

Role of farmer's indigenous knowledge for adaptation and mitigation to climate change in Kgalagadi-North District, Botswana

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ARTICLE INFORMATION

Keywords

Indigenous knowledge
Climate Change
Adaptation
Mitigation
Vulnerability

Article History:

Submission date: 22 Sep. 2019
Revised: 06 Dec. 2019
Accepted: 20 Jan. 2020
Available online: 04 Apr. 2020
<https://bojaas.buan.ac.bw>

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Abstract: This paper presents perceptions of farmers in terms of adaptation and mitigation to climate change in Kgalagadi-North District. The study used a qualitative survey method and results were derived from purposively selected interviews using semi-structured questionnaire. The research focused on participants who were aged 50 years and above. Data were summarized and analysed qualitatively using descriptive statistics. Perceptions of farmers showed that frequent wildfire was a major cause of climate change. Farmers further stated that they were affected by irregular rainfall, increased temperature and recurrent droughts. The findings confirmed that the milk production and number of calves per cows were in a declining trend over the last 30 years. The results showed an increasing trend in the population of donkeys signifying the importance and inclusion of donkeys into farmer's herd as adaptation strategy. The results revealed that livestock diversification, making use of migratory approach in search of pasture and water, and sale of livestock before the onset of drought were key adaptation strategies developed by farmers in Kgalagadi-North District. The results also displayed that farmers mainly used to practice different strategies such as saving food and seeds, use of drought tolerant crops, diversifying crop varieties and changing of planting dates to overcome the irregularity of rainfall. Results revealed that farmers mostly used to pray for rains and involved in environmental management for adaptation and mitigation to climate change. It seems that adaptation and mitigation measures employed by farmers helped them to enhance resilience and reduce vulnerability. We suggest that the experience of farmers for adaptation and mitigation to climate change plays a crucial role in scientific research and sustainable development.

Introduction

Climate change is a real threat to the global community throughout the world (Masipa, 2017). Climate variability and change are among the greatest challenges for sustainable development (IPCC, 2007). This paper examines the indigenous knowledge of farmers to cope up with climate change, their experience on various indicators of climate variability, and its effects on the livelihoods of the local people. Climate change is a serious challenge in Africa because it affects food security and the livelihoods of the farming communities

(O'Farrell et al., 2009). Climate change causes a rise in average surface temperatures on earth leading to the alteration of rainfall and temperatures that affect negatively the agricultural production. In southern Africa, climate variability and change are linked to the declining patterns of rainfall, increased drought frequencies, floods, and extreme temperature (Lesolle, 2012).

Botswana is prone to climate change due to its fragile environments and semi-aridity (Botswana Guardian Newspaper, 2001). Botswana's vulnerability to climate change is most likely intensify the existing burdens that further lead to

significant changes in terms of indigenous vegetation and rangeland coverage. The impact of climate change can affect considerably the species types, composition and their distribution, as well as the livelihoods of the farming communities who are depending on the rangeland components of the natural resources (Naidoo et al., 2013). Prolonged drought conditions have caused massive loss of livestock and notably affected the livelihoods of the livestock producers (Opiyo et al., 2015). Despite Botswana's extensive rangeland coverage, climate change might pose difficulty in terms of providing enough feed for livestock production and receiving adequate rainfall for cropping.

Climate change is critical for the economy of Botswana and livelihoods of its people (Lesolle, 2012). It has been agreed that the Emissions of Greenhouse Gases contribute to the Global warming causing the Greenhouse effect and associated climate change. Initial efforts in addressing the problem of climate change has revolved around the effects of greenhouse gases (GHGs) in the atmosphere (Nyong et al., 2007). Even if this stabilization was achieved, the impacts of climate change would still be felt because GHG is not the only factor contributing to climate change but there is also a combination of other factors. These factors include variations in solar radiation, the earth's orbit and reflectivity of the earth's surface, atmosphere, oceans, mountains, buildings, continental drift and changes in greenhouse gas concentrations (Smith, 2013). Hence, as climate change and its effects can last for many years, adaptation and mitigation strategies are necessary.

Smith et al. (1996) argued that adaptation is a central component of climatic change. Adaptation to climate change is critical and of much concern in countries like Botswana where exposure is expected to be high (Hassan et al., 2008). However, for effective results, the process of adaptation and mitigation must be integrated to overcome the problem posed by climate change. According to the IPCC Fourth Assessment Report (2007), effective adaptation and mitigation strategies are necessary in minimizing environmental changes, improving economic growth and enhancing social development. Adaptation and mitigation to climate change is not a new concept in Botswana. This is due to the interdependence between the well-being of people and the physical environment. Exposure to climate variability, especially drought is a major challenge to the population of Botswana. According to Dube (2003), frequent droughts in Botswana occurred every 3-5 years over the last 65 years. The fact that the communities have survived these droughts shows that a range of local and societal coping mechanisms might have evolved. These mechanisms are referred

to as either indigenous knowledge or local knowledge and such knowledge is unique to every society (Dube, 2003).

Berkes (1993, 2012) stated that indigenous knowledge is a collective form of knowledge, practice and belief, evolving by adaptation processes and handed down through generations by cultural transmission. Previous evidences (The IPCC's Fourth Assessment Report, 2007; Parry et al., 2007) have also shown that 'indigenous knowledge is a basis for adaptation and mitigation strategies' in response to environmental changes. As a result, indigenous knowledge is more recognized as an important source of information on environmental and climate related issues (Egeru, 2012).

In Botswana, information on indigenous knowledge of farmers in terms of adaptation and mitigation to climate change is limited, except in the Okavango and Kweneng regions (Kgosikoma et al., 2018). As a result, this research aims to understand the indigenous knowledge of farmers in terms of adaptation and mitigation to climate change in the Kgalagadi-North District, Botswana. The objectives of this study were: (1) to understand perceptions of farmers about climate change; (2) to assess the impacts of climate change on trends of agricultural production; and (3) to assess the experience of farmers on climate change adaptation and mitigation strategies.

Methodology

Study area

Kgalagadi- North is a sub-District of Kgalagadi District in southwest Botswana. It is composed of 14 villages (Statistics Botswana, 2014). The total area of the District is 72,400 km² with a population of 20,484 and 5,561 households (Statistics Botswana, 2014). The elevation of the study area has an average of 915 m above sea level. The vegetation types include open savanna, shrubs and tree savanna. The average annual precipitation is about 25 cm (9.8 in), most of which is received from November to May (Singh, 2011). Out of the total population in the District, 3,353 residents were involved in agriculture (Statistics Botswana, 2014). Generally, the District has 10,530 workers of which 6,334 males and 4,196 females (Statistics Botswana, 2014).

Methods

In January 2019, interviews of households were carried out in five most populated villages in the Kgalagadi- North District, southwest Botswana. Fifteen households per village were selected, among those residents involved in Agriculture, using a purposive sampling method guided by the village household register book with the assistance of the

extension officers. The research focused on participants whose ages were equal to 50 and more years old.

A total number of 75 households were interviewed from the five villages, which were selected and an equal number of sample sizes (i.e., 15 households per village) were taken from the five villages. All of the interviewed households were visited, and the household heads were the ones who filled out the questionnaires for this study. The questionnaires were translated to the respondent’s local language for ease of understanding and those who were not able to read and write were assisted with reading and writing by the first author. A focus group discussion was also conducted and the selection for interviewees was guided by the village leaders. Further discussions were also held with key informants such as the District heads of departments of Agricultural Development and Food Security using the same questionnaire applied to farmers. Such key informant interview using the same questionnaire applied to farmers was helpful in identifying extension officers who were working in each study village. Five extension officers were interviewed, i.e., one extension officer per each study village. The interviews with extension officers were important as they provided more information about the context of agriculture, livestock keeping practices, livelihood activities and the way the local communities adapted to various risks caused by climate change.

Generally, this study used a qualitative method. Semi-structured questionnaire was used to obtain appropriate information related to the perceptions of households about climate change, its impact, local adaptation and mitigation measures by farmers in the studied villages.

Data Analysis

The data collected through household survey were analysed using descriptive statistics. Number of respondents and percentages were used in presenting the analyzed data.

Results

All of the respondents mentioned that they were aware of the occurrence of climate change (Table 1). Almost all of the respondents (96%) also reported that rainfall was irregular over the last 30 years. Of the total number of respondents about 87% of them reported that temperature was increasing.

All respondents (100%) stated that the onset and timing of rainfall was late with early cessation over the last 30 years in their localities. Similarly, participants of the focus group discussion perceived that temperature was increasing with irregular patterns of rainfall over the last 30 years.

Table 1: Perception of respondents on indicators of climate change in Kgalagadi-North District, southwest Botswana.

Indicators of climate change	Households responses (n=75)	
	Number of respondents	% Respondents
Awareness of climate change	75	100
Increasing temperature	65	87
Prolonged drought	40	53
Irregular rainfall	72	96
Strong wind	16	21

All the respondents mentioned that the number of hot days, frequency of drought and length of the dry season had increased over the last 30 years (Table 2). All of them also believed that the length of the rainy season and rain distribution had decreased over the last 30 years and similar responses were indicated by the focus group participants. All respondents and FGD participants perceived that the duration of the dry season was increased over the last 30 years.

Table 2. Perceptions of respondents on trends of climate change in Kgalagadi-North District, southwest Botswana.

Variables	Perceived trends of climate change over the last 30 years			
	Increased		Decreased	
	(n=75)	%	(n=75)	%
No. of hot days	74	99		
Frequency of drought	75	100		
Change in rainfall amount	69	92	6	8
Length of rainy season	1	1	75	100
Rain distribution			75	100
Length of dry season	75	100		

About 44% of the respondents believed that wildfire was the main cause of climate change in their localities (Table 3). This was followed by a group of respondents (37%), who mentioned that they did not know the root causes of climate change. Most of the participants of focus group discussions also perceived that wildfire is among the major factors triggering climate change in their locality. Some respondents believed that climate change was a curse from God.

Table 3. Perception of respondents on causes of climate change in Kgalagadi-North District, southwest Botswana.

Causes of climate change	Households response (n=75)	
	Number of respondents	% Respondents
Do not know	28	37
Deforestation	5	7
Wildfire	33	44
Livestock	2	3
Industries	19	25
Use of vehicles	17	23
Curse from God	9	12

All the respondents mentioned that milk production had decreased over the last 30 years. Almost all the respondents (93%) said that the number of calves per cow and number of kids per doe showed a declining trend over the last 30 years (Table 4). Similarly, about 99% of the respondents stated that forage production was in a decreasing trend.

Out of the total number of respondents, about 97% of them mentioned that feed costs had increased over the last 30 years.

Almost all the respondents (99%) mentioned that cattle mortality had increased over the last 30 years (Table 5). About 52% of the respondents stated that they did not see any change in terms of mortality of donkeys over the last 30 years. Respondents perceived that donkeys were performing better than cattle, goats and sheep under changing climate. Generally, about 77% of the respondents perceived that cattle population was in a declining trend over the last 30 years and highly vulnerable to climate change. Similarly, participants of the focus group discussions also confirmed that cattle population had decreased over the last 30 years while the population of donkeys increased over the same period.

All the respondents mentioned that invasive plants, food insecurity of households and grassland degradation had increased over the last 30 years in their localities. Moreover, the great majority of respondents perceived that pests and ticks as well as drying of water sources had increased.

Table 4: Perception of respondents on trends of livestock production in Kgalagadi-North District, southwest Botswana.

Variables	Perceived trends over the last 30 years							
	Increased		Decrease		No change		Do not know	
	No. of respondents	%	No. of respondents	%	No. of respondents	%	No. of respondents	%
Milk production			75	100				
No. of calves/cow			70	93	2	3	3	4
No. of lambs/ewe	2	3	40	53	3	4	30	40
No. of kids/doe	1	1	70	93	3	4	1	1
Feed costs	73	97					2	3
Forage production	1	1	74	99				

Table 5: Perceptions of respondents about impacts of climate change on livestock in Kgalagadi-North District, southwest Botswana.

Perceived impacts of climate change	Perceived trends over the last 30 years (n = 75)							
	Increased		Decreased		No change		I do not know	
	Respondent	%	Respondent	%	Respondent	%	Respondent	%
Cattle mortality	74	99					1	1
Goats mortality	73	97			1	1	1	1
Sheep mortality	47	63	1	1			27	36
Donkeys mortality	26	35	2	3	39	52	8	10
Cattle population	5	7	58	77			12	16
Goats population	28	37	23	31			24	32
Donkeys population	27	36	3	4			45	60
Sheep population	10	13	6	8			59	79

Table 6: Perception of respondents about impacts of climate change on crop yield, range resources and livelihoods of households in Kgalagadi-North District, southwest Botswana.

Parameters	Increased		Decreased		No change	
	Respondents	%	Respondents	%	Respondents	%
Crop yield	1	1	69	92		
Invasive plants	75	100				
Tree mortality	29	39	3	4	43	57
Pests and ticks	73	97			2	3
Drying of water sources	74	99			1	1
Food insecurity of households	75	100				
Grassland degradation	75	100				

About 92% of the respondents mentioned that crop yields had decreased, which also coincides with the focus group discussions, who also stated that crop yields were in a declining trend over the last 30 years (Table 6).

Table 7: Perception of respondents regarding their adaptation practices to climate change in Kgalagadi-North District, southwest Botswana.

Perceived adaptation practices to CC	Respondents (n=75)	%
Livestock diversification	62	83
Crop diversification	56	75
Use of disease and pest resistant varieties	12	16
Saving food and seeds	51	68
Migration/mobility in search of pasture and water	52	69
Selling livestock before onset of drought	44	59
Supplement with emergency feeds (acacia pods, melons, bran)	30	40
Seek for employment	34	45
Involve in petty trade	8	11
Change of planting dates	23	31
Plantation of trees	8	11
Build water harvesting practices (boreholes)	15	20
Use of drought tolerant animal species	32	43
Use of drought tolerant crop varieties	51	68
Transporting water for cattle to the far rangelands	17	23
Use of organic fertilizer (manure)	8	11
Vaccination	6	8

Most respondents (83%) mentioned that they had diversified their livestock species to adapt to the

impact of climate change (Table 7). Whereas 75% of the respondents said that they used to practice crop diversification to adapt to the changing condition of climate. Others said that they used to practice different strategies such as saving food and seeds (68%), migration in search of pasture and water (69%), sell of livestock before the onset of drought (59%) and keeping drought tolerant livestock species (68%) (Table 7).

Some of the respondents (53%) mentioned that they used to pray for rains to pour as a mitigation strategy to climate change. About 47% of the respondents said that they engaged in environmental management activities to mitigate the impact of climate change. Similarly, most of the participants of the focus group discussion mentioned that they used to pray for rains as well as engaged in environmental management activities as ways of mitigating the impact of climate change (Table 8).

Table 8: Perceptions of respondents on mitigation strategies to climate change in Kgalagadi-North District, southwest Botswana.

Perceived mitigation strategies to CC	No. Respondent	% Respondents
Environmental management	35	47
Soil conservation	4	5
Reduce the use of chemicals	3	4
Plantation of trees	18	24
Praying for rains	53	71

Discussion

Results from Table 1 depicts that almost all of the respondents (96%) indicate that rainfall was irregular over the last 30 years. The observations of respondents agree with the findings of Gomme and Petrassi (1996), who pointed out that rainfall fluctuations with varying lengths and intensities are common to arid and semi-arid regions of Africa. According to most respondents (87%), the

temperature was increasing over the last 30 years. In the current finding, the perception that temperature has been on the rise is supported by Maddison (2006), who reported the perception of farmers that suggested that an increase in the trend of temperature with a declining amount of precipitation in some African countries. Similarly, Roco et al. (2014) stated that a prevailing perception in many agricultural areas is that temperature is rising while precipitation is decreasing. According to the reflection of all respondents, the onset and timing of rainfall is late with early cessation over the last three decades. Furthermore, all respondents indicate that the duration of rainy season and rain distribution are decreased over time. The findings are consistent with the results reported by Juana et al. (2013), who pointed out that farmers in Sub-Saharan Africa have experienced a similar situation in terms of the delay in the timing of rainfall and early cessation. It has also been shown that farmers in Southern Africa experience a decrease in rainfall pattern over years (Fauchereau et al., 2003).

About 44% of the respondents believed that wildfire was a major driver of climate change in their localities. The current results are in agreement with the work of Berwyn (2018), who points out that wildfire most likely contributes to the global warming as it emits carbon dioxide and other greenhouse gases to the atmosphere. Furthermore, wildfires can also damage forests that would have removed CO₂ from the air (Berwyn, 2018). According to the Australian Academy of Science (2010), human interference is the primary cause of global warming.

All respondents' perceptions indicate that milk production was in a declining trend over the last 30 years. Similarly, about 93% of the respondents believed that the number of calves per cow and number of kids per doe were in a declining trend over the last 30 years. The findings are in agreement with Mader (2012) and Nardone et al. (2010), who have reported the vulnerability of livestock because of heat stress on animals resulting in reduced productivity. Barati et al. (2008) and Hansen (2007) also states that heat stress affects oocyte growth and quality, impairs embryo development, and pregnancy rate in cows and pigs. Almost all of the respondents mentioned that cattle mortalities were increased. Angassa and Oba (2007) have reported a similar case in southern Ethiopia, suggesting that repeated droughts caused severe mortalities of cattle between 1983 and 2003. Generally, about 77% of the respondents mentioned that the cattle population decreased and was highly vulnerable to climate change. Similarly, FGD participants confirmed that cattle population in the study villages had decreased while the population of donkeys increased. This is

supported by a study conducted by Nyathi (2017), who reported that donkeys are highly prized in the semi-arid region of Zimbabwe due to their importance as drought-tolerant animals as compared to cattle. Smith et al. (2005) also indicated that donkeys have greater ability to tolerate thirst and are able to select a better quality of diet than cattle from the same area of rangelands.

About 92% of the respondents and all FGD participants confirmed that there is a declining trend in crop yield over the last 30 years. During the focus group discussions, some of the participants stated that they have already deserted ploughing their crop fields because of the failure of crop yields for harvest due to the failure of rain. According to the observations of farmers, climate change adversely affected their crops and this is in agreement with the work of others (Schlenker and Lobell, 2010), who stated that a maize-based system in southern Africa is particularly vulnerable to climate change, with yield losses for South Africa and Zimbabwe predicted to be over 30%. Nelson et al. (2009) have also reported that rainfall variability and extreme temperatures across Sub-Saharan Africa are likely to decrease wheat productivity by 35% and that of sorghum by 2%.

All the respondents mentioned that grassland degradation had increased, while forage production was reduced as a result of invasive plants like *Prosopis juliflora* and a grass species locally known *Tlolele*. This agrees with CCSP (2008) that suggests that drought might have threatened rangeland productivity and livestock feed supply by reducing the quantity and quality of forage. IUCN (2017) also indicates that invasive species are one of the biggest causes for the loss of biodiversity and species extinctions. Furthermore, the same report has informed that climate change facilitates the spread and establishment of many alien species and creates new opportunities for them to become invasive. Respondents also reported that the drying of water sources have increased over the years. According to the observations of respondents, the drying of boreholes and/or water sources are attributed to the adverse effects of invasive trees as well. Overall, the perceptions of respondents confirm that the presence of *Prosopis juliflora* in the study areas resulted in the drying up of boreholes next to the invasive tree species. Kevin and Nicholas (2010) indicated that drought induced climate change has an impact on water sources in many African countries. For instance, in support of the observations of respondents concerning the problem caused by *Prosopis juliflora*, Prasad and Tewari (2016) have stated that the unusual deep root system of the plant can deplete groundwater reserves. The same authors have shown that once the roots of *Prosopis* reach a

water source, the roots extend horizontally in the direction of the water flow and end up blocking boreholes or reducing the quantity of water supply from the water sources.

Almost all respondents reflected that pests and ticks had been increasing over the last 30 years in their localities. Similarly, Leonard (2006) has reported that warmer temperatures probably create longer growing seasons and faster growth rates of plants, while increasing the metabolic rate and breeding cycles of insects. In parts of southern African region, a study by Olwoch et al. (2008) have shown that the distribution of tick vector that is causing East Coast Fever Disease increased with increasing temperature.

The experiences of respondents indicate that they used to diversify their livestock species, make use of migratory approach in search of pastures and water as well as sell their livestock ahead of the onset of drought to adapt to the impact of climate change. These adaptation strategies are widely practiced in Africa as some studies (Ng'ang'a et al., 2012; Oba, 1997; Tambo, 2016; Megersa et al., 2014a; Megersa et al., 2014b) have shown the experiences of pastoralists in diversifying their herds, culling drought intolerant livestock species and practicing seasonal migrations in search of pasture and water (Oba, 1998; Angassa and Oba, 2008).

About 75% of the respondents indicate that they practice crop diversification to adapt to the changing condition of climate. The knowledge of respondents also show that they practice different strategies such as saving food and seeds and make use of drought tolerant crop varieties. These are among the most common adaptation measures practiced by most farmers in Africa. Similarly, Bryan et al. (2009) have indicated that farmers in South Africa practiced planting of different crop varieties and change of planting dates as adaptation strategies to climate change. Furthermore, farmers in South Africa (Gandure et al., 2013), Senegal (Mertz et al., 2009) and Uganda (Egeru, 2012) have adopted early maturing crop varieties as compared to late maturing crop varieties.

The perceptions of farmers also indicated that they used to pray for rains as mitigation strategy to climate change in the study areas. A similar case was reported by Johnson (2018), suggesting that festivities are organized and performed when the severity of drought increased from November to January of each year in Basotho culture where men, women, girls and boys engage in praying for rain. Respondents also mentioned that they used to be involved in various environmental management and conservation activities to mitigate the impact of climate change. Data from several studies (Nyasimi et al., 2014; Kaczan et al., 2013; Bationo and Vlek,

1998; Naab et al., 2012) have shown that agroforestry and zero tillage are being adopted by farmers as mitigation strategy to combat climate change. Similarly, most of the FGD participants mentioned that they used to pray for rains as well as being engaged in environmental management.

Conclusion

The study concludes by arguing that farmers in the study area were affected by the irregular nature of rainfall, increased temperature and recurrent droughts. The observations of farmers have shown that wildfire was the main factor contributing to climate change. The findings further confirmed that milk production and number of calves per cows were in a declining trend over the last 30 years. Most importantly, the results provide evidence for increased trends of the population of donkeys over cattle signifying the importance of including donkeys in farmers' herd as mitigation strategy to climate change. The observations of farmers have also shown that crop yields were reduced, and crop fields deserted. The broad implication of this study is that the indigenous knowledge and experience of farmers for adaptation and mitigation to climate change play a crucial role in scientific research and sustainable development. Future research should consider the potential role of indigenous knowledge versus empirical evidence regarding the impacts of climate change on the livelihoods of farmers in the study areas. These findings provide a potential mechanism for a sustainable society where policy makers and planners should consider the necessary actions that facilitate to formulate climate change adaptation and mitigation options in the national policy framework and strategies. We suggest public awareness creation to strengthen community resilience and their adaptive capacities to the impacts of climate change in the region.

Acknowledgments

The authors thank respondents for their cooperation and participation at the time of data collection. We also thank the key informants and officials in the study area for their support during the data collection.

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