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## Climate, Land Use Change and Local Adaptation Strategies in Ecological Areas: Case of Miwaleni River Valley

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### **ABSTRACT**

Climate change issues are contemporary global phenomena which affect the largest part of the world in different ways. This paper explores how local communities living in sensitive ecological areas, particularly in river valleys, respond and adapt to climate change. By employing a qualitative research approach, findings have indicated that heavy rains and prolonged droughts coupled with population increase have led to land use changes and loss of biodiversity in the river valley. In turn, only one third of villagers practice agriculture but by shifting from rain-fed to irrigated agriculture. The majority don't practice agriculture anymore and residents continually abandon agriculture and establish new livelihood activities, particularly non-farm, which threaten the ecosystem and biodiversity in the river catchment area. Due to limited resources and technology, the conservation strategies adopted in the river catchment area have not yielded satisfactory results. As such, animal and plant species continually disappear and land is extensively being exhausted. Extreme measures to promote biodiversity and ecosystem conservation with a disregard of the changing realities of life in Miwaleni river valley and the catchment area, as well as multi-level actors should be upfront.

**Keywords:** Climate and land use change, ecological areas, adaptation strategies, Miwaleni river valley

## **1. INTRODUCTION**

The global climate is changing and its effects and impacts are being observed all over the world. Some extreme weather events such as heavy precipitation and heat waves have increased in terms of frequency and intensity. Studies on climate change have shown, for instance, that sea level has risen along most of the coasts and sea ice has been disappearing rapidly over time (PAICC, 2010). These changes are all expected to continue, which means that in many aspects, the climate of the future will be different from the climate of the past (ibid).

Concerning the predictions on climate change, Roggema (2009) argues that the predictions are more than once overtaken by reality. Climate change seems to accelerate sooner, faster and stronger. This means that the uncertainties on future changes are large. What is agreed on is the fact that even if the World succeeds in minimizing CO<sub>2</sub> emissions of today, the effects of the changes will continue to affect communities and ecologies all over the world. Supporting Roggema, McCarty (2001) maintains that global climate change is a current and future conservation threat. Changes in recent decades are apparent at all levels of ecological organizations, population and life-history changes, shifts in geographic range, changes in species composition of communities, and changes in the structure and functioning of ecosystems. These effects can be linked to recent population declines and to both local and global extinctions of species (McCarty, 2001; Roggema, 2009; IPCC, 2013). These studies emphasize the need for current conservation efforts to consider climate change as additional threats keep emerging especially due to interactions with other stressors such as habitat fragmentation.

Today, climate change is known worldwide as one of the most important challenges of the 21<sup>st</sup> century stressing the risk of human settlements based in the most vulnerable areas (UN-Habitat, 2011). The

society's ability to cope with the impacts of climate change and avoid unacceptable levels of social and environmental costs decreases as the severity of climate change increases (PAICC, 2010). Because of the regular surprises in the pace of climate change, and always at the top-line of predicted scenarios, mitigation and adaptation responses need to be even more rapid and ambitious. However the question is if mankind is aware of the urgency to adapt (Roggema, 2009).

Concerning the threats of climate change, other scholars, for example, Roaf (2009); Matthews (2011) and Dana (2013), describe climate change, identify its causes, effects, and adaptation as well as mitigation measures in different areas depending on the geographical context. Many of these present and discuss much on climatic changes in urban settings and very little has been directed to rural areas which suffer the same consequences from climate change and variability issues. For instance, Andreasen (2011) reports how the rural population can adapt and survive under the threats of climate change. In this study, the author discusses the perceptions of the rural community on climate change and how they adapt to it. He sets out several coping and adaptation strategies for the rural communities which include migration, off-farm diversification, on-farm diversification, technological improvements, individualized protection, structural protection, money borrowing and environmental restoration.

Changes in land use and land cover are among the most important human alterations affecting the surface of the earth (Lambin et al. 2001). Land-use land-cover changes (LULCC) not only directly impact biological diversity but also contribute to local and regional climate change as well as to global climate warming (Sala et al. 2000). With this note very few studies, e.g. UNESCO (2017); UKAID (2010) report and provide knowledge on climate change, land use change and

ecosystem adaptation in rural areas and ecological areas as well. The mainstream of studies ever conducted on climate change in rural areas, e.g. Ellis (2000); Jianchu (2005); Kamwi et al. (2015) and Kamwi et al. (2018), concentrate on population, land use and agriculture. This is due to the fact that the majority of the rural population depends on agriculture as their main activity to enhance livelihood. In reality, there are other livelihood activities in rural areas which are indispensable in human life which, sometimes, are not taken into consideration. From this argument, this work intended to conduct a study in rural ecological areas endowed with a wide spectrum of natural resources particularly rivers, natural forests and wildlife. These ecological aspects form a very sensitive platform to make decision on and adaptation to climate change and variability.

The reality from Miwaleni village, which is located within the slopes of Mount Kilimanjaro, has shown that soil within the valley has been eroded while the mountain slopes have also been severely degraded. Moreover, building structures, infrastructure services and human (livelihood) activities are being interfered and distorted. With a note that Mount Kilimanjaro is a sensitive and protected ecological area; there is a little knowledge and information on how the surrounding communities make decisions on the effects of climate change and variability within the area. Also the adaptive strategies, as a result of the decisions made within a protected area to enhance sustained survival are not well known. This study aims at filling this void.

## **2. CONCEPTUAL BASES**

This study adopts two related concepts: the adaption action cycles and the sustainable livelihoods concepts. From these concepts, it is worth noting that climate change causes negative impacts (shocks) to the society (WECD, 1987). Such shocks include drought, floods and landslides (Macaringue, 2010;

Cronin and Guthrie, 2011; Stal, 2011; Artur and Hilhorst, 2014). As shocks emerge, community's capabilities either in form of tangible such as financial resources or non-tangible such as skills and knowledge, absorb the negative impacts. The strength of the strategies mainly depends on the level of development of the community. With poor developmental practices, the society may position itself in a more vulnerable environment to the effects of climate change which results into a continuous process of the adaptation actions (Campos et al., 2016). Generally this concepts help to understand the relationship among people, ecological areas including resources available and their livelihoods.

Resulting from the above discussion, climate change poses effects or shocks in ecological areas. In this context, the shocks may include floods, drought and landslides. The shocks are usually observed by the community through negative outcomes portrayed on human life, e.g. on production, environment and health. As people observe these stimuli, they become sensitive and with their capacity which is enhanced by the assets in possession, the community decides to act. The actions taken can either be preventive or managing actions. Together they form local adaptive strategies which can either be incremental or transformative.

## **3. THE STUDY AREA**

The study was conducted in Miwaleni village which is located in Moshi Rural District in Kilimanjaro Region (see Map 1).

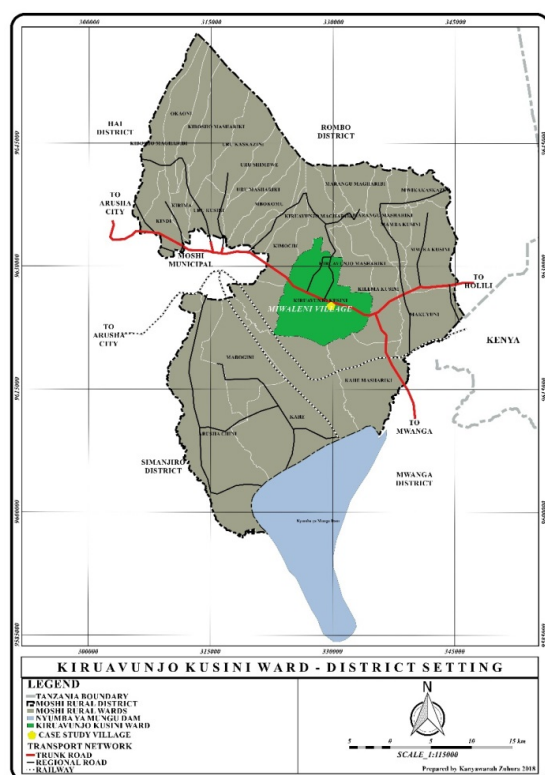
The village receives rainfall at an estimated amount of 500-700 mm per year. The maximum temperature is usually experienced in July at 26°C while the minimum temperature is experienced in February at 21°C. The area also endures a long dry season which starts from June to February (Kilimanjaro profile, 2005).

As noted earlier, the village is located on the slopes of Mount Kilimanjaro and it is a



low land (flat) area which in which two types of soils, silt and clay, are dominant. Silt is mostly found around Miwaleni springs and valleys due to depositions made during floods while clay dominates in other parts of the village where there are no depositions. The presence of these fine types of soils in Miwaleni favors the growth of different kinds of vegetation. The natural vegetation includes scattered trees and the forest found around the Miwaleni springs where the common tree species present in the area is known as Miwale. Planted trees and cultivated crops which cover the largest part of the village also exist and the most cultivated crops are maize, beans and paddy and are largely grown within the river valley.

**Map 1: Location of Miwaleni village**



Source: Field survey at Miwaleni village, April 2018

## **4. DATA COLLECTION METHODS AND TOOLS**

### **4.1 Interviews**

Two types of interviews were conducted: key informant and household interviews.

#### *Key informant interviews*

These involved key people within the river valley. These included village leaders particularly the Village Chairperson and the Village Executive Officer and Pangani Basin Water Office (PBWO) officials. The aim of this type of interview was to acquire quantitative and technical information concerning climate change and variability issues within the village as well as in the Pangani River Basin. Examples of such data were land use changes over time and space within the river valley. The main tool used for data collection was an official checklist.

#### *Household interviews*

This form of interview involved interactions between the researcher and a number of households within the Miwaleni river valley/catchment area. This generated qualitative data to support the data acquired from the field especially on climate change, land use change and local adaptation strategies. Due to limited time and resources, 30 households (25% of all households in the village) were taken as a sample. The analysis of the results obtained was done using the Statistical Package for Social Science (SPSS).

### **4.2 Mapping**

Land use changes over time and space were determined through mapping. By using satellite images from 1980s to 2018, it was possible to generate land use changes. Also villagers' representatives were involved in mapping resources and land use changes in their village on paper. In addition transect walks, using a resource map which was generated by villagers, complimented mapping of the resources in the river catchment area. In this case, a hand held GPS was used to capture data. Later on, the sketches were compared with processed GIS data extracted from satellite images.

### **4.3 Observations**

Apart from the methods and tools presented above, observations were

manifested to compliment. Issue that were being observed included the impacts of climate change on livelihood activities such as agriculture, its effects on land (soil) and the physical infrastructure such as roads. With the use of a camera, important events and realities were taken to support results obtained from interviews and mapping.

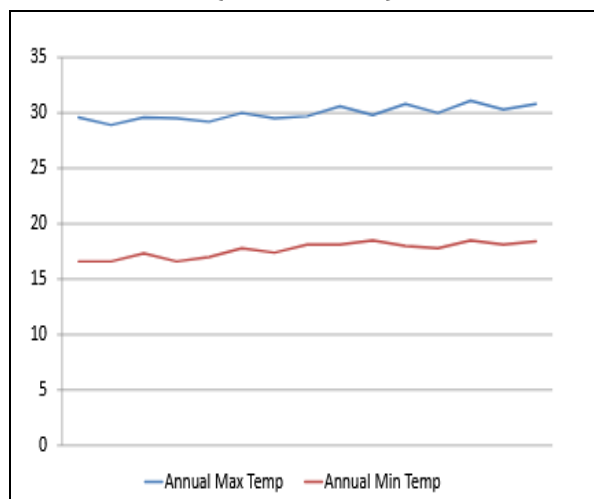
## **5. RESULTS AND DISCUSSION**

### **5.1 Climate change and its effects**

#### *Drought and flooding*

Since 1974, Miwaleni village has been experiencing slight temperature variations (Figure 1) and unpredictable rainfall patterns (Table 1). These two weather elements have led to shortage of water for different social and economic activities particularly for domestic consumption and [rain-fed] agricultural activities.

**Figure 1: Annual mean temperature (°C) (1974-2011)**



Source: Field survey at Miwaleni village, April 2018

**Table 1: Annual rainfall (1974-2010)**

Year	Annual rainfall (mm)
1974	1050
1977	990
1980	760
1983	640
1986	390
1989	640

1992	798
1995	410
1998	700
2001	390
2004	395
2007	360
2010	562

Source: Tanzania Wildlife Research Institute, 2012

On the one hand, prolonged and unpredictable rainfall change and droughts have resulted into deaths of livestock, water shortage and an acute crop production as Plate 1 illustrates. Limited crop production has given rise to acute food insecurity and villagers have been obliged to receive maize as aid from the government due to severe droughts. Moreover, the effects of droughts within the village have also had impacts on natural resources. As the village is located in an ecological area, mainly characterized by the presence natural springs and natural forest which is a habitat for different wild animals, these species have disappeared due to drought. The water level in the springs has also decreased due to excessive evaporation and over-utilization by villagers.

**Plate 1: Dried plants and water scarcity due to drought**



Source: Pangani Basin Water Office, 2017

On the other hand, due to its location [on Mt. Kilimanjaro slopes] and its flat topography, the village is exposed to floods every year especially during the heavy rain

season which starts from March to May. Field results have revealed that 60% of flooding is caused by storm water which flows from the upper streams and cause advert effects to the community living within the river valley (cf. Plate 2).

**Plate 2: Topography and flooding at Miwaleni village**



Source: Field survey at Miwaleni village, April 2018

Like drought, the increased frequency of flood has resulted into a number of economic and social effects. This study has noted that [also shown in Plate 3] flooding has given rise to the destruction of properties, crops and infrastructure for both motorized and non-motorized transport due to heavy soil erosion caused by surface water runoff.

**Plate 3: Erosion by surface water runoff**



Source: Field survey at Miwaleni village, April 2018

## 5.2 Land use change

Tracing back from 1987, Miwaleni to date, results have revealed a change in land use types in the village and within the river valley as summarized in Table 2. These changes were closely associated with rapid demographic as well as changes in climatic conditions. While some of land uses that existed in 1987 are non-existent today, some have expanded and others have diminished. Similar results have also been found in Menglong, rural China (Jianchu, 2005).

**Table 2: Land use change (1987- 2018)**

Land use type	1987	2002	2018
	Area (Ha)	Area (Ha)	Area (Ha)
Residential	48.82	74.24	155.28
Institution	4.11	4.11	4.11
Flood plain	17.01	17.01	76.03
Forest	341.91	146.69	91.93
Valley	25.24	27.42	29.47
Infrastructure	15.79	21.82	26.82
Scattered trees	280.60	304.69	-
Rain-fed agriculture	333.34	776.78	120.10
Grassland and bushes	305.94	-	-
Irrigated farms	-	-	869.02
<b>Total</b>	<b>1,372.76</b>	<b>1,372.76</b>	<b>1,372.76</b>

Source: Field survey at Miwaleni village, April 2018

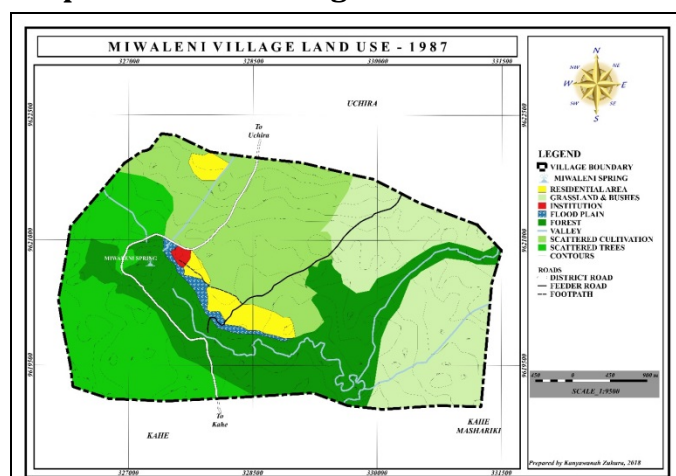
From Table 2 it is apparent that 24.9% of the total village land was covered by forest. In a close range, rain-fed cultivation which comprised nearly 24.3%, grassland which constituted about 22.3% and scattered bushes encompassing 20.4% of the village land were also in the category of the major land uses. The institutional area, infrastructure services, the flood plain, the river valley and the area for residential premises were ranked low. From the Table, it can be seen that irrigated agriculture was not being practiced due to the fact that climate change effects were not severe in such a way that rainfall and temperature supported rain-fed agriculture. Commenting on this aspect, 77% of households interviewed agreed that there was a very cool climate with moderate



temperatures and rainfall. This created a favorable environment for carrying out agricultural activities as well as for conserving biodiversity in the area. As such, wild flora e.g. *miwale* trees and fauna species such as monkeys, crocodiles and baboons existed within the area.

Also, the residential area constituted 48.82Ha (about 3.6%) of the total village land since the population was quite small. These changes are also very pertinent in many rural areas of the developing world particularly in Asia (Sala et al., 2000; Lambin et al., 2001; Jianchu, 2005).

**Map 2: Miwaleni village land uses in 1987**



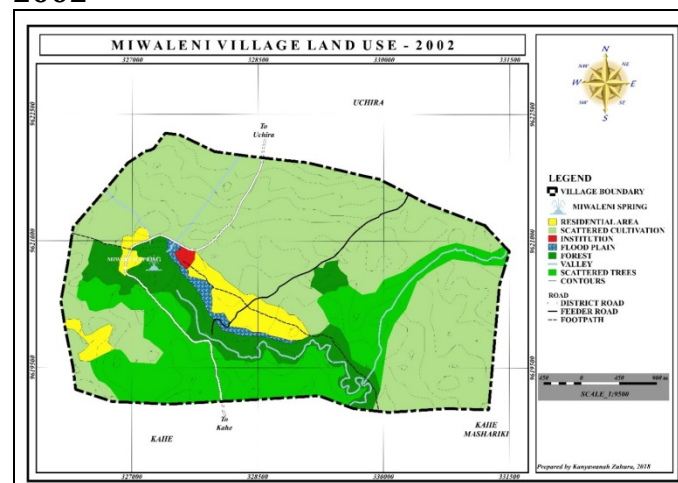
Source: Field survey at Miwaleni village, April 2018

As a consequence of change in climate and population increase, land uses started to change which imply that people started to adjust and adapt to match the changing climatic conditions. The increased number of people entailed increased demand for farming land, settlement areas, grazing areas, fuels (wood and charcoal) and building materials such as timber and poles which led to massive depletion of natural resources. By 2002, land use categories which existed in 1987 in the village had attained a notable change. During this time, the area which villagers used for rain-fed agriculture shot to 776.78Ha being driven by clearance of scattered trees and bushes in-situ. This practice has resulted to the disappearance of

bushes as a land use type. In a similar cosmetic vein, such changes were also notable in Menglong rural area in China whereby during 1965-1992 period, there was a loss of forestland from 36% to 24% of total land, bush/grassland from 26% to 14%, and an increase in rubber plantation from 8% to 27% (Jianchu, 2005). Moreover, the fact that irrigated agriculture had not taken pace implies that the effects of climate change had not been so infringing the human and wild animal species that lived in the ecological area (Sala et al. 2000).

During the same time, the residential area had almost doubled covering 74.24Ha of the village land compared to 48.8Ha which existed in 1987. This situation also implied an increase in the number of population which, in turn, had an impact on the environment of the village and the resources at large. In contrast, the institutional area and the flood plain had not undergone any change. Change in land use types are shown on Map 3.

**Map 3: Miwaleni village land use in 2002**

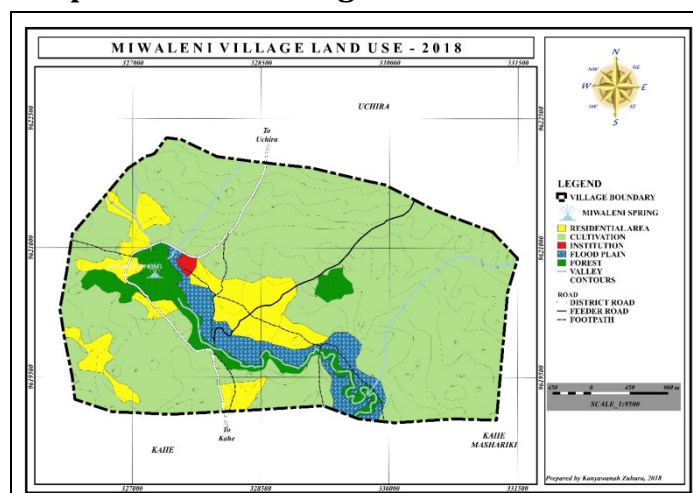


Source: Field survey at Miwaleni village, April 2018

When this study was carried out in May 2018, a very sharp and rapid change of land use was obvious. The Pangani Basin Water Office provided that the change in land use over time and space was influenced by climatic variability such as increased temperatures and increased frequency of

droughts and floods. As such, people have devised adaptive strategies to curb the situation. Unlike the years 1987 and 2002, 2018 portrays a massive increase in the residential area from 3.6% in 1987, 5.4% in 2002 to 11.3% in 2018. From Table 2 and Map 4 it can be deduced that because of the changing climate, the majority of people have shifted from practicing rain-fed agriculture to irrigated agriculture (see also Xu, 2002). A decrease in area which contained scattered trees as well as grassland and bushes is clear indicator of adaptation to the changing climatic conditions in the village.

**Map 4: Miwaleni village land use in 2018**

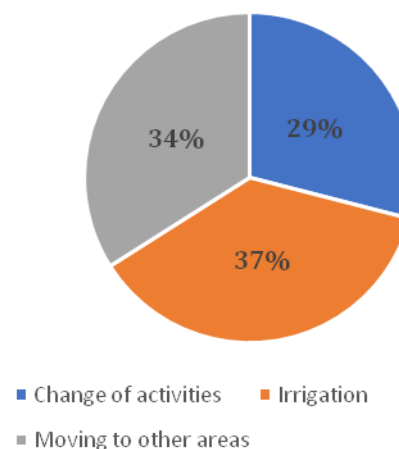


Source: Field survey at Miwaleni village, April 2018

### 5.3 Local adaptation strategies

As a response to the changing weather as a result of climate change, villagers have developed various adaptation strategies as Chart 1 illustrates. These include the use of irrigation schemes, changing economic activities and moving to other areas where the effects are not severe.

**Chart 1: Local adaption strategies at Miwaleni Village**



Source: Field survey at Miwaleni village, April 2018

As far as agriculture is concerned, people have shifted from rain-fed agriculture to irrigated agriculture. Two forms of irrigation are pertinent in the village. The first involves drip irrigation (see plate 4) whereby 67% of people engaged in agricultural activities, who make 55.3% of the total population, use this method. The remaining 33% use irrigation schemes as a second form of irrigated agriculture. In conducting irrigated agriculture, water from the river and harvested water are the two main water sources for irrigation. The latter has been persistent due to insufficient water from the river due to changing climatic conditions and a decrease of water from the river. Different social organizations in the village have facilitated the provision of the technology and infrastructure services to different groups particularly women and youths who cannot afford. The service is also facilitated by the government agency in the village, the Pangani Basin Water Office (PBWO), which is responsible for managing the Pangani River Basin. Management of the river valley also involves the distribution of water in settlements located within Kilimanjaro region.

**Plate 4: Drip irrigation in Miwaleni village**





Source: Pangani Basin Water Office, 2017

Individuals who cannot afford drip or irrigation schemes usually dig trenches from the river bank towards their farms for irrigation purposes. This method is frequently used during the dry season whereby water level in the river decreases to naturally flow to farms. Digging trenches is mainly done at individual (family) level as an adaptive strategy.

Because of the severity of the effects resulting from climate change and variability within the village, some people are moving to other villages, wards and districts to establish their livelihood activities.

Furthermore, people who still live in the village and cannot afford the irrigation technology have decided to change livelihood and economic activities. According to the field survey, it was revealed that 29% of Miwaleni village population have abandoned agriculture as their main economic activity and are now dealing with other economic activities, mainly business. In this case, villagers have resorted into clearing forests to make fuel wood and charcoal for commercial purposes. As a result of this, the natural vegetation covers only 6.7% of the total village area in 2018 as compared to 67.6% in 1987. Some villagers are conducting small-scale businesses especially food vending and selling home-based appliances and equipment. Moreover, the decision to engage in other activities is because of poor infrastructure services to farms especially during the rainy season for the roads are

completely impassable. This is due to the fact that the village is located more than 20km from the main road. This makes it difficult to reach farms and home.

Because of the severe effects of climate change on the environment, the village government and the other agencies such as PBWO present in the village have initiated a tree planting programme to curb effects related to the loss of natural vegetation, to control soil erosion, surface water run-off and to reduce the rate of evaporation within the area. Moreover, rain water harvesting is emphasized as a way to provide water for domestic consumption during the dry season.

## **6. CONCLUSION**

This paper has examined coping and adaptive strategies of Miwaleni rural community which is located within a river valley. Following the changing climatic conditions within the area, conceptually referred to as shocks (WECD, 1987), the community equally responds to these shocks. In most cases, as literature (Macaringue, 2010; Stal, 2011; Artur and Hilhorst, 2014) provides, floods are a common feature in the globe and rapid change in weather condition is a clear indication of climate change. In Miwaleni village, a decrease in land use/cover changes, and an increase in the new livelihood activities have been evident in the village. As a response to these changes, few villagers who still conduct agriculture apply drip irrigation technology or digging trenches.

The study noted that the majority of villagers have abandoned agriculture and establish new livelihood activities which require resources from forests found within the river valley. This practice is a serious threat to conservation (McCarty, 2001) in the ecological area which culminates into loss of habitation of different flora and fauna species. Attempts to restore and maintain the river valley ecosystem where natural vegetation has been widely destructed include tree

planting as a conservation strategy of Miwaleni springs catchment area.

Although the Pangani Basin Water Office (PBWO), local authorities and villagers have been trying to conserve the river valley through various ways it still implies that they are merely simplistic solutions; no very serious and effective actions at all have been appropriate to curb the calamity. This suggests that extreme measures and positions to promote biodiversity and ecosystem conservation with a disregard of the changing realities of life in Miwaleni river valley should be upfront. Also, a wide spectrum of actors apart from PBWO, local authorities and villagers needs to be integrated into the conservation initiative. In this regard, national and international level actors, NGOs, CBOs, CSOs and other environmental organs and agencies can bring positive outcomes.

## **7. ACKNOWLEDGMENT**

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## **9. KEY TERMS AND DEFINITIONS**

**Climate change:** Attributes directly or indirectly from human activities altering the composition of the global atmosphere (Macaringue, 2010; UNFCCC, 2011).

**Adaptation strategies:** Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects which moderate the harm or exploits beneficial opportunities (Schipper, 2004; Christoplos et al., 2009).

**Ecological areas:** Habitat areas which, themselves or in a network, contribute significantly to an ecosystem's productivity, biodiversity and resilience (Sala et al., 2000).

**Livelihood activities:** Means of gaining a living resulting from the combination of people, tangible assets and intangible assets (WECD, 1987; Kamwi et al. 2018; McWalter, 2018).