Chapter

Households' Adaptation to Climate Change Hazards in Semi-Arid Region of Mopani, South Africa

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Abstract

New climate change realities are no longer a doubtful phenomenon, but realities to adapt and live with. Its cogent impacts and implications' dispositions pervade all sectors and geographic scales, making no sector or geographic area immune, nor any human endeavor spared from the associated adversities. The consequences of this emerging climate order are already manifesting, with narratives written beyond the alterations in temperature and precipitation, particularly in urban areas of semi-arid region of South Africa. The need to better understand and respond to the new climate change realities is particularly acute in this region. Thus, this chapter highlights the concept of adaptation as a fundamental component of managing climate change vulnerability, through identifying and providing insight in respect of some available climate change adaptation models and how these models fit within the premises and programmes of sustainable adaptation in semi-arid region with gaps identification. The efforts of governments within the global context are examined with households' individual adaptation strategies to climate change hazards in Mopani District. The factors hindering the success of sustainable urban climate change adaptation strategic framework and urban households' adaptive systems are also subjects of debate and constitute the concluding remarks to the chapter.

Keywords: households, adaptation, climate change, semi-arid, South Africa

1. Introduction

Adaptation to climate change hazard is attracting growing international attention as confidence in forecasts for climate change is rising [1]. Developing countries have unique adaptation needs because of high vulnerabilities and the tendencies to bear a significant share of global climate change costs [2]. The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report noted that public recognition and concern about the global environmental issue of human-induced climate change has reached unprecedented heights. Research into the drivers, both natural and anthropogenic, the character and magnitude, their impact on human living conditions and ecosystems, and possible approaches to adaptation and

mitigation, as well-as understanding of the complex relationships with ecosystems interacting with them, has also increased in recent years [3].

While anthropogenic greenhouse gas emissions, which aggravates climate change are mainly from rich industrialized countries, the consequences of which are projected to be relatively acute and more serious in developing countries particularly in semi-arid region of Africa, where, for instance, rise in temperature and reduction in precipitation are likely to result in high evaporation, with serious health related consequences [4, 5]. South Africa like many developing countries' national economies and employment heavily rely on climate-fed activities [6], coupled with high poverty levels, limited technological and weak institutional ability to adapt to climate change qualifies for classical case in which urban populations (children, elderly, persons with disabilities and women) are more susceptible to climate change adversities [7].

Nonetheless, climate change adaptation strategies and projects on one hand, still focus mainly on sustainable rural adaptation, without much attention on urban areas, especially small and medium towns, where there is increasing household vulnerability and climate change pressures [8]. Current literature on adaptation to climate change in urban areas are largely coastal and big city biased [9–11]. On the other hand the early years of international climate change studies' attention on adaptation as a strategy was compromised by mitigation and impacts [12]. In recent years, several models incorporate mitigation, as an anthropogenic intervention to the changing climate [3] and has rapidly escalated, while models that incorporate adaptation are still in their various stages of development, advancement and yet to reach maturity [13].

Inherently, it has become urgent to focus on approaches and instruments that assist with the reduction and reversal of the prevailing and unescapable climate change hazards, coupled with the need to maximize the immediate manifestation of the net benefits of adaptation [14]. As an essential policy response, local level and individual (including private) households' adaptation strategies to climate change needs to be apportioned the desired priority in climate change policy agendas at all levels and scales of governance.

This chapter aims through a holistic approach, to provide the highlights of the South African governments at several levels and scales of governance to advance adaptation and mitigation urban household practices and interventions. This analysis and discussion is conducted within the global context of existing adaptation framework that incorporate the local level and individual households' (private) adaptive practices, efforts and initiatives. Furthermore, the chapter also identifies some of the key issues hindering the success of urban adaptation policies and interventions in the region.

In brief, the chapter places in perspective, the basic steps necessary for a more participatory urban management for sustainable households' adaptation to climate-related hazards in the semi-arid region of Mopani, South Africa.

2. Literature review

2.1 Adaptation, a fundamental component of climate change vulnerability

The new climate is no longer a doubtful global reality, but a phenomenon that we need to learn to live with for years to come [11]. Its disposition to leaving no facet of human endeavor immune from its negative externalities are unpredictable and presents very worrisome realities for the contemporary society and urban communities [15] largely manifesting beyond alterations in temperature and precipitation threatening the existence of humanity, particularly in Africa, and other developing countries [3, 16].

Adaptive ability to climate change hazard is considered a new field of endeavor, serving as a converging point for several experts, ranging from development experts, climate scientists, planners, disaster managers, and a host of other experts and disciplines/fields [17]. This has brought about divergent conceptual models to the study of vulnerability and adaptation, though addressing similar issues and emphasizing similar processes, but rather with different vocabularies [18]. The growth in the body of literature on the conceptual issue has brought about a confusing set of terminologies with unclear relationship [16, 19, 20]. However, notwithstanding the differences, the recognitions and understanding of the need to curtail the adversities of the phenomenon is the most crucial.

The frustrations from the present context of failure to successfully mitigate greenhouse gas emissions and curtail its associate developmental issues has resulted in adaptation becoming not only an inevitable strategy to frustrate vulnerability but also an integral social components for vulnerability assessment [16, 21]. However, this course of action is still in the trial periods of being considered relevant, particularly within science and policy contexts [22, 23].

Adaptation to climate change, is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" [24] as cited in [25]. It can take various dimensions from being reactive or anticipatory, private or public, and autonomous or planned [24], it can equally either be active or passive [26], spontaneous or prompted by alteration in conditions [27]. It is however a phenomenon that its success is hinges on the adoption of several co-and interdependent factors, including but not limited to human, technological y and policy matters.

However, many regions of the world, particularly Africa currently have limited access to these technologies, appropriate information and financial resources [28]. The cost-effective use of adaptation strategies will therefore depend upon the availability of financial resources, technology transfer, and cultural, educational, managerial, institutional, legal and regulatory practices, both applicable domestically and internationally [29, 30]. Hence "the need to consider indigenous knowledge system-based support and intervention", for effective climate change adaptation strategies as one of the under-studied and utilized adaptation and mitigation strategy especially in Africa and developing countries in general [31].

In this chapter we further argue that like all other cultures, in Mopani District people are essentially adaptive, while exposed to environmental variability and risky circumstances in the past. These events called to question the local people's adaptive capacity in respect to environmental variability and risk within the resources and technologies available options to them [32]. Therefore, to efficiently and adequately confront the prevailing and the potential climate change hazards, indigenous knowledge (IK) must be embraced, but be enhanced particularly beyond peoples' experienced coping option ranges [33, 34]. The development and adoption of IK notion has necessitated the paradigm shift from organic adaptation approach to scientific adaptation framework models that attempt to respond to gaps ranging from adaptation needs determination, to adaptation assessment and interventions. The ensuing section of this chapter attempts at the identification of some existing adaptation models from a historical lens perspective, to typologies of these models and gaps that characterized them as well-as offering suggestions for improvements.

2.2 Climate change adaptation models

Adaptation modeling field is wide, varied and is punctuated with largely unclear disciplinary/field boundaries [35]. The definition of what are its constituents is

equally open to numerous interpretations, with tagging of several models as adaptation models added another confusing layer to the identity and boundaries controversies [36]. In several contexts of science, models are considered very essential and key in different fields, disciplines and specialties. For instance, Evolutionary models are very important in the biological sciences disciplines while the agent-based models are a dominant feature in the social sciences [37]. Models are painstakingly built, tested, compared and revised in light of practice and feed-back loop for future lessons [36].

On a general note a classification of models on climate change adaptation was further made in line with the existing ones by [36] who identified two distinct typologies or categories of adaptation models, these include:

a. Adaptation Centered Models (ACMs); and

b. Impact Centered Models (ICMs);

Over time, advancement in understanding the consequences of climate change and policy interpretations and the associated challenges has occasioned a shift in global priority in climate change policy [37–40]. At the onset, an undeviating cause–effect style prevailed, then climate situations forms the foundation upon which future climate impacts is estimated, which then outlines the needs for adaptation. With this linear concept, on one hand, adaptation to climate change is divorced from social activities and processes where needs are informed by scientific manipulations [41, 42] on one hand. On the other hand, a more comprehensive approach where the risk assessment is guided by management of past climatic hazards experience, and adaptation recommendation are determined by the option's probability to reduce the prevailing and future climate risks while synergizing with other policy objectives, and existing management activity [43]. The later concept is currently in vogue and has enjoyed patronage from researchers, academics and policy makers, informed by its openness and comprehensiveness. Upon the determination and assessment of the needs, the choice of the form of adaptation will be made from the following identified three adaptation options:

a. No-regrets adaptation options;

b. Proactive anticipatory adaptation; and

c. Win-win adaptation

These options are not new, but the policies in various forms of decision models about them in Mopani District like other municipalities is currently characterized by limited attention and priorities [44]. Thus, making the success of the municipal adaptation efforts to appear unsuccessful.

However, a probe into the available literature and survey analysis with respect to climate change adaptation and the various adopted models in the study area, revealed some essential issues. These are policy related issues; Climate change issue; and adaptation issues. These issues form the fundamentals upon which the following identified gaps are considered critical in the existing models. These include:

2.2.1 Gaps regarding climate change adaptation models

With respect to climate change adaptation and the various adopted models, survey revealed some essential issues related to policy; Climate change issue; and

adaptation issues. These issues form the fundamentals upon which the following identified gaps are considered critical in the existing models. These include:

2.2.1.1 Gaps in relations to the current climate change adaptation models

Our findings revealed that many models on climate change adaptation, apart from being highly mathematical in nature, are based on methodological ideas that originate from the advanced economies [45], limiting their applicability in local African communities' context. This is because the assumptions upon which the models are largely based are alien to the prevailing realities in the region particularly in Semi-arid region of Mopani District in South Africa. In addition, several of these models are largely rural biased [46], or centered on metropolitan, big and coastal cities [47]. Similarly, some are rather infrastructure or sector-specific adaptation framework such as water, transport agriculture and energy sectors [48–52], while rather than local community based adaptation models, other models have focused on macro level postulations [53]. Hence the need for a flexible household-based conceptual framework model that is participatory and applicable at all levels of policy and decision making.

2.2.1.2 Gaps related to policies

Several studies have advocated for household-based climate change adaptation strategy to be anchored by municipal planning agency [54–56]. The study acknowledges that most local municipalities in the district are still relying on macro level climate change adaptation formulated policies from the national government. Despite that the impacts of climate change on both human and environment are well acknowledged in the various municipalities' planning instruments (Integrated Development Plans, Spatial Development Framework etc.), yet, little evidence exist to indicate the efforts to pragmatically and coherently address the challenges [44].

2.2.1.3 Gaps related to reporting climate change events

During data collection, our interactions with the community members, revealed that municipal governments were rather relying on reactive adaptation procedure rather than proactive. The delay in reporting of incidence of hazards have resulted in more costly, more devastating and sometimes unrepairable situations. Due to the devastating consequences often occasioned by late reporting of climate change emergencies, the climate change adaptation challenges are complex, dynamic and contextual, thereby requiring urgent attention by stakeholders.

For adaptation to be beneficial and cost effective, it should not be solely reactionary but rather proactive and anticipatory [57]. Changing climate is no longer in doubt so also is the likelihood of the trend to proceed to the coming century at an unprecedented rate in history, as projected [20, 58] with strong signals to a rising hazards for regions of such countries that are already water-stressed, like Mopani District, Limpopo province [5, 59] and other semi-arid regions of Africa are also projected.

Hence for effective communities adaptation, government at all levels have pivotal roles to play, particularly within the global context of adaptation framework as guided by the current regime. On this basis the chapter highlights the various steps taken by the South African governments (National, Provincial, District and Local Municipalities) with regard to adaptation needs of the citizens, through policies, program and projects interventions.

2.3 Efforts of South African governments within the global context of adaptation framework

In order to understand the roles of the various levels of government in South Africa in combatting the menace occasioned by climate change across the country, activities of government (National, Provincial, District as well-as local municipalities) regarding climate change adaptation were reviewed. This was assessed through the policies, strategies and legislations (Acts), and it was equally further done within the global context. The Republic of South Africa, being a signatory to Kyoto Protocol and a part of the United Nations Framework Convention on Climate Change (UNFCCC), has taken several initiatives (past and present) in striving to fulfil the expected obligations as regards the protection of citizens and the regional territory against the aggressiveness of climate change and its associated adversities. Some of these efforts as regards adaptation are highlighted in different eras in this section, and these include the following:

2.3.1 Apartheid era

The legal framework for managing disaster in South Africa preceding democratic rule, were largely administered by the Civil Protection Act No. 67 of 1977 [60]. The National Disaster Management Framework (NDMF) was initiated but was characterized by inadequacies following over a hundred lives lost to Lainsburg floods in the year 1981 alone [61]. In reaction to this incidence, out of various legislative and structural reforms that were put together to overhaul the system for proper integration of disaster management was the South Africa Constitution of 1996.

2.3.2 Post-apartheid era

The South Africa Constitution of 1996 marked the beginning of a prominent legislative and structural reforms of disaster management, by specifying the roles of the government at all levels in Part A Schedule 4 [62]. This necessitated the extension of the Civil Protection Act, the pioneer integrated policy on the management of disaster, called "the Green Paper on Disaster Management" [63].

The same era has witnessed active participation in various fora and conventions with respect to dealing with the challenges and opportunities that climate change presents since 1994. Commitment have been shown by the country to sustainable development with both active international participation and institutionalizing national frameworks. The frameworks include out of others: the Kyoto Protocol, the United Nations Framework Convention on Climate Change, the Cancun Agreement, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Ramsah Convention on Wetlands of International Importance, the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal, and the Montreal Protocol for the Protection of the Ozone Layer [64] cit. in [65]. This suggests an involving participation of the country on climate change issues at the global realm.

Similarly, South Africa has at various times successfully instituted some climate change related legal frameworks that are either sector-prone (e.g. waste management, carbon tax, transport, energy efficiency, renewable energy and several others). Other related planning instrument is the Integrated Development Planning (IDP), through which short and medium-terms development objectives, strategies and programs are prepared as strategic plans for municipalities. It is a key instrument for guiding and informing fiscal allocation (budget), administration and

decision making for service delivery and development within municipal's jurisdiction [66]. Subsequently, White Paper on Disaster Management was produced, emphasizing proactive and integrated approach in the management of disaster through public (stakeholders) participation and capacity building [67]. Targeting the creation of National Disaster Management Centre, enhance disaster prevention among the poor and disadvantaged zones, ensure adequate funding system and facilitate access to information (South African Government Gazette).

In 2002 Disaster Management Act 57 of 2002 was institutionalized, highlighting the guiding philosophies for disaster management and defined tasks [68]. The Act provides for the establishment of Intergovernmental Committee on Disaster Management, with powers to the Premier of the concerned Province and Local Government to select members. While at national level, the Minister of Cooperative Governance and Traditional Affairs is empowered to establish a National Disaster Management Advisory Forum with several governmental and non-governmental organizational representatives, traditional institutions and various professional, Sec 5. (1). Section 8. (1) Establishes a National Disaster Management Centre (NDMF) to form part of, at the same time functions within the control of the Minister under a state department of the public service. Provincial disaster management framework is instituted in Section 28. (1) of the Act not only to be established but also implement a disaster management framework aligned to the NDMF objectives and in consistent with the provisions of Act (No. 57,2002) and the NDMF, 33 (I). The local government is empowered under chapter 5 to appoint a disaster officer [62]. This gave birth to the establishment of Mopani District Disaster Management Centre at District Municipal level and the appointment of disaster manager in the five local municipalities in Mopani District as gathered during our field survey, they equally had plans for disaster management framework [69].

In 2011, the parliaments of South Africa adopted the National Climate Change Response Strategy (NCCRS). The policy document is generally anchored on some strategic priorities such as risk reduction and management; mitigation actions (with significant targeted outcomes); sectoral responses; policy and regulatory alignment.

The establishment of the National Climate Change Monitoring and Evaluation System came with the objectives of tracking South Africa's transition to a climate resilient society, by following-up on the country's transition to a lower carbon economy and by tracking climate finance. The benefits of the system include out of others, the provision of an evidence-based impacts and the vulnerabilities to climate change, and providing learning for the workability and otherwise of climate change response. This will inform the future responses to climate change as well-as facilitate the assessment of the impact and need for climate finance and institutionalizing national communication and biennial update reports. As promising as these objectives are, the M&E system has till now been struggling to find its rightful place, because of the disconnect between the municipalities and the grassroots where the data (for national communication and biennial reports) ought to be generated. Although the M&S system is substantially mitigation-focused not adaptation oriented, it still remains a viable too and mechanism for managing adaptation if well captured and harnessed.

The specific urban policy and planning that was institutionalized that "seek to influence the distributions and operations of investment and consumption processes in cities for the common good" [70] was the South African Integrated Urban Development Framework (IUDF) as approved in 2016 by Cabinet. Although attempt by various Government's Departments have in different ways attempted to address the challenges of urban areas since 1994 with significant achievements in areas such as service extension, municipal reform, urban renewal and economic

infrastructure development, these efforts are largely viewed as inadequate [71]. Not so much achievements have been recorded in the mainstreaming of climate change to urban planning. The municipalities in Mopani District are still relying on the National Urban Policy without plans (currently) to have theirs that embrace the economic, political, social and environmental peculiarities of their respective areas. However, the adoption of the Paris Agreement as well as the New Urban Agenda, signaled a renewed motivation for action, particularly to mainstreaming climate change in Urban Policy.

The Mopani District Municipality in line with the National Disaster Management Act 2005 acknowledges the current and the potential climate change threats to both human and the environment. It equally recognizes the need for actions to mitigate, as well as prepare for the projected changes (adaptation) in the District. Consequent upon this, the district municipality in 2016 developed Vulnerability Assessment and Climate Change Response Plan to prioritize the development of Climate Change Response strategies. The Plan recognizes several numbers of ways that climate change will impact on human settlements across the district and thus identifies related indicators, sub-projects and actions for inclusion in the service delivery and the plans for budget implementation [72]. Our field survey revealed that the identified projects are held for paucity of funds.

The frustrations from the failure of municipalities to guarantee the protection of households through the implementation of a pragmatic actions have prompted private adaptation initiatives across the selected towns in the district to curtail the impacts of climate change. The section of this chapter succeeding the description of the study area and methods, addresses the various initiatives of households towards coping with climate change in the selected towns.

3. Study area and methods

3.1 Description of the study area

Located in the semi-arid region, the northern-most province (Limpopo) of South Africa, Mopani District Municipality is a category C municipality (**Figure 1**).

The district consist of five local Municipalities, including: Greater Giyani, (the district administrative seat), Maruleng, Greater Letaba, Ba-Phalaborwa and Greater Tzaneen. The municipality is situated 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. It shares boundaries in the east with Mozambique, in the north, with Vhembe District Municipality through Thulamela & Makhado municipalities, while bordered in the south, by Mpumalanga province through Ehlanzeni District Municipality and, by Capricorn District Municipality to the west [72].

3.2 Climate of Mopani District

Being within the semi-arid region, the district is characterized by temperature that ranges from a high average of 21°C in the Mountainous areas with a very high average of 25°C in the dry low-veld areas of Kruger National Park. In the district Frost rarely occurs, while the monthly distribution of the average daily maximum temperatures indicates that the average midday temperatures for Mopani Rest Camp (Kruger) range from 23.7°C in June to 30°C in January. The region is the coldest during June when the mercury drops to 8°C on average during the night. The District falls within the Letaba Catchment area, which is 13 779 km^2 and has a mean annual

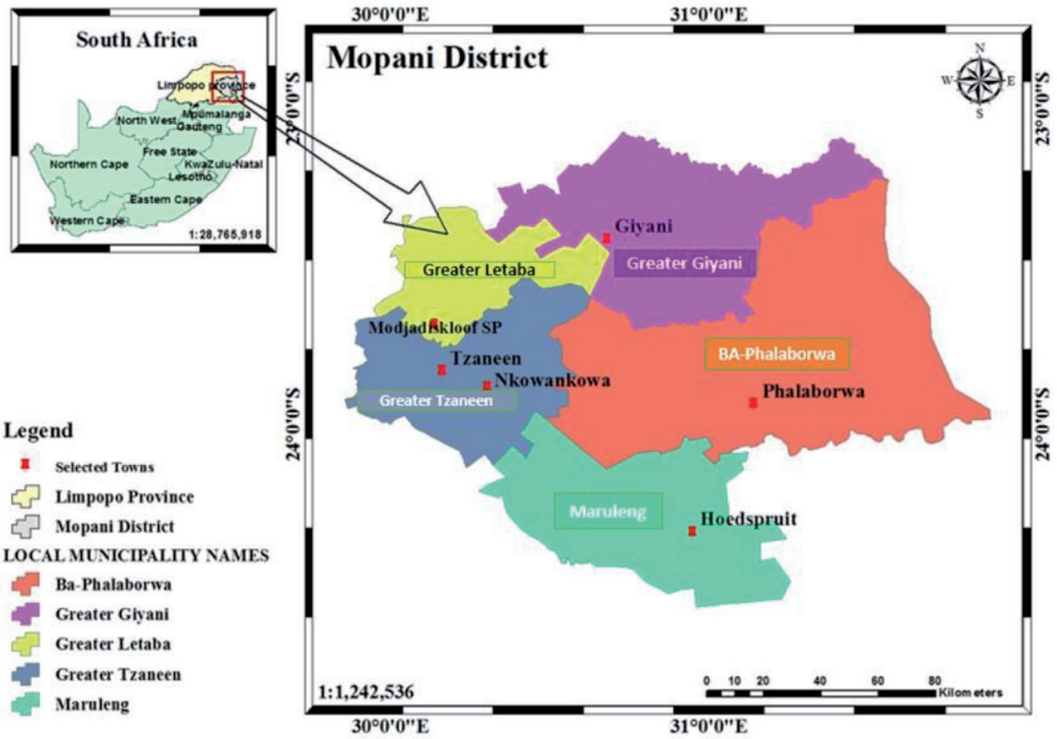

Figure 1.
Mopani District municipality showing the five local Municipalities within the context of Limpopo Province and South Africa Context.

precipitation of 612mm (Environmental Management Framework for the Olifants and Letaba river catchment areas, Report, 2009).

Mopani Rest Camp (Kruger) receives about 520 mm of rain per year, with most proportion (85%) of precipitation in Mopani District is received in mid-summer, while with the lowest (3 mm) is received in June and the highest (96 mm) in January [72]. The rainfall varies from the mountainous zones in the Drakensberg Mountains (2000 mm/a) and the dry low-veld in the Kruger National Park (400 mm/a). The district is situated within the Letaba Catchments area which has a 612 mm Mean annual precipitation.

Climate is recognized by the municipality to be changing, altering and resulting to rising temperature and reduced and erratic rainfall across the district, which is a reflection of the regional climate [58, 75]. The new climate pattern according to the district Integrated Development Plan has caused reduction of access to potable water, food security threats and increase health effects to poverty stricken communities [72]. Part of the strategies identified in the planning instrument for the mitigation of the emission of global warming causing-gases include: utilizing every space for plants, using alternative forms of energy and strict control against deforestation.

3.3 Methods

Consequent upon climate change challenges, households in Mopani have consistently adopted several private and individual strategies to adapt with the varying climate change extreme events. In line with this, we examine the individual household coping strategies to climate change related extreme events and hazards in six purposively selected small and medium-sized towns (Tzaneen, Nkowankowa, Hoedspruit, Modjadjiskloof, Phalaborwa and Giyani) in Mopani District. Sample size of 500 were estimated and drawn using multistage random sampling method,

with proportional share to each towns. Guided by the focus of this chapter, data collection methods emphasizes direct/personal interviews, questionnaire and visual inspection/ transect walk in order to ensure a high rate of response. Though the study adopts mixed method, open-ended questions were minimized, and well-ordered, where necessary. Review of existing literature was used to complement the current research findings. The investigated variables were isolated because of their being the direct location-specific effects occasioned by climate change. These variables are categorized into three, these include: those strategies related to increased temperature; reduced water level (rainfalls); and incidence of flood. These variables were cross tabulated against the selected towns of respondents and are discussed as follow.

4. Result and discussion

4.1 Households' efforts towards adapting to climate change in the semi-arid region of Mopani District

Although efforts are on-going globally, regionally and nationally to reverse the trend in climate variability through research, treaties, collaborations, dialogues and other mechanisms, it is essential to appreciate that adaptation to the new climate change regime remains for now, the only realistic and sustainable option that is available [73, 74]. However, household's private adaptation strategy is becoming an increasingly important component to the urban setting, since the end to the failure of Municipal governments to effectively deal with adaptation to climate change in urban center is indeterminate.

4.1.1 Households' temperature coping strategies

Occurrence of heat waves as a result of rise in temperature is generally evident in the semi-arid region of South Africa [58] and particularly in Mopani District of Limpopo province [75]. According to [76], households' and municipal responses to cope with high temperature or heat waves can be undertaken via tree planting and several other strategies. In line with this understanding, household's individual rising temperature coping strategy in the selected towns in the district were identified. The strategies include tree planting, minimizing bush burning, preservation of water bodies, eco-friendly faming practice, Flower and Grass Planting, the use of Fan and Air conditioner and the creation of Parks and Gardens. **Table 1**, depicts the responses from households, on the preferred coping strategies for increasing temperature across the selected towns in Mopani, these are subsequently discussed.

Tree planting is one of the popular coping strategies and was recommended for mitigating the impact of high temperature [77]. This assertion was validated in the selected towns, with the results obtained from our investigation where 63.3% of households in Tzaneen, and 56.6% in Nkowankowa were in agreement with tree planting strategy to cope with heat waves. Hoedspruit accounted for 88.9%, Modjadjiskloof 50% while in Phalaborwa and Giyani 95.2% and 100% of households employed the strategy respectively. The findings suggests wide range of acceptability of tree planting as temperature coping strategy. The general acceptability of the strategy across the towns was adduced to its affordability and effectiveness as a coping strategy for increasing temperature.

An examination of the relevance of reducing bush burning as a strategy for coping with temperature in the selected towns in Mopani District was undertaken and the results of the respondents' answers to the strategy reveals that

Towns	Tree planting	Flower and grass planting	Create parks & garden	Minimize bush burning	preserve water bodies	Eco-friendly farming	Use of fans and air condition
Tzaneen	66.3	45.6	0.0	100.0	0.0	0.0	100.0
Nkowankowa	56.6	18.3	0.0	100.0	0.0	0.6	100.0
Hoedspruit	88.9	100.0	0.0	100.0	83.3	11.1	100.0
Modjadjiskloof	50.0	80.0	0.0	100.0	60.0	0.0	100.0
Phalaborwa	95.2	98.8	0.0	98.0	77.4	0.0	100.0
Giyani	100.0	51.5	0.0	100.0	2.3	0.0	100.0

Source: Authors' Field Data, 2019.

Table 1.
Temperature coping strategies across Mopani District.

in Nkowankowa, Tzaneen, Hoedspruit and Modjadjiskloof, minimizing bush burning was considered by every household, as an appropriate strategy, while in Phalaborwa, 2% of the entire households surveyed declined the choice of the strategy. The employment of bush burning minimization to curtail the impact of heatwaves at municipal level will be an acceptable and effective strategy that will make meaningful impacts across the district.

With respect to the respondents adopting the conservation of water bodies in their communities, **Table 1** shows that more than four in every five respondents in Phalaborwa, three in every five in Modjadjiskloof respectively endorsed the strategy to cope with temperature. However, the strategy only enjoyed the acceptability of only 2.3% respondents in Giyani. This strategy was equally unpopular in both Tzaneen and Nkowankowa. The reason for Hoedspruit, Phalaborwa and Modjadjiskloof in favor of this strategy was traced to the awareness of the benefits of the strategy among households, facilitated by NGOs and the respective municipalities. This result reflects that the municipalities of the two towns complied with the water conservation Act No. 36 [78].

In the narratives of current literature reviewed on the adoption of eco-friendly farming practices as temperature coping strategy, it shows that it is a promising strategy as reported by [79]. But the results of the acceptability test of the strategy in the selected towns show otherwise. For example, in Tzaneen, Modjadjiskloof, Phalaborwa and Giyani, no respondent indicated adopting it as a strategy. Only Hoedspruit accounted for 11.1%. The result reflects the economic activities of significant proportion of respondents from non-primary sources particularly agriculture. Thus, prescribing it as coping strategy for temperature in the district might not be very impactful to the majority of households.

However, According to [80] as cited in [81] Green infrastructure is very useful in contributing to mitigate the effects of hard surfacing by modifying ambient temperatures as well as creating recreational opportunities among other advantages. Our investigation revealed that every households in Hoedspruit town adopted the strategy, while 98.8%, 80% and 51.5% households in Phalaborwa, Modjadjiskloooof and Giyani towns adopted the green infrastructure strategy respectively too. Flower and grass planting seems to be a widespread and suitable temperature coping strategy in the selected towns, except in Nkowankowa where only 18.3% of the household embraced the strategy.

The use of Fan and Air conditioner appeared to be a very satisfactory strategy that was favored by every households traversing the selected towns in Mopani. This was adduced to by the respondents that the former (fan) is affordable, accessible

and environmentally friendly. However, while the latter (air conditioners) was enhanced by the stability of electricity, it does not only escalates the energy bills because of the increased loads resulting from cooling, but it equally exacerbates urban heat island in its own capacity. Thus [82] submit that for effective alleviation of urban warming and enhanced cooling, there is, as a necessity the need to reduce air-conditioning anthropogenic heat.

The responses obtained from the survey conducted on the creation of Neighbourhood Parks and Garden as a temperature coping strategy by the households across the selected towns is presented in **Table 1**. The result shows a consensus among the households that the siting and development of neighborhood parks and garden was the responsibility of the governments at different levels. This was reflected in households' responses where no household indicated creating Parks and Garden as a personal temperature coping approach. However, children who desire to recreate use available spaces like access road around them to play soccer, not minding risks involved.

4.1.2 Households' water scarcity coping strategies

With respect to water scarcity, the households were required to indicate the strategy they use during climate related drought or long heat waves that reduce the water quantity in their area. The variable used to capture the households' responses include: rain water harvesting, water embankment, use of storage tanks, water treatment to improve quality and use of water vendor service. These results are presented in **Figure 2**.

An examination of household coping strategies regarding change in water level in the selected towns, as summarized in **Figure 2**, shows that rainwater harvesting as a strategy was not popular among the households. The results shows that 5.1% respondents in Tzaneen and 5% in Nkowankowa adopted water harvesting as a strategy, while in Phalaborwa and Giyani both accounted for 5% and 3.1% respectively. However, both Modjadjiskloof and Hoedsrpruit towns did not use such a strategy because according to them, it is time consuming and that the quality of harvested water was most times compromised.

However, **Figure 2** shows the results of the examination of the use of storage tanks to cope with reducing water level. It was discovered that 100% and 81% of households in Hoedspruit and Phalaborwa respectively used the strategy to backup, to forestall the impacts of water shortages. In Tzaneen and Nkowankowa 54.4% and 51% of their respective household used same strategy. Similarly, in Modjadjiskloof

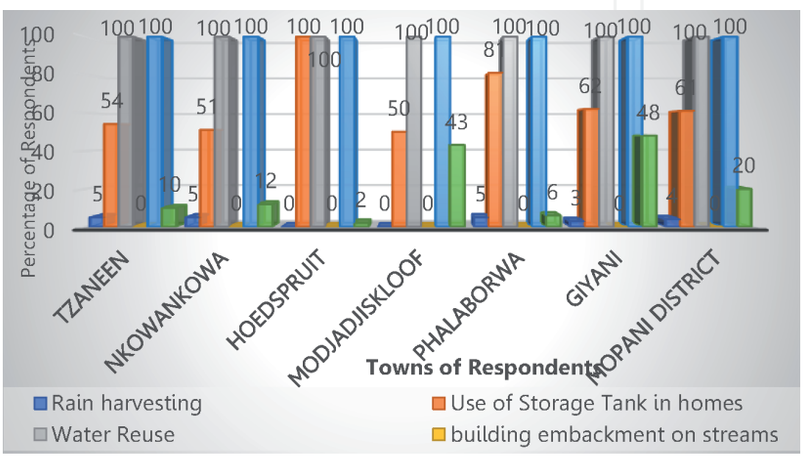

Figure 2.
Coping strategies for change in water level across towns and Mopani. Source: Author's Field Data, 2019.

and Giyani the households that used storage tanks were respectively 50% and 61.5%. On the average 61.1% of the respondents have used or still using storage tanks to adapt to reducing water level in their communities. The study implied that the storage of water in tanks is an acceptable strategy because water provision is not always at RDP level.

A significant indicator of health is water scarcity, which includes both its availability and quality [83]. Water use is beyond drinking, it is intimately linked to food security, sanitation and hygiene contributing to health burdens. Poor and vulnerable communities suffer the most from the adverse effects of climate change on water and health related issues and that the adaptation strategy which can effectively reduce the strain on water resources include wastewater recycling and reuse [84]. This was tested in the selected towns, and was found that when water became scarce, such as in 2016 and 2017 droughts periods in Limpopo province, most households turned to the re-use of water due to the scarcity of water for domestic and others uses. Our investigation further showed that 100% of the respondents re-use water as was advised by the Department of Water Affairs, when Limpopo Province, was declared a disaster province.

Water treatment was one of the variables we requested the households to give their response if they use such strategy. Although according to the science of water treatment which involved reverse osmosis etc, we were more interested in treatment such as water boiling, using aqua active bleaching agents such as hypochlorite to disinfect the water before use. The results in **Figure 2** shows that 100% of the respondents use non-complicated methods to treat their water when it becomes very scarce and necessary.

The general practice particularly in the peri-urban areas of the selected towns is that most of them buy water from water vendors who sell water in containers ranging from R5 to R25 depending on the quantity sold. The study showed that not all respondent were disposed to buying water from vendors maybe because some could not be guaranteed the quality of the water. Patronage of water vendors was common among those households who did not have stand pipes in their yards. However, in Modjadjiskloof and Giyani 43% and 48% respectively used water vendor services to cope with water scarcity (**Figure 2**).

4.1.3 Household strategy for flood control in Mopani

As rightly noted [85] that with increasing havoc of floods in the urban center, and its negative impacts particularly on the poorest and the most susceptible, effective coping strategies require the combination of protective infrastructure, nature-based approaches, and risk financing (insurance) schemes to curtail floods and cushion their adversities. Flash floods has resulted into several degrees of damages in South Africa [65] as well-as some parts of the selected towns in Mopani District Municipality [75]. This occurred at different times, frequencies and intensities. This phenomenon has in the past resulted in households loosing properties ranging from home assets to farm crops and farm produce. The results of the survey showed that with respect to flood control strategies, the most popular include the construction of embankment to prevent over flow of rivers, the use of Furrow around their house, building of walls to protect houses during flash floods, growing of lawns, removal of solid waste from the storm water drainages, re-enforcement of dwellings with stones and concretes.

Our findings suggest that building embankment around houses is a popular strategy particularly among those residing close or whose offices are in close proximity to rivers, along erosion line, or terrain threatening sites. Embankments are usually constructed by the community or the local municipality. One aspect

of the embankment as a strategy to cope with floods is that it fends off water and shelters settlements from flooding. About 58% of respondents was recorded in Modjadjiskloof and 32% in Phalaborwa, Hoedspruit was 23%, while Giyani and Nkowankowa both depicted 27% and 36% accordingly. In a further probe to why majority did not adopt the strategy, respondents noted it to be an expensive option, which often failed when the construction was not done to structural specifications.

With respect to the use of Sandbags, as a strategy, in Giyani 24% of the households indicated its adoption as the option to protect their properties against flood. In Nkowankowa 17%, Tzaneen was 11%, while Modjadjiskloof households accounted for 22% that used sandbags. The households' justification for the use of sandbags as a coping strategy to protect against flooding was hinged on its affordability, ease of building and availability of the material components.

The use of furrow was equally investigated to ascertain whether or not is an acceptable strategy among the households in the district. The result indicates that 5% of Tzaneen residents are using Furrows around their properties, while about one in every four households in Nkowankowa adopted the same strategy. Households in Hoedspruit and Modjadjskloof that used the strategy accounted respectively for 16% and 36% and both Phalaborwa and Giyani accounted for 12% and 18%. The result suggest that the strategy was not embraced by the majority of the households across the selected towns. According to the respondents, the option was considered costly and not an effective strategy compared to others.

The proportion of households' that adopts the building of protective walls around their houses to cope with flood in the six selected towns indicates that this is a commonly used strategy in the study area. Both Modjadjiskloof and Nkowankowa used it as a strategy mostly. With 76% of its household, Modjadjiskloof recorded the highest proportion of household that used the protective walls as strategy, while 18% of the households in Nkowankowa used the strategy. These results was significantly influenced by the terrain of individual towns under consideration as towns with relatively low lying terrain recorded lower patronage of the strategy, while town with steep slope like Modjadjiskloof adopted it most.

According to [80], Green infrastructure is useful in curtailing surface runoff among other benefits [81]. From the results of analysis, households' response with respect to growing grasses to reduce the effects of floods in the selected towns revealed that 60% of households in Hoedspruit grew lawn to reduce the flow of surface run off that erodes the top soil. The study showed that 37% of the households in Modjadjiskloof and 36% in Tzaneen grew lawn to reduce erosion while 2.5% and 20% employed the same strategy in Nkowankowa and Giyani towns respectively. This strategy apart from protecting the surface top soil from erosion, it also keep a good ambient of the environment.

The respondents' answers to the cleaning and removal of waste from drainage channels and systems appeared an acceptable coping strategy across the selected towns in Mopani. 32% of households in Tzaneen do evacuate waste from drainages, while as low as 5% of Nkowankowa households used the strategy to avoid over flow of drainages. However, more than two out of every five Phalaborwa residents engaged in clearing of their drainages to prevent flooding. The study further shows that one tenth of Giyani household embraced the strategy as well. Further to this, drainage and stream channelization was popular, accounting for 25% of Tzaneen households, while one fifth of Hoedspruit households embraced drainage channelization in coping with the incidence of flood.

The use of concrete and stones by households to reinforce their housing foundation serves dual purposes as a way to stabilize the building as well-as safeguard it against any unexpected floods that can erode the building foundation.

About 88% of Hoedspruit household endorsed it, while 87% of the households in Modjadjiskloof as well-as 78% of them in Phalaborwa used it as a strategy to cope with floods. However, Tzaneen account for 40% of houses in this category, while Giyani town accounted for 34%.

Obviously without waiting endlessly for government, households across the district have taken creative initiatives to respond within the available resources at their disposal to climate change related hazards. However, households' capacities are limited by several factors, ranging from economic, social, and attitudinal. Unless pioneered, championed and facilitated by government, household adaptation may not achieve the desired goal. Although several factors collaborate to hamper the success of urban adaptation in the semi-arid region of Mopani, South Africa. These limiting factors are identified in the next section.

4.2 The factors hindering the success of urban adaptation strategies in the Mopani region

This section identifies the factors that inhibit the successes of urban adaptation to climate change hazards. Through our interactions with the households in the selected towns, the key informant (particularly the municipal staff and professionals) and other stakeholders, buttressed by the findings from the planning instruments (IDPs) of the five local municipalities in Mopani District, several inhibiting factors clogging the successes of urban climate change adaptation in these municipalities were uncovered. These out of others can be stratified into both internal and external factors. These are discussed as follow:

Internal factors are those factors that the local municipalities recognized as being within their mandates and powers, on one hand. These include but are not limited to paucity of fund, principally from budgetary allocation. Limited human capacity to embark on the required types of planning for integrated adaptation mainstreaming, compounded by the paucity of knowledge of adequate climate issues at the local municipal level. Higher competition that exist between the mandates of government, resulting in less priority being accorded to long-term planning issues (like climate change) in favor of short-term actions and gains. The Situation is further compounded by the South African need to tackle the backlogs of service amidst coping with both current and future needs of the people. Thus, rendering long-term interventions unattractive to politicians who run a short political tenure to execute. With long-term horizon nature of climate change projections, it contradicts with the short-term political and development programs of these municipalities.

In addition, system's failure manifest across the selected towns, for instance drainages and water ways blockages, absence of drainages in many instances, sewer leakages (like the case of Nkowankowa and Phalaborwa), and backlogs of service across the municipalities are clear indicators. Others factors include policy inadequacies resulting from municipal reliance on national policies (such as urban and other climate adaptation-related policies). The dichotomized land management and operational deficiencies where traditional institutions are in charge of unproclaim land with no responsibility to provide services. Absence of interface programs between the municipalities and the Universities and other research institutions for information and knowledge sharing as well-as research activities regarding climate change and urban development. There was equally no evidence to show collaborations with private sector (banks, insurance and individual philanthropists) on adaptation issues.

Furthermore, external factors include high poverty rate, low literacy level and unemployment. Lack of reliable and verifiable hazard incident reporting systems

that can guarantee disaster hotspot identification and monitoring for early warning. Nevertheless, some of these identified factors (policy shortcomings, institutional weakness etc.), lack of political will plays a significant role.

5. Conclusion

There is no doubt that the new climate is here so also are the attendant hazard that we have to live with in decades to come. With the long-term nature of ongoing global mitigation efforts, adaptation remains the available strategy that must be collaboratively embraced to cope with climate change prone hazards in the urban centers of semi-arid region of South Africa.

Thus, we emphasize the need for a participatory urban management strategy for sustainable adaptation to climate-related hazards, while calling on Scholars to develop models of urban adaptation to climate change that may not necessarily be highly mathematical, but recognize the technological level, social and economic peculiarities of urban Africa, particularly in the semi-arid region of Mopani, South Africa.

The need to urgently review the procedure for reporting climate change hazards and emergencies to promote early warning system, should be revisited. Hazards reporting should be facilitated by the incorporation of instant reporting components in to the existing or a new reporting protocols. This chapter referred to this as "hotspot reporting and monitoring system", through the implementation and development of a mobile phone facilitated protocol that makes citizens the reporters of climate hazards.

It is therefore important to identify and simplify trends and carry out assessment of the effectiveness of prevailing and future policies that may be directed towards urban households' adaptation to climate change hazard in semi-arid region of Mopani South Africa for impactful delivery. In addition, such adaptation policies should be locally-driven and must address climate change as a multifaceted phenomenon and not limited as solely to being tackled as an environmental issue, while integrating local knowledge approaches.

Although, it may be uneasy to convince politicians to prioritize climate change (a long-term development agenda) over and above short tenure political agenda, conversations and strategies to encourage the implantation of long-term sustainable projects should be persuaded. But, because climate change phenomenon as well-as its related consequences are real and already manifesting [58], thus, research institutions, private sector (corporate organization) and NGOs are urged to assist in facilitating training of municipal staff and reorientation program for politicians, particularly by promoting the inclusion of climate change hazard management agenda in the political parties manifestoes while facilitating private adaptation strategies at community level.

Strategies like tree planting, urban greening, drainage channelization, and harmonization of the dichotomized land management in the district are some of the strategic window to curtail climate change hazards in the semi-arid region of Mopani South Africa.

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References

[1] Mertz O, Halsnæs K, Olesen JE, Rasmussen K. Adaptation to climate change in developing countries. Environmental management. 2009 May 1;**43**(5):743-752

[2] Huq S, Reid H, Konate M, Rahman A, Sokona Y, Crick F. Mainstreaming adaptation to climate change in least developed countries (LDCs). Climate Policy. 2004 Jan 1;**4**(1):25-43

[3] Change IP. Climate change 2007: the physical science basis: summary for policymakers. Geneva: IPCC; 2007 Feb.

[4] Christensen JH, Christensen OB. A summary of the PRUDENCE model projections of changes in European climate by the end of this century. Climatic change. 2007 May 1;**81**(1):7-30

[5] Thompson AA, Matamale L, Kharidza SD. Impact of climate change on children's health in Limpopo Province, South Africa. International Journal of Environmental Research and Public Health. 2012 Mar;**9**(3):831-854

[6] Bryan E, Deressa TT, Gbetibouo GA, Ringler C. Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environmental science & policy. 2009 Jun 1;**12**(4):413-426

[7] Yohe G, Tol RS. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Global environmental change. 2002 Apr 1;**12**(1):25-40

[8] Thomas et al. (2009)

[9] Bigio A. Adapting to climate change and preparing for natural disasters in the coastal cities of North Africa. In: Urban Research Symposium. Cities and Climate Change: Responding to an Urgent Agenda; 2009 June. pp. 28-30

[10] Hallegatte S, Corfee-Morlot J. Understanding climate change impacts, vulnerability and adaptation at city scale: an introduction. Climatic Change. 2011 Jan 1;**104**(1):1-2

[11] Nhuan MT, Tue NT, Hue NT, Quy TD, Lieu TM. An indicator-based approach to quantifying the adaptive capacity of urban households: the case of Da Nang city, Central Vietnam. Urban Climate. 2016 Mar 1;**15**:60-69

[12] Kates RW. Cautionary tales: adaptation and the global poor. Climatic change. 2000 Apr 1;**45**(1):5-17

[13] Dickinson T. The compendium of adaptation models for climate change. Environment Canada; 2007.

[14] Berkhout F. Rationales for adaptation in EU climate change policies. Climate Policy. 2005 Jan 1;**5**(3):377-391

[15] Adger WN, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. Progress in development studies. 2003 Jul;**3**(3):179-195

[16] Burton I, Huq S, Lim B, Pilifosova O, Schipper EL. From impacts assessment to adaptation priorities: the shaping of adaptation policy. Climate policy. 2002 Jan 1;**2**(2-3):145-159

[17] Taylor M. The political ecology of climate change adaptation: Livelihoods, agrarian change and the conflicts of development. Routledge; 2014, Nov 17

[18] Dewulf A. Contrasting frames in policy debates on climate change adaptation. Wiley Interdisciplinary Reviews: Climate Change. 2013 Jul;**4**(4):321-330

[19] Smith JB, Schneider SH, Oppenheimer M, Yohe GW, Hare W, Mastrandrea MD, et al. Assessing dangerous climate change through an

update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern". Proceedings of the national Academy of Sciences. 2009 Mar 17;**106**(11):4133-4137

[20] Adger WN, Arnell NW, Tompkins EL. Successful adaptation to climate change across scales. Global environmental change. 2005 Jul 1;**15**(2):77-86

[21] Schipper EL. Climate change adaptation and development: Exploring the linkages. Tyndall Centre for Climate Change Research Working Paper. 2007 Jul;**107**:13

[22] Klein RJ. Adaptation to climate variability and change: what is optimal and appropriate. Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation. 2003;**32**

[23] Schipper L, Pelling M. Disaster risk, climate change and international development: scope for, and challenges to, integration. Disasters. 2006 Mar;**30**(1):19-38

[24] Parry ML, Canziani OF, Palutikof JP, Van Der Linden PJ, Hanson CE. IPCC, 2007: climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge Uni-versity Press, Cambridge, UK. 2007.

[25] Levina E, Tirpak D. Adaptation to climate change. Key Terms.

[26] Stakhiv, EZ, Policy Implications of Climate Change Impacts on Water Resources Management, Water Policy, 1(2), pp. 159-175, 1998

[27] Watson RT, Zinyowera MC, Moss RH. Climate change 1995. Impacts, adaptations and mitigation of climate change: Scientific-technical analyses. 1996.

[28] Collier P, Conway G, Venables T. Climate change and Africa. Oxford Review of Economic Policy. 2008;**24**(2):337-353

[29] Laukkonen J, Blanco PK, Lenhart J, Keiner M, Cavric B, Kinuthia-Njenga C. Combining climate change adaptation and mitigation measures at the local level. Habitat international. 2009 Jul 1;**33**(3):287-292

[30] Hannah L. A global conservation system for climate-change adaptation. Conservation Biology. 2010;**24**(1):70-77

[31] Brook T. Collaboration: Japanese agents and local elites in wartime China. Harvard University Press; 2005

[32] Nyong A, Adesina F, Elasha BO. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation strategies for global Change. 2007 Jun 1;**12**(5):787-797

[33] Newton J, Paci CJ, Ogden A. Climate change and natural hazards in northern Canada: integrating indigenous perspectives with government policy. InMitigation of Natural Hazards and Disasters: International Perspectives 2005 (pp. 209-239). Springer. Dordrecht.

[34] Adger WN, Brown K. Vulnerability and resilience to environmental change: ecological and social perspectives. London: Wiley-Blackwell; 2009 Feb 11

[35] Miller F, Osbahr H, Boyd E, Thomalla F, Bharwani S, Ziervogel G, et al. Resilience and vulnerability: complementary or conflicting concepts? Ecology and Society. 2010 Sep 1;**15**(3)

[36] Dickinson T. The compendium of adaptation models for climate change. In: Environment Canada (EC). 2008

[37] Frigg R. Hartmann S. In: Models in science. 2006

[38] Krankina ON, Dixon RK, Kirilenko AP, Kobak KI. Global climate change adaptation: examples from Russian boreal forests. Climatic Change. 1997 May 1;**36**(1-2):197-215

[39] Lewis JI. China's strategic priorities in international climate change negotiations. Washington Quarterly. 2008 Jan 1;**31**(1):155-174

[40] Thaker J, Leiserowitz A. Shifting discourses of climate change in India. Climatic Change. 2014 Mar 1;**123**(2):107-119

[41] Carter JG, Cavan G, Connelly A, Guy S, Handley J, Kazmierczak A. Climate change and the city: Building capacity for urban adaptation. Progress in planning. 2015 Jan 1;**95**:1-66

[42] Adger WN, Arnell NW, Tompkins EL. Successful adaptation to climate change across scales. Global environmental change. 2005 Jul 1;**15**(2):77-86

[43] Huq S, Reid H, Konate M, Rahman A, Sokona Y, Crick F. Mainstreaming adaptation to climate change in least developed countries (LDCs). Climate Policy. 2004 Jan 1;**4**(1):25-43

[44] Pieterse A, du Toit J, van Niekerk W. Climate change adaptation mainstreaming in the planning instruments of two South African local municipalities. Development Southern Africa. 2020 May 13:1-6.

[45] Füssel HM. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustainability science. 2007 Oct 1;**2**(2):265-275

[46] Bharwani S. Understanding complex behavior and decision making using ethnographic knowledge elicitation tools (KnETs). Social Science Computer Review. 2006 Feb;**24**(1):78-105

[47] Kithiia J, Dowling R. An integrated city-level planning process to address the impacts of climate change in Kenya: The case of Mombasa. Cities. 2010 Dec 1;**27**(6):466-475

[48] Draper AJ, Jenkins MW, Kirby KW, Lund JR, Howitt RE. Economic-engineering optimization for California water management. Journal of water resources planning and management. 2003 May;**129**(3):155-164

[49] Jenkins MW, Lund JR, Howitt RE, Draper AJ, Msangi SM, Tanaka SK, et al. Optimization of California's water supply system: results and insights. Journal of Water Resources Planning and Management. 2004 Jul;**130**(4):271-280

[50] Lin QG, Huang GH, Bass B. An energy systems modelling approach for the planning of power generation: a North American case study. International journal of computer applications in technology. 2005 Jan 1;**22**(2-3):151-159

[51] Callaway, J., and Hellmuth, M. Climate risk management for development: economic considerations', presented at Stern Review Workshop on "Economics of Adaptation", 2006 May, available from http://www.sternreview.org.uk.

[52] deBruin KC, Dellink RB, Tol RS. AD-DICE: An implementation of adaptation in the DICE model. Working Papers FNU-126

[53] Mendelsohn R, Nordhaus W. The impact of global warming on agriculture: Reply. The American Economic Review. 1996 Dec 1;**86**(5):1312-1315

[54] Adger WN, Agrawal S, Mirza MM, Conde C, O'brien

KL, Pulhin J, Pulwarty R, Smit B, Takahashi K. Assessment of adaptation practices, options, constraints and capacity.

[55] Huq S, Kovats S, Reid H. Satterthwaite D. Reducing risks to cities from disasters and climate change.

[56] Milly PC, Betancourt J, Falkenmark M, Hirsch RM, Kundzewicz ZW, Lettenmaier DP, et al. Stationarity is dead: Whither water management? Earth. 2008;**4**:20

[57] Bouwer LM, Aerts JC. Financing climate change adaptation. Disasters. 2006 Mar;**30**(1):49-63

[58] Chikoore H. Drought in southern Africa (Doctoral dissertation, UNIVERSITY OF ZULULAND South Africa).

[59] Niang I, Osman-Elasha B, Githeko A, Yanda PZ, Medany M, Vogel A, Boko M, Tabo R, Nyong A. Africa Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change..

[60] Zuma BM, Luyt CD, Tandlich R, Chirenda T. Flood disaster management in South Africa: legislative framework and current challenges. INTECH Open Access Publisher; 2012 Sep 10

[61] Zuma BM, Luyt CD, Tandlich R, Chirenda T. Flood disaster management in South Africa: legislative framework and current challenges. IntechOpen; 2012 Sep 10.

[62] South African Local Government Association (SALGA). Disaster Risk Management Status Assessment at Municipalities in South Africa. South Africa: Pretoria; 2011

[63] South Africa Republic. Green Paper Disaster Management. Vol. 1998. Government Printer: Pretoria; 1998

[64] Montmasson-Clair G. Green economy policy framework and employment opportunity: A South African case study. Trade and Industrial Policy Strategies (TIPS), Working Paper Series. 2012 Aug;2.

[65] Lethoko MX. Inclusion of climate change strategies in municipal Integrated Development Plans: A case from seven municipalities in Limpopo Province, South Africa. Jàmbá: Journal of Disaster Risk Studies. 2016;**8**(3)

[66] Department of Provincial and Local government, IDP guide pack, Government Printers, Pretoria. 200b

[67] South African Government Gazette. Pretoria: Government Printer. 1999.

[68] South Africa Republic. Disaster Management Act No. 57 of 2002. Pretoria: Government Printer.2003

[69] Jimoh MY, Bikam P, Chikoore H. The Influence of Socioeconomic Factors on Households' Vulnerability to Climate Change in Semiarid Towns of Mopani, South Africa. Climate. 2021 Jan;9(1):13.

[70] Pillay U. Urban policy in post-apartheid South Africa: context, evolution and future directions. InUrban Forum 2008 Jun 1 (Vol. 19, No. 2, p. 109). Springer Netherlands.

[71] Nel E, Rogerson CM. Evolving local economic development policy and practice in South Africa with special reference to smaller urban centres. InUrban Forum 2007 Jun 1 (Vol. 18, No. 2, pp. 1-11). Springer Netherlands.

[72] Mopani District Municipality Demographic (2016). https://municipalities.co.za/demographic/128/mopani-district-municipality

[73] Barreca A, Clay K, Deschenes O, Greenstone M, Shapiro JS. Adapting to climate change: The remarkable decline in the US temperature-mortality

relationship over the twentieth century. Journal of Political Economy. 2016 Feb 1;124(1):105-159.

[74] Zacharias M, Naresh Kumar S, Singh SD, DN SR, Aggarwal PK. Assessment of impacts of climate change on rice and wheat in the Indo-Gangetic plains.

[75] Munyai RB, Musyoki A, Nethengwe NS. An assessment of flood vulnerability and adaptation: A case study of Hamutsha-Muungamunwe village, Makhado municipality. Jàmbá: Journal of Disaster Risk Studies. 2019;**11**(2):1-8

[76] Hayley L, David S. Local Authority Responses to Climate Change in South Africa: The Challenges of Transboundary Governance. Sustainability. 2018;**2018**(10):2542. DOI: 10.3390/su10072542 www.mdpi.com/journal/sustainability

[77] Saxe H, Cannell MG, Johnsen Ø, Ryan MG, Vourlitis G. Tree and forest functioning in response to global warming. New phytologist. 2001 Mar;**149**(3):369-399

[78] Republic of South Africa. National Water Act 36 of 1998 [online] Available at www.gov.za (accessed 20.08.2020)

[79] Vincent K, Cull T, Chanika D, Hamazakaza P, Joubert A, Macome E, et al. Farmers' responses to climate variability and change in southern Africa–is it coping or adaptation? Climate and Development. 2013 Jul 1;**5**(3):194-205

[80] Pataki DE, Boone CG, Hogue TS, Jenerette GD, McFadden JP, Pincetl S. Socio-ecohydrology and the urban water challenge. Ecohydrology. 2011 Mar;**4**(2):341-347

[81] Matthews T, Lo AY, Byrne JA. Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. Landscape and Urban Planning. 2015 Jun 1;**138**:155-163

[82] Kikegawa Y, Genchi Y, Kondo H, Hanaki K (2006) Impacts of city-block-scale countermeasures against urban heat-island phenomena upon a building's energy-consumption for air-conditioning. Appl Energy **83**:649-668

[83] DeNicola E, Aburizaiza OS, Siddique A, Khwaja H, Carpenter DO. Climate change and water scarcity: The case of Saudi Arabia. Annals of global health. 2015 May 1;**81**(3):342-353

[84] Jongman B. Effective adaptation to rising flood risk. Nature communications. 2018 May 29;**9**(1):1-3

[85] Congedo L, Macchi S. The demographic dimension of climate change vulnerability: exploring the relation between population growth and urban sprawl in Dar es Salaam. Current Opinion in Environmental Sustainability. 2015 Apr 1;**13**:1-10