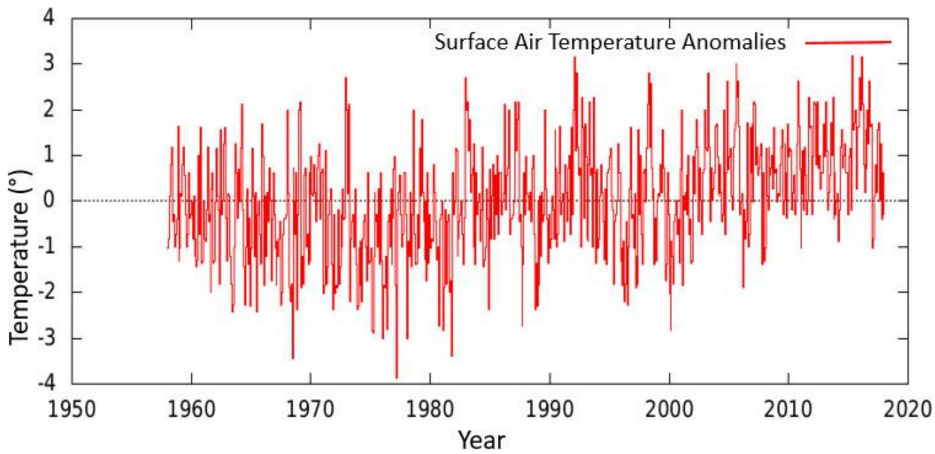

Figure 2. Anomalies in mean monthly temperature (1958–2017) across Mopani District. Source: Authors' Field Data, 2019.

However, despite the long-term trend, there are still seasonal differences from year to year with hotter temperature during drought seasons. It is equally clear that interannual unevenness across seasons in the district as shown in Figure 3 signifies high rainfall variability in the district.

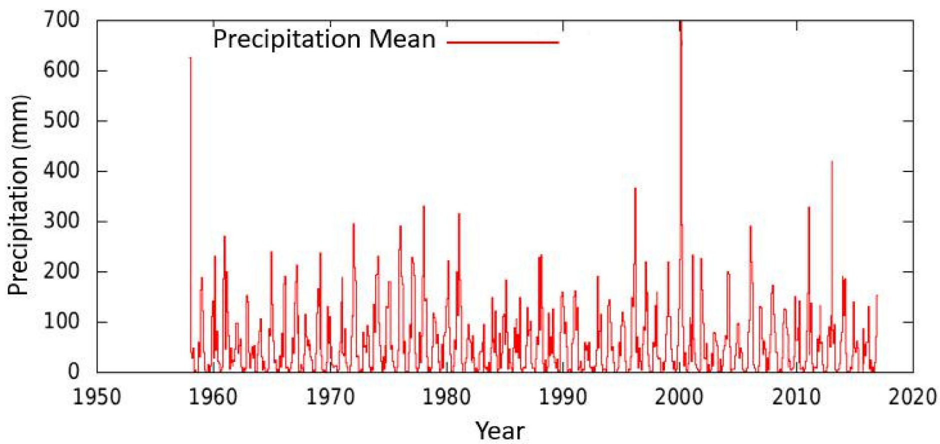

Figure 3. Mean interannual variability of precipitation over Mopani District (1958–2016). Source: Authors' Field Data, 2019.

These have consequently occasioned a shift in rainfall to a later onset (extending the dry fire season), whereas extreme floods, often due to cyclones and droughts, connected to the El Nino phenomenon, have turned out to be more frequent. The recent incidences of extreme events have continuously put Mopani towns in an untold hardship, particularly, the most vulnerable groups (children, older adults, and women).

This study adopted the temperature projections from existing studies [18,25,28]. The studies have very strong increasing temperature signals for southern African region with more than 150% higher than the global rate. Precipitation is projected to assume about 5%–10% reduction over South Africa in the next five decades [6], with greater uncertainties than those of temperature. The situation calls for pragmatic policies and serious attitudinal change, to forestall devastating human consequences as may likely be escalated by socioeconomic attributes of the people.

3.2. Households' Socioeconomic Characteristics

Table 2 summarizes in no specific order, the households' socioeconomic attributes considered in this study. It is shown that the larger proportion of the household's heads are still in their prime and active ages between the range of 20 and 50 years. The category laid claim to over 80% of the total samples across the district. The number of household heads decrease with increased age, implying that the younger household heads are more than the older ones. The implication of this scenario suggests that any program that is targeted towards economic empowerment of the people that have special focus on gender and young people will significantly be impactful across the selected towns. This will equally be true on programs focusing on climate change adaptation and early warning propagation programs in the district by the local municipalities, targeting this population category. These groups are not only young but also are economically and socially active that, if facilitated, they can be productively engaged to initiate and champion climate change risk sensitization, mitigation, and adaptation initiatives. These findings validate the findings of [66,67] In their respective studies of Livelihood and income diversification strategies among rural farm households in Niger State, (Northern) Nigeria, and that of poverty and rural livelihood diversification among farming households in southwest Nigeria.

The results further show that about 57% of household heads are married, while about 43% are either divorced, single, widow, or separated. This may suggest additional pressure from extra responsibility or imply an extra burden to adapt during and after climate change extreme events.

Table 2, also shows that about one-third of the sampled population is either job seekers or surviving on income below or equivalent to R16.44 per day (R6000, i.e., $312 per annum). Quiet a significant proportion (56%) engaged in activities that earn them between R240,000 ($12,400) and R480,000 ($24,960) per annum, while about 1% earn above R480,000 ($24,960) per annum. Majority of the household heads having financial resources at their disposals (as indicated) signifies a higher household affordability. This is capable of enhancing the households' coping capacity during and after climate change extreme events. These findings validate those of [68,69] in their analysis of the determinants of rural poverty among small holder farmers in South-western, Nigeria and that of the examination of livelihood strategies of indigenous nationalities in Nepal, the case of Chepangs.

Considering the activities from which the incomes are sourced in Mopani District, about 23% of household heads are without any economic engagement, while about 8% accounted for by climate-fed economic activities (farming and lumbering) and 69% are in the category of remunerative income activities. However, it is observed that more than half (51%) of the sampled households have streams of livelihood activities across the town. This is expected to boost households' coping capability with additional income. The findings reinforced the stand of [70] in their study of smallholder farmers' livelihood security options amidst climate variability and change in rural Ghana.

An examination of the educational qualification of the respondents shows a clear indication of average literacy level of households in Mopani District, i.e., about 72% are holders of Matric and various higher qualifications (out of which 34.2% hold degree and above), while 19.8% have qualifications lower than Matric. This may guarantee interest and access to useful climate change-related information that could facilitate early warning and promote propagation of adaptation actions; this finding is contrary to the findings of [1].

Table 2. Distribution of respondents according to socioeconomic characteristics. * NR: no response; ZAR@ 0.052 USD (Source: Author's Field Data 2019).

Variable	Values	Percentage
Age	13–19	2.2
	20–35	37.7
	36–50	44.4
	51–65	12.5
	66 and above	2.2
Marital status	Married	56.7
	Single	29.8
	Divorced	4.6
	Widow	5.2
	Widower	0.6
	Separated	2.8
	Others	0.2
Duration of stay	1–3 years	10.1
	4–6	11.1
	7–10 years	5.8
	Above 10 years	51.0
	Since birth	22.0
No. of male children	0	3.6
	1	42.5
	2	31.0
	3	12.3
	NR	10.5
No. of female children	0	14.7
	1	45.0
	2	28.6
	3	4.6
	NR	7.1
Monthly income	No income	24.0
	R500	5.0
	R501–5000	2.0
	R5,001–10,000	3.0
	R10,001–15,000	3.0
	R15,001–20,000	6.0
	R20,001–25,000	11.0
	R25,001–30,000	16.0
	R30,001–35,000	17.0
	R35,001–40,000	11.0
	>R40,000	1.0
Qualification	No formal education	3.2
	Quranic education	0.2
	Grade 0–7	8.5
	Grade 8–12	11.3
	Matric	32.9
Certificate/diploma	Higher diploma/	14.7
	bachelor/honors	12.5
	masters/PhD	11.7
	Others	3.2

More than one in every five of sampled household heads have been exposed to their towns' microclimatic condition by virtue of their home locations since birth while another 51% have been for nothing less than a decade or more. A climatic condition was characterized by an upward temperature trend and erratic precipitation occasioning heat waves, flash floods, and drought. This exposure level might imply high vulnerability especially if low adaptive capacity compliments.

Household heads across the district are dominated by females, about 51% of the entire sample. The results from gender analysis were buttressed as a reflection of the situation in almost all the municipalities in the district according to [71] having more females than males. However, most momentous is Greater Giyani and Greater Letaba municipalities with both Giyani and Modjadjiskloof as administrative headquarters. The scenario was significantly adduced to domestic group's reorganization, low levels of literacy and affluence, worsened by men's mobility for greener pasture away from homes. With some comparable equilibrium in figures flanked by males and females, Phalaborwa, however, has more males than females at working age categories. This may best explain the reason for employments in mining sector by young men than women, coupled with more young women's unwillingness to take on dirty and hard jobs. However, there is a need for a more focus employment balance while gender equity is emphasized in labor.

The number of children per household, in both male and female categories, according to Table 2 depicts that households with no male child accounted for 3.6% while those with no female child are 14.7% across the district. Those categories with one male and female child are 42.5% and 45% 183, respectively, and forms the majority, while the category with three of each of the sexes claims 12.3% (male) and 4.6% (female) accordingly. This implies more male children in households across the district depicting the likelihood to reduce vulnerability. This is not only a reflection of high poverty among women per se but also the apportioned societal gendered roles and restrictions, see [72–74].

3.3. Household Vulnerability Levels

The results of vulnerability analyses reveal that there exists a high exposure level (92%) to changing climate in Mopani (Table 3). It was also found that Nkowankowa, Giyani, and Phalaborwa towns recorded the highest proportion (96.58%, 91.50%, and 89.28%, respectively) of households in exposed category. Being the town with the least (though still high) in the category, Modjadjiskloof accounted for about 60%. Tzaneen recorded the lowest mean exposure score (7.9%), and Phalaborwa the highest mean score (12.42%). Hoedspruit, Modjadjiskloof, and Giyani have almost the same average exposure score as summarized in Table 3. The high level of exposure across the towns reflects the consistent regional warm temperature, as over 72% have lived and exposed to the prevailed climatic condition continuously for over a decade. However, the variation in exposure levels in the towns was accounted for by the varying households' economic engagements like Hoedspruit with largest proportion of households in climate-fed venture. The towns' central areas were also dominated by impervious surface cover with attendant heatwaves and escalated runoff.

Low level of sensitivity is generally evidenced in the district with 80.24% of the sampled population to be insensitive (Table 3). The Sensitivity Index across the six towns is equally very low, except in Hoedspruit town where 38.9% of the households are sensitive and a similar proportion is very sensitive. The situation was similar in Giyani town with 21.54% sensitive group and 4.62% very sensitive households. The low levels of sensitivity in the towns explains the low level of recorded casualties (human lives and livestock) in a general term and the low level of reported climate-related ailments. Across the Mopani District, a significant proportion of sampled households (76.2%) has capacity to adapt to climate change impacts. Tzaneen had the highest adaptability rating with an aggregate of 86.5%, while Modjadjiskloof of the six towns has the least (28%) followed by Nkowankowa with 40% (Table 3). With 31.28%, Hoedspruit had the highest mean adaptive capacity, while Phalaborwa followed with 20.51% and Tzaneen with the least. The backlogs of infrastructure and services, coupled with unemployment rate and low income level, have collaboratively compromised households' affordability level to reduce their capacity to adapt to climate change in the towns.

Table 3. Summary of the Distribution Households' Vulnerability Index across towns.

Variable Indices										
				Means	**Std. Dev**	**Std. Err.**	**Lower Bound**	**Upper Bound**	**Min**	**Max**
Exposure	NE	JE	E							
Tzaneen	5.0600	53.1700	41.7700	7.9430	4.0072	0.4508	7.0455	8.8406	2.0000	21.0000
Nkowankowa	3.4200	54.2900	42.2900	9.6571	3.9946	0.3020	9.0612	10.2531	3.0000	21.0000
Hoedspruit	33.3333	16.6700	50.000	10.9722	1.8188	0.4287	10.0678	11.8767	7.0000	14.0000
Modjadjiskloof	40.000	0.0000	60.0000	10.6000	1.9551	0.6182	9.2014	11.9986	7.0000	14.0000
Phalaborwa	10.7100	32.1400	57.1400	12.4167	4.6800	0.5106	11.4010	13.4323	4.0000	21.5000
Giyani	8.5000	55.4000	36.1000	10.2577	4.4186	0.3875	9.4909	11.0244	2.4000	27.0000
Mopani	8.1000	48.2000	43.7000	10.0756	4.3410	0.1949	9.6926	10.4586	2.0000	27.0000
Sensitivity	NS	S	VS							
Tzaneen	82.3000	17.7000	0	0.0403	0.3734	0.0420	−0.0434	0.1239	−0.2200	1.5400
Nkowankowa	82.9000	17.1000	0.0000	−0.0741	0.2760	0.0209	−0.1153	−0.0329	−0.2200	0.9200
Hoedspruit	22.2000	38.9000	38.9000	0.3680	0.5492	0.1295	0.0948	0.6411	−0.2200	1.4700
Modjadjiskloof	100.0000	0.0000	0.0000	−0.1740	0.0634	0.0201	−0.2194	−0.1286	−0.2200	−0.1000
Phalaborwa	92.9000	6.000	1.2000	−0.0802	0.2596	0.0283	−0.1365	−0.0239	−0.2200	0.9200
Giyani	73.8500	21.5400	4.6200	0.0896	0.6084	0.0534	−0.0160	0.1951	−0.7000	4.2600
Mopani	80.2400	16.9400	2.8000	0.0000	0.4218	0.0189	−0.0372	0.0372	−0.7000	4.2600
Adaptive Capacity	C	NC	NCA							
Tzaneen	86.5000	12.7000	1.3000	17.3291	7.9158	0.8906	15.5561	19.1022	4.0000	38.0000
Nkowankowa	71.4000	28.6000	0.0000	21.8629	8.0590	0.6092	20.6605	23.0652	5.0000	36.0000
Hoedspruit	61.1000	27.8000	11.1000	31.2778	2.0809	0.4905	30.2430	32.3126	28.0000	34.0000
Modjadjiskloof	60.0000	40.0000	0.0000	19.0000	12.4450	3.9356	10.0971	27.9029	3.0000	34.0000
Phalaborwa	78.6000	21.4000	0.0000	20.5119	7.1515	0.7803	18.9599	22.0639	8.0000	37.0000
Giyani	74.6000	20.7800	4.6000	22.2615	9.3299	0.8183	20.6425	23.8805	5.0000	41.0000
Mopani	76.2000	22.4000	1.4100	21.3004	8.5810	0.3853	20.5434	22.0574	3.0000	41.0000
Vulnerability	LV	MV	HV							
Tzaneen	10.1300	11.3900	78.4800	0.1051	1.6343	0.1839	−0.2610	0.4712	−3.4000	4.2900
Nkowankowa	12.0000	18.4000	68.6000	−0.1562	1.6380	0.1238	−0.4006	0.0882	−3.0800	4.9900
Hoedspruit	55.6000	33.3000	11.1000	−0.1157	1.6653	0.3925	−0.9438	0.7124	−2.4500	2.9300
Modjadjiskloof	30.0000	10.0000	60.0000	0.6233	1.8053	0.5709	−0.6681	1.9147	−1.6900	2.4700
Phalaborwa	3.8000	22.6000	73.8000	−0.1838	1.5443	0.1685	−0.5189	0.1513	−3.3700	2.8400
Giyani	16.8000	20.7000	62.3000	0.2333	1.9501	0.1710	−0.1051	.05717	−3.1100	12.0600
Mopani	13.5000	19.4000	67.1000	0.0000	1.7170	0.0771	−0.1515	0.1515	−3.4000	12.0600

X^2 = 2341, p = 0.002, and d f = 2150 *NE: not exposed; JE: just exposed; E: exposed; NS: not sensitive; S: sensitive; VS: very sensitive; C: capable; NC: not capable; NCA: not capable At-all; LV: lowly vulnerable; MV: moderately vulnerable; HV: highly vulnerable (Source: Author's Field Data, 2019).

Household vulnerability across Mopani District as summarily presented in Table 3 is generally high with about 67.14% household across the district vulnerable. The HVI presents a similar scenario in the six sampled towns with exception of Hoedspruit town with about 11% of highly vulnerable households and 33.3% of moderately vulnerable. Tzaneen, Phalaborwa, Giyani, and Nkowankowa accounted for three out of every five highly vulnerable households. With X^2 = 2341 and p = 0.002 as summarized in Table 3, there is statistically significant variation in HVI level across the towns in Mopani District. This implies that households' levels of vulnerability differ from town to town. This may not be unconnected with the variations in socioeconomic attributes that informed households adaptive capacities as the towns were expose to similar climatic conditions. This led the study to investigate the extent of influence of households' socioeconomic factors on the household vulnerability levels.

3.4. The Nexus between Socioeconomic and Households' Vulnerability Index

The influence of households' socioeconomic factor on the HVI was examined, using the Ordered Logit Regression Model (OLRM) and the estimated results are summarized and presented in Table 4. In Table 4, the result indicates with respect to the influence of households' age on the households' vulnerability levels that a unit in upward shift in the age of respondent in Mopani District (i.e., going from 0–1) brings about 0.333 increase in the log odd of HVI. It then implies that the older the head of household, the higher the vulnerability level of the household. Likewise, in Nkowankowa town, a positive relationship exists with a unit increase in age of respondent increases the log odd of HVI by 2.345. The finding confirms the submission of [33] in their study of climate change vulnerability in Nordic region. However, R^2 value for all the models are low, i.e., in Nkowankowa (being the highest) where age only explained 19% of HVI variations.

Table 4. The summarized regression results socioeconomic and HVI nexus.

Variables	Mopani	Tzaneen	Nkowankowa	Hoedspruit	Modjadjiskloof	Phalaborwa	Giyani
Age	0.333 **	0.2220	2.345 ***	−0.0000	−0.3200	0.0417	0.0180
	(0.1430)	(0.3370)	(0.4660)	(0.7120)	(1.3470)	(0.3270)	(0.2290)
Pseudo R^2	0.0100	0.0030	0.1970	0.0000	0.0040	0.0000	0.0000
Wald Chi^2	5.44 **	0.4300	25.38 ***	0.0000	0.0600	0.0200	0.0100
Genders	−0.2100	−0.4980	−0.0827	1.6090	0.3200	−0.2120	−0.0680
	(0.1930)	(0.5630)	(0.3640)	(1.5360)	(1.3180)	(0.5000)	(0.3890)
Pseudo R^2	0.0010	0.0080	0.0000	0.0600	0.0040	0.0010	0.0000
Wald Chi^2	1.1800	0.7800	0.0500	1.1000	0.0600	0.1800	0.0300
Marital status	0.535 ***	0.7570	0.618 *	−0.4560	0.3200	−0.0374	0.3520
	(0.1900)	(0.5560)	(0.3380)	(1.1620)	(1.3470)	(0.5150)	(0.3570)
Pseudo R^2	0.0090	0.0180	0.0120	0.0060	0.0040	0.0000	0.0040
Wald Chi^2	7.95 ***	1.8600	3.34 *	0.1500	0.0600	0.0100	0.9800
Education qualification	−0.0706	0.384 *	−0.253 ***	0.0708	−0.788 *	−0.0793	0.299 ***
	(0.0527)	(0.2050)	(0.0835)	(0.4140)	(0.4600)	(0.1540)	(0.1120)
Pseudo R^2	0.0020	0.0520	0.0270	0.0010	0.2280	0.0030	0.0310
Wald Chi^2	1.7900	3.5000	9.2000	0.0300	2.9300	0.2700	7.1200
Income	−0.147 ***	0.0389	−0.244 **	0.1010	0.3320	−0.1030	−0.0428
	(0.0341)	(0.0833)	(0.1040)	(0.0703)	(0.2130)	(0.0804)	(0.0715)
Pseudo R^2	0.0230	0.0020	0.0230	0.0140	0.2130	0.0170	0.0010
Wald Chi^2	18.56 ***	0.2200	5.47 ***	1.4400	2.4400	1.6400	0.3600
Duration of stay	−0.1420	−0.5280	0.244 *	−0.0793	−1.067 ***	−0.2830	0.616 ***
	(0.0870)	(0.3310)	(0.1380)	(0.0870)	(0.3180)	(0.2520)	(0.2280)
Pseudo R^2	0.0040	0.0390	0.0160	0.0040	0.1100	0.0130	0.0410
Wald Chi^2	2.680	2.5400	3.1600	8.00 **	11.2600	1.2600	7.2600
No. of male child	−0.204 ***	−0.2980	−0.363 ***	−0.1620	0.2510	0.0696	−0.1370
	(0.0723)	(0.2490)	(0.1120)	(0.3830)	(0.7490)	(0.2360)	(0.1300)
Pseudo R^2	0.0100	0.0140	0.0350	0.0040	0.0060	0.0010	0.0050
Wald Chi^2	8.00 ***	1.4300	10.46 ***	0.1800	0.1100	0.0900	1.1000
Female child	−0.0486	0.00703	−0.1220	0.5090	0.3980	0.0974	−0.2190
	(0.0801)	(0.2340)	(0.1190)	(0.4560)	(0.7860)	(0.2380)	(0.1780)
Pseudo R^2	0.0010	0.0000	0.0040	0.0530	0.0260	0.0020	0.0090
Wald Chi^2	0.3700	0.0000	1.0400	1.2400	0.2600	0.1700	1.5200
Livelihood Diversification	−0.729 *	−3.092 *	0.1030	–	−9.24 ***	−0.3910	−1.29 *
	(0.4140)	(1.6790)	(0.8000)	–	(2.7960)	(0.9110)	(0.7680)
Pseudo R^2	0.0030	0.0430	–	–	0.2420	–	0.0110
Wald Chi^2	3.10 *	3.39 *	0.0200	–	10.91 ***	0.1800	2.80 *

Note: Robust standard errors in parentheses; *** means p < 0.01 and significant impact at 1%, ** means p < 0.05 and significant impact at 5%, * means p < 0.1 and significant impact at 10% (Source: Author's Field Data, 2019).

The relationship between genders and HVI as indicated in Table 4 indicates an insignificant relationship existing between gender and HVI in Mopani District, with Wald Chi^2 value of 1.18, as well as the selected towns. This result is contrary to the submissions of [61] in his study of semiarid regions of Africa and Asia. However, the results reflect Wild

Chi^2= (0.78) for Tzaneen, Nkowankowa (0.05), Hoedspruit (1.10), while Modjadjiskloof, Phalaborwa, and Giyani being 0.06, 0.18, and 0.03, respectively. The regression coefficient (R^2) across the towns as well as the district are observed to be very low (Table 4), implying that gender only explains for a very small variation in HVI in the models, with Hoedspruit (being the highest) with only 6%. With these findings, it is inferred that since no significant relationship exists between genders of household and HVI levels, the HVI is not a function of household's genders in the towns as well as the district. This finding is contrary to that of [60–62].

Analyzing the nexus between marital status and HVI, the variable, marital status was dichotomized to currently married = 1 and not currently married = 0, (this includes every other category of marital status aside being currently married). The result depicts a significant unidirectional (positive) relationship where a unit increase in being married in Mopani District increases the log odd of HVI by 0.535. It is a statistically significant relationship with Wald Chi^2 = 7.95, though with low regression coefficient R^2 = 0.009. The result implies that households with married heads have higher HVI in Mopani District. The result validates the findings of [75] while examining the gendered vulnerabilities to climate change from the semiarid regions of Africa and Asia in 2016. On the contrary, the result of the examination across the selected towns shows that, except for Nkowankowa town, having significant positive relationship, with X^2 =0.618 and all the model in good fits, results for every other town is contrary and statistically insignificant (Table 4). By implication, marital status does not have any significant impact on HVI in these towns.

The ordered logit regression result for the level of educational qualification and its nexus with the HVI shows a statistically insignificant relationship in Hoedspruit, Phalaborwa, and the district. However, results for other towns depict that for Nkowankowa and Modjadjiskloof, the two variables have statistically significant and opposing (negative) relationship with X^2 = 0.253 and 0.788, respectively, while in Tzaneen and Giyani, the educational qualification has unidirectional significant relationship with HVI. This finding corroborates the findings of [76] in their assessment of the effects of educational attainment on climate risk vulnerability.

The number of male children in a household reflected an opposing (negative) relationship with HVI to climate change. Table 4 shows that a unit increase in the number of male children in a household reduces the log odd of HVI in Mopani as a district and Nkowankowa town by 0.204 and 0.363, respectively. This suggests that the higher the number of male children in a household, the lower the HVI. However, for other towns, number of male children does insignificantly relate with HVI. For the number of female children and HVI to climate change, the relationship across the entire Mopani District, as well as the selected towns, is statistically insignificant (Table 4).

Income as another important socioeconomic component was examined against HVI. Table 4 shows that income from primary source has a significant negative relationship with HVI to climate change in Mopani District as a whole, with X^2 =18.56 and $p < 0.01$. The result indicated that a unit increase in income reduces the log odd of HVI to climate change by 0.147 in Mopani. The result across towns shows that an insignificant relationship occurs between the two variables, with Chi^2 values of 0.22 (Tzaneen), 2.44 (Modjadjiskloof), 1.64 (Phalaborwa), and 0.36 (Giyani) and $p > 0.05$ in all cases. However, for Nkowankowa town, a unit reduction in income heightens the log odd of HVI to climate change by 0.244, see Table 4. This relationship is found to be statistically significant with X^2 = 5.47 and $p = p < 0.01$. The submission corroborates that of [40,77].

An investigation into the nexus between duration of stay and HVI shows that Nkowankowa has positive significant relationship between length of stay and HVI, with a unit increase in length of stay occasioning an upward shift in log odd of HVI by 0.244. The result implies that the longer the length of stay, the higher the HVI to climate change in Nkowankowa. However, towns like Modjadjiskloof and Giyani show negative relationships that are statistically significant between length of stay in locality and HVI to climate change. This implies that in these two towns, the longer the length of stay in locality, the lower the HVI to climate change, with the two models significant and in good fit, and X^2 = 11.26 and 7.26 with p = 0.01, respectively, for Modjadjiskloof and Giyani. With this result, one can infer that the longer the duration of stay in locality by household, the lower the HVI to climate change in both Modjadjiskloof and Giyani and vice versa. However, length of stay in locality does not significantly relates with HVI to climate change in Mopani as a district and Tzaneen and Phalaborwa towns.

In case of Vulnerability Index and the Livelihood Diversification Index (LDI) across the district of Mopani, a unit increase in (LDI) reduces HVI log odd by 0.729. This implies that the more diversified the livelihood of a household is, the lower the level of vulnerable to climate change. Similar results were obtained for Tzaneen, Modjadjiskloof, and Giyani. For these three towns, a unit increase in LDI reduces Vulnerability Index by 3.092, 9.238, and 1.29, respectively, in the three towns. On the other hand, contrary results were obtained for Nkowankowa and Phalaborwa, where Livelihood Diversification Index does not significantly affect Vulnerability Index with p = >0.05. The results obtained from the four models depict statistically significant scenario and all in good fit, with X^2 = 0.10, 3.39, 10.91, and 2.80 while the latter two models are not statistically significant. By implication, an increase in the diversification in livelihood among households will reduce the vulnerability level in Tzaneen, Modjadjiskloof, and Giyani towns. This result suggests that any innovative idea that can facilitate diversification in these towns will significantly enhance the households' adaptive capacity and invariably reduces their vulnerability levels.

4. Discussion

In line with the research questions, three important findings can be drawn from this work. First, climate is changing and the trend reported during the period of examinations revealed an increasing trend in both minimum and maximum temperature, while reducing erratic trend was recorded in rainfalls. The scenario was predicted to have come to stay for some decades to come. Thus, in a business as usual scenario, living and livelihood will continue to be threatened. The development is considered dangerous for households, as continuous subjection to reducing precipitation suggests an intensified risk of water stress [8]. This will sadly aggravate the plights and escalate the several millions of people in Africa that are already battling with acute water trauma, water pressure, and water unavailability. This burden would mostly be confronted by the most vulnerable (women, elderly, and children) class on one hand [11]. On the other hand, the upward trend in both maximum and minimum surface air temperature significantly evidenced local warming with varying degrees of looming costs, ranging from discomfort to heat-related ailments (asthma, malaria, measles, typhoid fever, cholera, diarrhea, and others). Climate change-related challenges are already constituting serious threat to water resources in South Africa, overwhelming food security, compromising health, destroying infrastructure, as well as endangering the ecosystem services and biodiversity [19]. Bearing in mind the high level of poverty and inequality in South Africa, these critical impacts will be devastating if left unabated. This justifies the need for a pragmatic and integrated interventions to stem the negative impacts of the changing climate phenomenon. The strategic intervention should be eco-friendly and sustainable. Aggressive tree (fruits) planting, among other greening strategies should be embarked upon, which will not only reduce heat (adaptation) and sink carbon (mitigation) but also equally provide food (nutrients) as well as generate additional income for the households.

Second, the four estimated indexes of Household Vulnerability (Exposure index (EI), Sensitivity Index (SI), and Adaptive Capacity Index (ACI) aggregate Household Vulnerability Index (HVI)) suggested: (i) the selected towns across the district are very high in terms of EI, but relatively low in SI and relatively high in ACI, while the estimated aggregate HVI is equally high across the district as well as in the selected towns, except Hoedspruit with relatively low HVI. This proves that urgent attention is required by all stakeholders (particularly government) towards a pragmatic, integrated, and inclusive adaptation policy, programs, and projects to curtail HVI. Although, low level of sensitivity is generally evidenced in the district, nonetheless, efforts must not be surrendered because of the dynamic nature of climate. Increased investment in the basic infrastructure and services development supported by livable housing through Public–Private–Partnership will reduce the households' exposure level and further boost their adaptability of the vulnerable households to the adversities of climate change, thus reducing the vulnerability. The high level of EI in the selected towns was exacerbated by the process of urbanization that is characterized by deforestation and impervious dominance. These towns will require more resources from local and districts municipalities to create a nature-balance development, as they are all prone to becoming more urbanized in the coming decades. This manner of growth is capable of reducing household vulnerability and enhance sustainable development in the context of climate change.

Although commendable attempts by South African national government has been made to develop a National Climate Change Response White Paper, it is unable to actualize the mainstreaming of adaptation policy in daily planning practice as well as medium and long-term planning, at every level (particularly the local municipality) of governance [78]. Therefore, the need to expedite the process of mainstreaming adaptation policy into day-to-day spatial planning activities as well as prioritizing climate change matter in municipality's long-term plan is no time better than now. This require a strong political will because the five-year term of political tenure that was unfavorable to long-term issues as climate change makes them suffer lack of political attention.

Third, the key contributing socioeconomic factors to households' vulnerability were uncovered, which should provide yardstick and position for decision-making in mitigating households' vulnerability in the district and beyond. (a) The manifestation of HVI across the district is influenced decreasingly in the district and Nkowankowa town. This proves that attention is needed to enhance households' income across the district and Nkowankowa, while in other selected towns, the influence of income on HVI is yet not a serious issue. However, with majority of the household heads having financial resources at their disposals signifies a higher household affordability. A further enhancement of economic engagement of households across the district will further boost the households' affordability level and resultantly reduce their vulnerability level. (b) The number of household heads decrease with increased age implies that younger household heads are more than the older ones with majority being females. The aged were more prone to vulnerability to the impacts of climate change in the district as applicable to Nkowankowa, whereas in the cases of Tzaneen, Phalaborwa, and Giyani towns, the influence of age on vulnerability were yet not a serious issue. Thus, extra efforts are required at district municipal level to facilitate the adaptability of the old (aged) with reduction in their exposure level to climatic factors. The scenario of young household head dominating in the selected town suggests that any program that is targeted towards economic empowerment in the district with special focus on young people will impact significantly across the selected towns. This will equally be true of programs that focus on climate change adaptation and early warning propagation in the district, targeting this population category. (c) There is no evidence of statistical significance of gender's influence on the HVI in the study area. However, women accounted for more than half of the entire household in the district. The fact that females outnumber males in every age category, it is imperative that gender issues be taken seriously in climate change-related matters. The men's and gender fora that was established in the district to handle gender-related matters and to facilitate the participation of families, communities, and work place discussions but suffered from budgetary suffocation should be resuscitated, with more creative and involving efforts to bring about the desired turn around impacts. (d) Being married in Mopani District influenced higher vulnerability, but not statistically significant in the selected towns (except in Nkowankowa). With high proportion of household heads in either divorced, single, widow, or separated category may suggest an additional pressure from extra responsibility and burden to adapt for these classes of household during and after climate change extreme events, because they lack supports, as a result of absence of partners. (e) In Tzaneen, Modjadjiskloof, Giyani, and Nkowankowa higher educational qualification reduces HVI. This implies that an improved education among households can help to reduce HVI to climate change [79]. Therefore, further adjustment strategies and more work are required to get more citizen acquire additional qualifications, to enhance their resilience and reduce their vulnerability to climate change. (f) The nonclimate-fed nature of economic activities of significant proportion of households signaled a lower sensitivity. Thus, a collaborative effort by governments at various levels must be mobilized to facilitate jobs creation, through the green economic policy of the national government in renewable energy, this should be championed by the private sector. (g) Moreover, more than one in every two residents had multiple sources of income, thus, the potentials of households' enhanced affordability (with extra incomes) and opportunity to swap among income source options in case one is affected by climate change adversity are higher. This is a pointer to a stronger capacity to cope with climate change hazards and a lowered vulnerability. However, policy and intervention efforts of government should be geared towards income diversification to strengthen the citizens' buffer for cushioning the households' susceptibility during and after climate change extreme events.

The upcoming attempt at national level to scope long-term adaptation scenarios aiming at focusing on creating linkages across sectors in climate change adaptation and responses should pay more attention to active local level participation. Although some notable city-scale and project-based adaptation interventions were already executed, yet the huge institutional challenges still persist. The best time is now to make climate change adaptation responses the responsibility of the local municipality, and they should be household based. This approach will enhance the effectiveness of spatial planning-climate change adaptation designated strategy [32], by conducting assessment on location-specific basis, to cater for the peculiarities and priorities of the local community. Thus, macroplanning policies will be enabled by micro level input [80], which will in a long run mitigate the consistent failure of microlevel-based policy with no sufficient local input. Hence, there is the need to emphasize municipal governments' collaboration with private sector to drive the facilitation of private households' indigenous (microlevel) capacities for adaptation and its mainstreaming in urban planning across the district.

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References

1. Nhuan, M.T.; Tue, N.T.; Hue, N.T.H.; Quy, T.D.; Lieu, T.M. An indicator-based approach to quantifying the adaptive capacity of urban households: The case of Da Nang city, Central Vietnam. *Urban Clim.* **2016**, *15*, 60–69. [CrossRef]
2. Hulme, M.; Barrow, E.M.; Arnell, N.W.; Harrison, P.A.; Johns, T.C.; Downing, T.E. Relative impacts of human-induced climate change and natural climate variability. *Nature* **1999**, *397*, 688–691. [CrossRef]
3. Schlyter, P.; Stjernquist, I.; Bärring, L.; Jönsson, A.M.; Nilsson, C. Assessment of the impacts of climate change and weather extremes on boreal forests in northern Europe, focusing on Norway spruce. *Clim. Res.* **2006**, *31*, 75–84. [CrossRef]
4. Frumkin, H.; Fried, L.; Moody, R. Aging, climate change, and legacy thinking. *Am. J. Pub. Health* **2012**, *102*, 1434–1438. [CrossRef] [PubMed]
5. Engelbrecht, F.; Adegoke, J.; Bopape, M.J.; Naidoo, M.; Garland, R.; Thatcher, M.; McGregor, J.; Katzfey, J.; Werner, M.; Ichoku, C.; et al. Projections of rapidly rising surface temperatures over Africa under low mitigation. *Environ. Res. Lett.* **2015**, *10*, 085004. [CrossRef]

6. Raper, S.C.B.; Wigley, T.M.L.; Warrick, R.A. Global sea-level rise: Past and future. In *Sea-Level Rise and Coastal Subsidence*; Springer: Dordrecht, The Netherland, 1996; pp. 11–45.
7. Huq, S.; Reid, H.; Konate, M.; Rahman, A.; Sokona, Y.; Crick, F. Mainstreaming adaptation to climate change in least developed countries (LDCs). *Clim. Poli.* **2004**, *4*, 25–43. [CrossRef]
8. Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; Van Der Linden, P.J.; Hanson, C.E. *Climate change 2007: Impacts, adaptation and vulnerability*; IPCC 2007; Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change; Cambridge University Press: Cambridge, UK, 2007.
9. Watts, M.J. *Silent violence: Food, famine, and peasantry in northern Nigeria*; University of Georgia Press.: Athens, GA, USA, 2013; Volume 15.
10. Montgomery, M.R. The urban transformation of the developing world. *Science* **2008**, *319*, 761–764. [CrossRef]
11. Thomas, T.; Tom, M.; Emily, P.; Bruce, G. Urban Governance for Adaptation: Assessing Climate Change Resilience in Ten Asian Cities. Institute of Development Studies at the University of Sussex: Brighton, UK, 2009. Available online: https://www.ids.ac.uk/files/dmfile/Wp315.pdf (accessed on 20 May 2019).
12. Thompson, A.A.; Matamale, L.; Kharidza, S.D. Impact of climate change on children's health in Limpopo Province, South Africa. *Int. J. Environ. Res. Public Health* **2012**, *9*, 831–854. [CrossRef]
13. Adeniji, G.; Ogundiji, B. Climate adaptation in Nigerian cities; Regularising informal and illegal settlements in Ibadan. Proceedings of World Bank Fifth Urban Research Symposium, Marseille, France, 28–30 June 2009; pp. 1–21.
14. Tomlinson, R. Urbanization in post-apartheid South Africa. Routledge: Abingdon, UK, 2017.
15. Ziervogel, G.; New, M.; van Garderen, E.A.; Midgley, G.; Taylor, A.; Hamann, R.; Stuart-Hill, S.; Myers, J.; Warburton, M. Climate change impacts and adaptation in South Africa. *WIREs Clim. Chang.* **2014**, *5*, 605–620. [CrossRef]
16. Plecher, H. Total population of South Africa 2024. Available online: https://www.statista.com/statistics/578867/total-population-of-south-africa/2019 (accessed on 18 April 2020).
17. WBT. World Bank Open Data. 2018. Available online: https://data.worldbank.org/country/ZA (accessed on 18 May 2020).
18. Christensen, J.H.; Christensen, O.B. A summary of the PRUDENCE model projections of changes in European climate by the end of this century. *Climat. Chang.* **2007**, *81*, 7–30. [CrossRef]
19. DEA. *Response Measures for South African Biomes*; Department of Environmental Affairs: Pretoria, South Africa, 2011.
20. Sánchez-Rodríguez, R.; Seto, K.C.; Solecki, W.D.; Kraas, F.; Laumann, G. *Science Plan: Urbanization and Global Environmental Change*; International Human Dimensions Programme, Annual Report; Köllen Druck + Verlag GmbH: Bonn-Buschdorf, Germany, 2005.
21. Satterthwaite, D. The implications of population growth and urbanization for climate change. *Environ. Urbaniz.* **2009**. [CrossRef]
22. Jörn, B.; Matthias, G.; Frauke, K.; Nguyen, Q. Adaptive urban governance: New challenges for the second generation of urban adaptation strategies to climate change. *Sustain. Sci.* **2010**, *5*, 185–206.
23. Bigio, A. Adapting to climate change and preparing for natural disasters in the coastal cities of North Africa. Proceedings of Urban Research Symposium, Cities and Climate Change: Responding to an Urgent Agenda, Marseille, France, 28–30 June 2009.
24. Hallegatte, S. A cost effective solution to reduce disaster losses in developing countries: Hydro-meteorological services, early warning, and evacuation. The World Bank: Geneva, Switzerland, 2012.
25. Chikoore, H. Drought in southern Africa. PhD Thesis, University of Zululand, South Africa, Durban, 2016.
26. Munyai, R.B. An assessment of community flood vulnerability and adaptation: A case study of Greater Tzaneen Local Municipality. Ph.D. Thesis, University of Venda, Thohoyandou, South Africa, 2017.
27. Mopani District Municipality Integrated Development Plan. Available online: http://www.mopani.gov.za/documents/idp.php2018/19 (accessed on 10 May 2020).
28. LDEDET; Limpopo Provincial Government. *Environmental Implementation Plan 2016-2020*, 2nd ed.; Limpopo Department of Economic Development, environment and Tourism: Polokwane, South Africa, 2016.
29. Khwashaba, M.E. Vulnerability and resilience in the Mopani district municipality in a changing climate. Ph.D. Dissertation, North-West University, Vanderbijlpark, South Africa, 2018.
30. Ndamulelo, N. Vulnerability and Adaptation to Drought Hazards in Mopani District Municipality, South Africa: Towards Disaster Risk Reduction. Ph.D. Dissertation, University of Venda, Thohoyandou, South Africa, 2019.
31. Manyika, J. Bigdata: The next frontier for innovation, competition, and productivity. Available online: http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Big_data_The_next_frontier_for_innovation2011 (accessed on 12 June 2020).
32. Tanner, T.; Mitchell, T.; Polack, E.; Guenther, B. Urban governance for adaptation: Assessing climate change resilience in ten Asian cities. *IDS Work. Paper.* **2009**, *2009*, 1–47. [CrossRef]
33. Carter, T.R.; Fronzek, S.; Inkinen, A.; Lahtinen, I.; Lahtinen, M.; Mela, H.; O'Brien, K.L.; Rosentrater, L.D.; Ruuhela, R.; Simonsson, L.; et al. Characterising vulnerability of the elderly to climate change in the Nordic region. *Region. Environ. Chang.* **2016**, *16*, 43–58. [CrossRef]
34. Waiyaki, E.; Angwenyi, H.O.R.; Muriuki, T. An assessment of the percieved socioeconomic impacts of climate change on the community of Faza Island, Lamu East Distrcit, Kenya. 2012, pp. 83–118. Available online: https://www.oceandocs.org/bitstream/handle/1834/6959/ktf0331.pdf?sequence=2 (accessed on 3 May 2020).
35. DEA. *Environmental Management Framework for the Olifants and Letaba river catchment areas*; Report (OLEMF); Environmental Management Framework Report; Department of Environmental Affairs: Republic of South Africa, 2009; Volume 1.

36. MD. MOPANI DISTRICT. Available online: https://municipalities.co.za/districts/view/28/Mopani-District-Municipality#demographic)2016 (accessed on 12 April 2019).
37. Nkondze, M.S.; Masuku, M.B.; Manyatsi, A. Factors affecting households' vulnerability to climate change in Swaziland: A case of Mpolonjeni area development programme (ADP). *J. Agricult. Sci.* **2013**, *5*, 108. [CrossRef]
38. Nelson, R.; Kokic, P.; Crimp, S.; Martin, P.; Meinke, H.; Howden, S.; de Voil, P.; Nidumolu, U. The vulnerability of Australian rural communities to climate variability and change: Part II—Integrating impacts with adaptive capacity. *Environ. Sci. Polic.* **2010**, *13*, 18–27. [CrossRef]
39. Vincent, K. *Creating an index of social vulnerability to climate change for Africa*; Tyndall Centre Working Paper No. 56; University of East Anglia: Norwich, UK, 2004; pp. 1–50.
40. Adger, W.N. Social vulnerability to climate change and extremes in coastal Vietnam. *World Develop.* **1999**, *27*, 249–269. [CrossRef]
41. Gbetibouo, G.A.; Ringler, C. *Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment*; International Food Policy Research Institute (IFPRI); Center for Environmental Economics and Policy in Africa (CEEPA): Washington, DC, USA, 2009.
42. Cutter, S.L. Vulnerability to environmental hazards. *Progr. Human Geogr.* **1996**, *20*, 529–539. [CrossRef]
43. Gallopín, G.C. *A systems approach to sustainability and sustainable development*; Economic Commission of Latin America and the Caribbean: Santiago, Chile, 2003.
44. Cutter, S.L.; Boruff, B.J.; Shirley, W.L. Social vulnerability to environmental hazards. *Soc. Sci. Quart.* **2003**, *84*, 242–261.
45. Filmer, D.; Pritchett, L.H. Estimating wealth effects without expenditure data—or tears: An application to educational enrollments in states of India. *Demography* **2001**, *38*, 115–132.
46. McCullagh, P. Regression models for ordinal data. *J. Royal Statist. Soc. Ser. B (Method.)* **1980**, *42*, 109–127. [CrossRef]
47. Dragos, C.; Veres, V. Romanian Farmers' Market-A Multinomial Logit Model Approach. Zbornik radova Ekonomskog fakulteta u Rijeci, casopiš za ekonomsku teoriju i praksu-Proceedings of Rijeka Faculty of Economics. *J. Econom. Bus.* **2007**, *25*, 291–308.
48. Mitchell, T.D.; Jones, P.D. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *Int. J. Climat.* **2005**, *25*, 693–712. [CrossRef]
49. Harris, I.; Jones, P.D.; Osborn, T.J.; Lister, D.H. Updated high-resolution grids of monthly climatic observations–the CRU TS3. 10 Dataset. *Int. J. Climat.* **2014**, *34*, 623–642. [CrossRef]
50. Brooks, N.; Adger, W.N.; Kelly, P.M. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Glob. Environ. Chang.* **2005**, *15*, 151–163. [CrossRef]
51. Kuo, Y.L.; Xiao, D.J.; Lin, Y.L.; Hsieh, H.W.; Chang, M.C. *Review of Vulnerability of Natural Disasters and Factors of Social Vulnerability*; National Science and Technology Center for Disaster Reduction: New Taipei, Taiwan, 2009. (In Chinese)
52. Chen, L.Y. *The Assessment of Typhoon and Flood Vulnerabilities in Ta-Chia River Basin: The Application of Analytic Network Process*; Department of Real Estate & Built Environment, College of Public Affairs, National Taipei University: New Taipei, Taiwan, 2009. (In Chinese)
53. Chen, Y.C.; Li, C.H.; Su, W.R.; Tsai, Y.F. Using AHP to map flood vulnerability of the Ping-Tung coastal area. *J. Taiwan Water Conserv.* **2011**, *59*, 30–46 (In Chinese). (In Chinese)
54. Dwyer, A.; Zoppou, C.; Mielsen, O.; Day, S.; Roberts, S. *Quantifying Social Vulnerability: A Methodology for Identifying Those at Risk to natural Hazards*; Geoscience Australia Record; Australia Government: Canberra, Australia, 2004.
55. Marshall, K.E.; Sinclair, B.J. Repeated stress exposure results in a survival–reproduction trade-off in Drosophila melanogaster. *Proc. Royal Soc. London B: Biolog. Sci.* **2009**. [CrossRef]
56. Daze, A.; Ambrose, K.; Ehrhart, C. *Climate vulnerability and capacity analysis handbook*; Care International: Atlanta, GA, USA, 2009.
57. Fekete, A.; Damm, M.; Birkmann, J. Scales as a challenge for vulnerability assessment. *Nat. Hazards* **2009**, *55*, 729–747. [CrossRef]
58. Yap, K.H. *Assessment of Social Vulnerability of Environmental Disasters in Taiwan*; Taiwanese Sociological Association: Taipei, Taiwan, 2010. (In Chinese)
59. Chen, L.C. *A Study on the Vulnerability and Resilience Assessment of Spatial Planning and Management in Community-Level Area*; National Science Council: Taipei, Taiwan, 2009. (In Chinese)
60. Slovic, P. *Perception of Risk*; Earthscan: London, UK, 2000.
61. Lioubimtseva, E.; Henebry, G.M. Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. *J. Arid Environ.* **2009**, *73*, 963–977. [CrossRef]
62. Füssel, H.M. Vulnerability: A generally applicable conceptual framework for climate change research. *Glob. Environ. Chang.* **2007**, *17*, 155–167. [CrossRef]
63. Jorgenson, M.T.; Romanovsky, V.; Harden, J.; Shur, Y.; O'Donnell, J.; Schuur, E.A.; Kanevskiy, M.; Marchenko, S. Resilience and vulnerability of permafrost to climate change. *Canad. J. For. Res.* **2010**, *40*, 1219–1236. [CrossRef]
64. Strauss, B.H.; Ziemlinski, R.; Weiss, J.L.; Overpeck, J.T. Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. *Environ. Res. Lett.* **2012**, *14*, 014033. [CrossRef]
65. Woodroffe, C.D. Reef-island topography and the vulnerability of atolls to sea-level rise. *Glob. Planet. Chang.* **2008**, *62*, 77–96. [CrossRef]
66. Sallawu, H.; Tanko, L.; Coker, A.; Sadiq, M. Livelihood and income diversification strategies among rural farm households in Niger State, Nigeria. *Asian J. Agricult. Extens.Econom. Soc.* **2016**. [CrossRef]

67. Awotide, O.D.; Kehinde, A.L.; Agbola, P.O. Poverty and rural livelihood diversification among farming households in southwest Nigeria. *J. Food Agricult. Environ.* **2010**, *8*, 367–371.
68. Apata, T.; Apata, O.; Igbalajobi, O.; Awoniyi, S. Determinants of rural poverty in Nigeria: Evidence from small holder farmers in South-western, Nigeria. *Int. J. Sci. Tech. Edu. Res.* **2010**, *1*, 85–91.
69. Piya, L.; Maharjan, K.L.; Joshi, N.P. Livelihood strategies of indigenous nationalities in Nepal: A case of Chepangs. *CiNii* **2011**, *17*, 99–113.
70. Yamba, S.; Appiah, D.O.; Pokuaa-Siaw, L.; Asante, F. Smallholder farmers' livelihood security options amidst climate variability and change in rural Ghana. *Scientifica* **2017**. [CrossRef]
71. Cannon, T. Gender and climate hazards in Bangladesh. *Gend. Develop.* **2002**, *10*, 45–50. [CrossRef]
72. Skutsch, M.M. Protocols, treaties, and action: The climate change processes viewed through gender spectacles. *Gend. Develop.* **2002**, *10*, 30–39. [CrossRef]
73. UNDP. Gender and Climate Change: Impact and Adaptation. Available online: http://asia-pacific.undp.org/practices/gender/publications/Gender_and_Climate_Change-Impact_and_Adaptation-5.pdf2009 (accessed on 23 July 2020).
74. Nelson, V.; Meadows, K.; Cannon, T.; Morton, J.; Martin, A. Uncertain predictions, invisible impacts, and the need to mainstream gender in climate change adaptations. *Gend. Develop.* **2002**, *10*, 51–59. [CrossRef]
75. Rao, N.; Lawson, E.T.; Raditioaneng, W.N.; Solomon, D.; Angula, M.N. Gendered vulnerabilities to climate change insights from the semi-arid regions of Africa and Asia Information brief. 2016. Available online: www.idl.bnc-dspacedirect.org/handle/10625/57375 (accessed on 23 November 2019).
76. Striessnig, E.; Lutz, W.; Patt, A.G. Effects of educational attainment on climate risk vulnerability. *Ecol. Soc.* **2013**, *18*. [CrossRef]
77. Moser, C.; Satterthwaite, D. Toward pro-poor adaptation to climate change in the urban centers of low-and middle-income countries. In *Social dimensions of climate change: Equity and vulnerability in a warming world*; World Bank Group: Geneva, Switzerland, 2010; pp. 231–258.
78. Van Aelst, K.; Holvoet, N. Climate change adaptation in the Morogoro Region of Tanzania: Women's decision-making participation in small-scale farm households. *Climat. Develop.* **2018**. [CrossRef]
79. Piya, L.; Joshi, N.P.; Maharjan, K.L. Vulnerability of Chepang households to climate change and extremes in the Mid-Hills of Nepal. *Climat. Chang.* **2016**, *135*, 521–537. [CrossRef]
80. Niang, I.; Ruppel, O.C.; Abdrabo, M.A.; Essel, A.; Lennard, C.; Padgham, J.; Urquhart, P. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects*; Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; 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., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 1199–1265.