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Effects of Climatic Variability and Non-Climatic Factors on Mopane Worms' (*Gonimbrasia Belina*) Distribution and Livelihood Options in North Central Namibia

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Abstract

Mopane worms (*Gonimbrasia belina*) are an important source of food and income for households in Northern Namibia. However, their access and availability in many areas have declined, mainly due to climate change and human activities. This has affected many households' livelihoods, making them vulnerable to poverty and food insecurity. With these factors in mind, this study sought to identify the extent to which the availability and distribution of mopane worms are influenced in the Tsandi and Okahao constituencies. The study used structured questionnaires to collect information from households in the study area, to interview key informants, and to carry out group discussions. A total of 70 households and 6 key informants were interviewed, along with 4 focus group discussions that were carried out to elicit perceptions, and to obtain views on the availability of mopane worms, and possible causes of the decline in the study area. Data were analysed using descriptive statistics, while GIS was used to determine trends in vegetation cover, temperature and rainfall in the area. The rainfall trend indicates variability, with a generally declining trend. A slight increase in temperature has been observed too. Vegetation showed a browning trend in the study area, indicating declining habitats of mopane worms. The results have indicated that more women depend on mopane worms for survival, mainly as a source of income. Thus the decline in their availability greatly affects their food sources and their income diversification opportunities. Trading was found to be an important form of employment for the unemployed rural people, but with the potential to generate higher income levels that can improve their livelihoods. Moreover, despite the climatic factors, human activities seemed to indicate a greater influence on the availability of mopane worms, due to activities such as overharvesting, land clearing for agriculture and household use/fencing. Thus, there is a greater need to control the harvesting of mopane worms and to control tree cutting activities in order to reduce the impacts of climatic and non-climatic factors on their availability.

Keywords: Climate Change, Non-Timber Forest Products, Overharvesting, Livelihoods

1. Introduction

Mopane worm is utilized as a delicacy in most rural households in Africa (Thomas, 2013). These caterpillars are also considered as being of economic importance, as they are sold to generate income (Stack *et al.*, 2003). However, their survival is threatened by climate change and over-harvesting (Mataboge *et al.*, 2016). Mopane worms are commonly found in mopane tree-dominated habitats, where they play an important ecological role in converting plant matter into animal and plant nutrients (Ghazoul, undated). Nevertheless, abundant mopane worm populations can have detrimental effects on the browsers, as they can defoliate large tracks of vegetation (Thomas, 2013).

Generally, sufficient rainfall, proper temperature, and vegetation are needed to facilitate egg-laying by the emperor moth (*Gonimbrasia belina*), whose larvae turn into the mopane worm caterpillars (Mataboge *et al.*, 2016). On the contrary, low, erratic and irregular rainfall and the temperature lowers the mopane worm population. Research has revealed that climatic factors are important determinants of the survival of mopane worms, as they undergo different developmental stages, from hatching to pupation (Connolly-Boutin & Smit, 2016). Sadly, the various stages of the life cycle of *Gonimbrasia belina* provide food for numerous natural predators, including insects, reptiles, birds, jackals, bats, warthogs, and monkey; which unfortunately a significant impact on the caterpillar yield (Senkonya, 2016).

Various studies have confirmed that the population of mopane worm is declining (Mataboge *et al*., 2016; Senkonya, 2016; Gwavuya, 2003). One of the contributing factors to this decline is their overexploitation, coupled with deforestation, which is known to destroy food plants that are consumed by *Gonimbrasia belina*. Destruction mainly happens as a result of clearing land for crop production, and through the cutting down of trees for firewood, fencing and building materials (Ghazaoul, undated). Other factors such as soil type, fire and browse quality may also contribute to the population decline. In addition, the increased trade of the mopane worm in Southern Africa has led to overharvesting, as a result of greedy people harvesting more than needed for a single person. Overharvesting can be attributed to the absence of harvesting guidelines/regulations, or failure to implement them, which has further increased the harvesting competition between local people and outsiders (Mataboge *et al*., 2016; Quang & Anh, 2006). Ultimately, this also affects the worms' life cycle. Traditional regulations may include the monitoring of caterpillar development and abundance, while harvesting should take into account the age and size, such that mature larvae are preferred to younger ones (Quang & Anh, 2006). Therefore, the population of mopane worms that are not harvested in one period determines the amount that will be harvested in the next period.

The decline discussed earlier has stimulated interest in options for small-scale farming of mopane worms in southern Africa, for example, in Zimbabwe (Quang & Anh, 2006). This is due to their reliance on such forest products as a source of their livelihood. However, given the uneven geographical distribution of mopane woodlands and climate variability in the region, the distribution of mopane worms is sparse. Interestingly, their distribution extent in the direction of the prevailing winds during years of good rain (Connolly-Boutin & Smit, 2016). As a result of the uneven distribution of mopane worms in the region, countries have been importing them to meet their increasing demand.

A number of factors determine the occurrence of mopane worms, including prevailing climatic conditions, habitats, predation, and the harvesting pressure on the available population (Makhado *et al*., 2012). These factors are therefore an assurance that constant availability of mopane worms throughout their breeding season cannot be guaranteed (Phiri & Chiname, 2004; Senkonya, 2016). Given their dependency on the above factors, it is essential to understand the impact of such factors on mopane worms, and the resulting effect it has on the harvesters in the context of rural poor households (Dube & Phiri, 2013). Moreover, given, the value of mopane worms, especially in efforts to reduce poverty and ensure food security, securing the sustainable harvest of mopane worms is highly significant.

A notable decline in the availability of mopane worms has been observed in Namibia for over 15 years (Thomas, 2013). However, the contributing factors behind the decline have not been documented. Climate change and variability are among the issues being attributed to such a decline, along with the human activities in the habitats of the mopane worms (Gwavuya, 2003; Nikodemus & Hájek, 2015; Mataboge *et al*., 2016). Such factors are said to affect the distribution and livelihood options for various households which heavily depend on forestry resources.

1.1 Ecology and Value of Mopane Worms

Mopane worms are the caterpillar stage of the emperor moth, *Gonimbrasia belina*, which feeds almost exclusively on the leaves of the mopane tree *Colophospermum mopane,* mainly the mature green leaves (Kumirai, 2017; Pillay, 2015). The *Gonimbrasia belina* species is said to be native to the warmer seasons in southern Africa, with a lifespan of mopane worms starting in summer when the female moths lay eggs, which eventually hatch to larva (Pillay, 2015). In some countries, outbreaks of mopane worms are experienced twice a year, the first being the period of December to January, while the second one occurs between April to May, following good rains (Potgieter, 2015). However, Namibia being a semi-arid country, it only experiences one outbreak, as it depends on the annual rainfall (Thomas, 2013). Their occurrence is directly linked to the presence of fresh leaves. In terms of size, emperor moths are large, with a wingspan of 120 to 150 mm (Chidumayo & Mbata, 2002). The front wings have two black and white bands isolating the eyespots, while the hind ones have orange eyespots. Compared to females, male moths have feathery antennae, which are used to detect female sex pheromones in efforts to find mates (Chidumayo & Mbata, 2002; Kumirai, 2017). The larvae are black, peppered with round scales in indistinct alternating whitish-green and yellow bands, and armed with short black or reddish spines covered in fine white hairs, which can grow as long as 10cm when mature (Kumirai, 2017; Makhado *et al*., 2015).

In spite of the fact that mopane worms feed on mopane trees, they can cause extensive damage to individual trees, hence they are often referred to as pests (Pillay, 2015). This can have a detrimental impact on the mopane herbivores that heavily depend on mopane trees, and on the next harvest. Equally worthwhile to note, human activities can have impacts on the mopane vegetation, further impacting the harvest (Nikodemus & Hájek, 2015).

On the national scale, mopane woodlands cover about 77,000 km^2 of Namibia and are mainly densely distributed in the northern parts, which are home to at least 60% of the Namibian population (Gondo *et al*., 2010). As a result of high human population pressure on the mopane vegetation for different purposes, deforestation is experienced, which has a negative impact on the yields of mopane worms (Senkonya, 2016).

Mopane worms are valuable non-timber forest products (NTFP) resources that are harvested as a source of nutrition in the southern African region, in countries such as Botswana, Namibia, South Africa, Zambia and Zimbabwe (Heuback *et al*., 2011). Traditionally, they used to be an important food source for the rural communities within the range of mopane woodland; however, upon realising their economic value, they have become an important trading commodity across the region, and are considered as an important source of income (Stack *et al*., 2003). When harvested sustainably, mopane worms could yield larger financial returns to poor people living in rural areas. Mopane worms are not only valued as being a source of food, but their nutritional value has also been realised. Research has revealed that mopane worms have a high nutritional value, as they contain high levels of crude protein, many vital minerals, and vitamins (Kwiri *et al*., 2014; Makhado *et al*., 2016). Consequently, these worms are utilized as a food supplement, especially in times of economic and climate stress (Potgieter *et al*., 2012).

1.2 Harvesting and Trading of Mopane Worms

With the increasing demand for income opportunities for very poor rural people, there is a tendency to over harvest mopane worms, to the point of over-exploitation (Chamber & Conway, 1992). Traditionally, mopane worms were harvested for subsistence in rural households, however, their nutritional and economic value has also been realised in urban areas (Pillay, 2015; Thomas, 2013). This realization has often resulted in over-exploitation, further leading to their population decline. Because of the seasonal nature of the occurrence of these edible caterpillars, they are not a year-round food source (Potgieter, 2015). However, traditional mopane worm harvesting is evolving to be more commercially-driven, the driving factor behind their over-exploitation (Stack *et al*., 2003). Sadly, over-exploitation is further worsened by competition between harvesters (Senkonya, 2016).

Since the 1950s, commercial farming methods have been applied to the harvesting of mopane worms, particularly in South Africa (Phiri & Chiname, 2004). Harvesters can organise teams of hundreds of people to hand-pick the caterpillars from the trees, after which they are bagged, massed, weighed, and sent off to be processed. In Namibia, harvesters of mopane worms are mainly people living within outbreak areas (Thomas, 2013). However, other people can travel as far as 250 km to harvest mopane worms in outbreak areas. These long-distance harvesters often camp in the outbreak area for a period of time, until they harvest enough to take along.

1.3 Factors Affecting the Availability of Mopane Worms

Climate change is among the factors known to affect the availability and harvesting of mopane worms (Senkonya, 2016). Research has revealed that sufficient rainfall, conducive temperature, and vegetation facilitate the egg-laying by the emperor moth (Mataboge *et al*., 2016). On the contrary, low, erratic and irregular rainfall, and temperature contribute to the reduction of mopane worm populations, as the emperor moth breeding gets negatively impacted. However, mopane worms can survive both at high and low temperatures, although their physiology and behaviour can be influenced by host plants (Mataboge *et al*., 2016). In addition, high temperatures can cause eggs of emperor moths to burst, as a result of extreme heatwaves. As a result of variable rainfall, the production of mopane worms becomes variable too, making them an unreliable source of income (Stack *et al*., 2003). According to Boon and Ahenkan (2012), climatic factors are an important determinant of the number of mopane worms that survive from hatching to pupation. The first generation is mostly affected by adverse weather conditions. Interestingly, the distribution of mopane worms tends to go the direction of the prevailing winds during good rainfall (Boon & Ahenkan, 2012). It is also worthwhile to note that climate change further impacts the survival of the mopane trees, which provide a home to mopane worms (Mataboge *et al*., 2016).

Apart from climate change and variability, human activities contribute to the reduction of mopane worms. Increasing human pressure on vegetation through land clearing for crop production, collection of firewood, and collection of fencing and construction materials results in deforestation (Nikodemus & Hájek, 2015). As a consequence, the food plants get destroyed, such that the production of mopane worms will be affected (Mataboge *et al*., 2016). Other factors such as soil type, fire and browse quality may also contribute to the decline in the population of mopane worms (Chidumayo & Mbata, 2002). Urbanization is also among the contributing factors to the reduction of mopane worm populations (Senkonya, 2016). In addition, accumulation of dust on mopane tree leaves, for example, in mining areas affects the laying of eggs for the emperor moth, as it can be toxic (Pillay, 2015).

The need to document the factors contributing decline of the mopane worm population necessitated this study. Therefore, this paper presents the findings of the study that aimed to identify the factors that determine the abundance and distribution of mopane worms in north-central Namibia, with particular focus on the significance of climate change and variability; and on the livelihood options. Two constituencies i.e. Tsandi and Okahao we used as study areas. The specific objectives were to 1) identify the effects of climate variability on the distribution of mopane worms, 2) identify the effects of human activity on the distribution of mopane worms, 3) determine the effect of mopane worm decline on the household livelihood options in the two constituencies, and 4) determine the perceptions of mopane worm harvesters on the effect of climate change on mopane worm availability, distribution, and livelihood strategies.

2. Method

2.1 Description of the Study Area

The study was conducted in the northern parts of Namibia, with a specific focus on the Tsandi and Okahao constituencies in the Omusati Region. With a surface area of approximately 2362 km^2, the Tsandi Constituency is located 30 km south of Outapi and Okahao and has an estimated population of 28,018 (ORC, undated). It is in this constituency where Uukwaludhi and Ongulumbashe are found. Compared to Tsandi, Okahao Constituency is quite big, with a surface area of 9910.5 km^2, however, its population is lower, of approximately 17,548 people. In terms of climate, the temperature of 22.6˚C, and about 446 mm of annual precipitation.

Figure 1. Map of Namibia, with study area, indicated as dark brown

2.2 Research Design and Sampling

A combination of two research techniques, qualitative and quantitative was considered by this study. The aim was to understand and interpret the social interactions on the topic under study (Maree, 2008). For the purpose of getting an in-depth understanding of the situation at hand, the qualitative method was employed (Mouton, 2001). The quantitative method was used to quantify the collected data. As part of the qualitative technique, questionnaires comprising open-ended questions were prepared, particularly targeting key informants through interviews. In addition to the interviews, focal group discussions were held. Ideally, focus group discussions seek to get an enhanced understanding of the subject matter, through interaction from a target group (Smithson, 2007). To identify and select the participants from the target constituency, purposeful sampling was used, a well-known non-random technique for selecting informants (Tongco, 2007).

2.3 Data Collection

In efforts to collect valuable data through focus group discussions, a checklist containing questions on different topics was used. The questions were prepared in such a way that they were open-ended to allow interaction

(Smithson, 2007). Sets of 8 to 10 questions were prepared under each topic. A total of 4 groups consisting of 10 to12 members was interviewed in the two constituencies. Interviews were conducted with all target informants. However, key informants with professional ranks were interviewed through office visits. Apart from the group discussions and interviews, a household survey was conducted in the two constituencies.

2.4 Data Analysis

Descriptive statistics were used to describe the features of the data in the study, from the qualitative and quantitative data outcomes. All data were analysing using the Statistical Package for Social Science (SPSS). The collected data were entered in the SPSS spreadsheet, and the results were presented in the form of graphs, tables, revealing frequencies and averages. Climate data trends were used to corroborate observations and perceptions of the households on mopane availability and distribution. In addition, a Geographical Information System (GIS) software was used to determine trends in vegetation cover, temperature and rainfall in the area.

3. Results

3.1 Demographic Information of the Respondents

In total, 70 interviews were conducted, 40 in Okahao and 30 in Tsandi. Of the respondents, majority female, 53.3% from Tsandi (53.3%) while 62.5% were from Okahao (62.5%), aged between 31 and 40 years (Table 1). At least 40% of males were from Tsandi, while 35% were from Okahao, of which 16.7 % from Tsandi and 7.5 % from Okahao were in the age group of 20 – 30 years. The majority of respondents are married, of which 60% from Okahao, while 56.7% are from Tsandi. Almost half of all respondents have reached the secondary level, 37.5% of which were from Okahao, while 43.3% are from Tsandi. As for those with primary school level, 32.5% were from Okahao, while 30 % were from Tsandi. Only a few respondents had attained tertiary level were, with 7.5% from Tsandi and 13.3% from Okahao.

Based on the results, most harvesters got introduced to harvesting from an early age. This early introduction served a good purpose, as it increased the available labour, indigenous knowledge and skills, which are passed on from one generation to the next one. The findings indicated that most of the harvesters have been involved in harvesting since childhood.

The study revealed that trading was an important form of employment for unemployed rural people, which is a case in the 2 constituencies. It was found that unemployed rural people depend on mopane worms, and have the potential to generate higher income levels that can improve their livelihoods (Figure 2).

Table 1. Demographic information of harvesters and traders and livelihood options

		Okahao %	**Tsandi %**
Gender	Female	25 (62.5)	16 (53.3)
	Male	15 (37.5)	14 (46.7)
Age	20-30	3 (7.5)	5 (16.7)
	31-40	14 (35.0)	12 (40.0)
	41-50	6 (15.0)	5 (13.3)
	51-60	9 (22.5)	4 (13.3)
	61-70	8 (20.0)	4 (13.3)
Marital Status	Married	24 (60.0)	17 (56.7)
	Single	16 (40.0)	13 (43.3)
Level of education	Non-formal	9 (22.5)	4 (13.3)
	Primary	13 (32.5)	9 (30.0)
	Secondary	15 (37.5)	13 (43.3)
	Tertiary	3 (7.5)	4 (13.3)
Employment	Unemployed	32 (80.0)	23 (76.7)
	Employed	8 (20.0)	7 (23.3)
Livelihoods	Trading	22 (55)	13 (43.3)
	Crop farming	19 (47.5)	11 (36.7)
	Livestock	14 (35)	3 (10)
	Employment	9 (22.5)	8 (26.7)

Figure 2. Trading of products, including mopane worms

3.2 Perception of Climatic Variability

The research participants were requested to rank the different forms of climatic variability that have an effect on the distribution of mopane worms, their availability, and livelihood options. All the respondents confirmed that rainfall was a leading factor contributing to the decline of mopane worms. Lack of rainfall causes poor facilitate of egg-laying by the emperor moth (Mataboge *et al*., 2016). The high temperature was also one of the factors that were ranked to have an effect on mopane worms. All the respondents from Okahao agreed to such, while only 87% of the respondents from Tsandi were in agreement.

Vegetation cover was also regarded as having an effect on the decline of mopane worms. Based on the findings, the change in vegetation can be attributed to the high demand for firewood and building materials, as a result of cutting down. Such destruction leads to a decrease in mopane tree density, which the habitat for mopane worms.

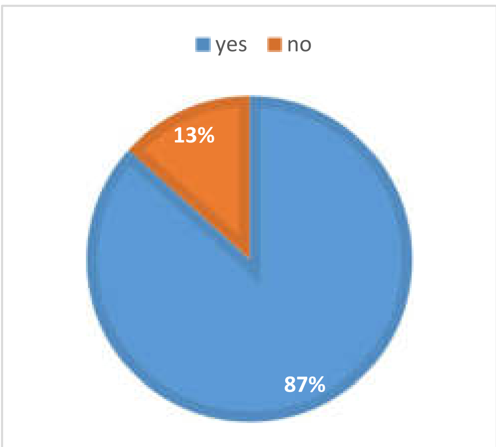

Figure 3. Indication by % whether temperature impacts the production of mopane worms in Tsandi

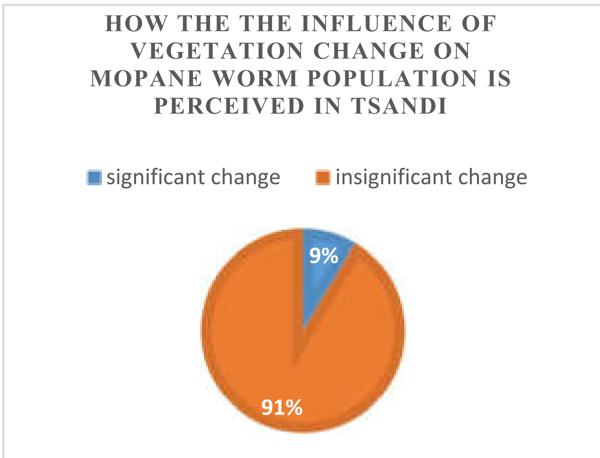

Figure 4. Indication by % whether the change in vegetation influences the richness of mopane worms in Tsandi

3.3 Climatic Data from the Omusati Region

3.3.1 Rainfall

Figure 5 indicates the total average of rainfall per year been received in the Omusati Region between 1990 and 2017. The rainfall anomaly, which determines whether the rainfall is above or below the average rainfall per year is presented in Figure 6. Based on the statistics, the rainfall was below average between 1990 and 2005 but has above average during the years 1999 and 2002. However, from 2005 to 2011 the rainfall was above average and went below between 2012 and 2015, the years when the drought was experienced (NRCS, 2013). It then started to pick up again between 2016 and 2017.

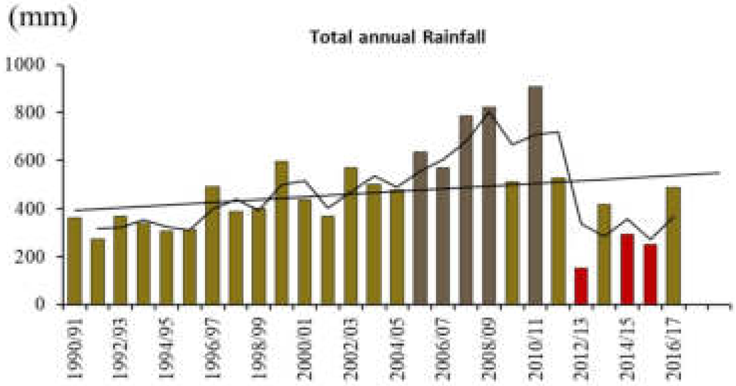

Figure 5. Average annual rainfall

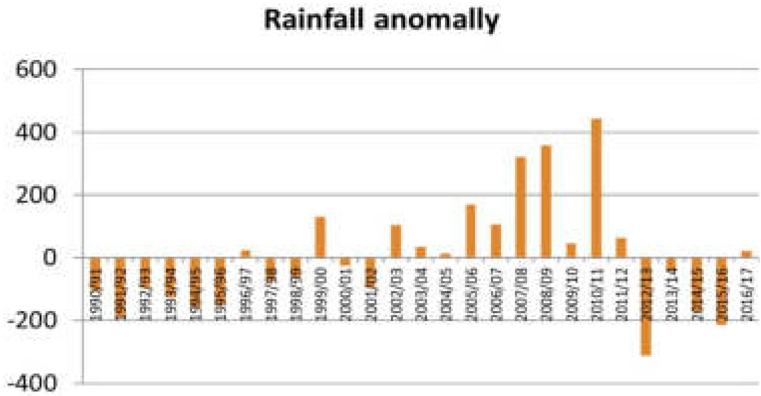

Figure 6. Rainfall anomalies between 1990 and 2016

3.3.2 Temperature and Precipitation

The monthly mean temperature and precipitation between the years 1982 and 2015 in Omusati Region are presented in Figures 7 and 8. Based on the graph, the temperature was high in January, February, November and December. A slight decrease in temperature was observed between March and August. The monthly mean precipitation is presented in Figure 8. According to the graph, sufficient and well-distributed rainfall was received in January, February, March, and December. However, it was insufficient from March onwards, with some months with no rainfall distributed at all.

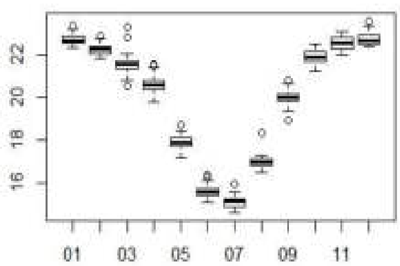

Figure 7. Mean monthly temperature

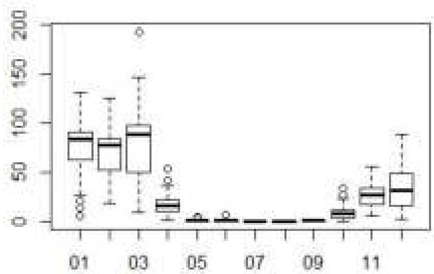

Figure 8. Monthly precipitation

3.3.4 Vegetation-NDVI Range in Omusati Region between 1982 and 2015

The figures below (Figure 9 and 10) elucidate the clip of the vegetation cover in the study area. The slope specifies the gradient, change in vegetation, brown indicates a negative change in vegetation while green indicates a positive change in vegetation.

Intercept

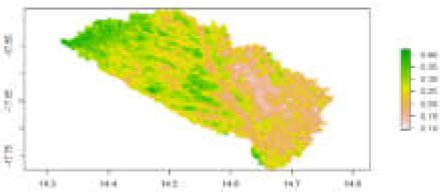

Figure 9. Watershed of the study area

Slope

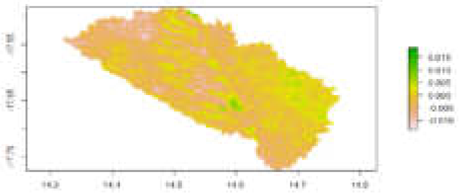

Figure 10. The change in vegetation

3.3.5 Change in Vegetation for Areas with Significance at 10% and 5% Respectively (1982-2015)

The Figures below (Figure 11 and 12) indicate the vegetation NDVI range with the significance of 10% and 5 % respectively, filtered from the watershed of the study area in Omusati region on how the change in vegetation has resulted due to human activities such deforestation for fuelwood, building materials among others. The figures indicate the areas that have had a significant decrease in vegetation over the years (brown) and a significant increase in vegetation over the years (green). However, it seems the most change was a decrease in vegetation cover as indicated by the brown colour.

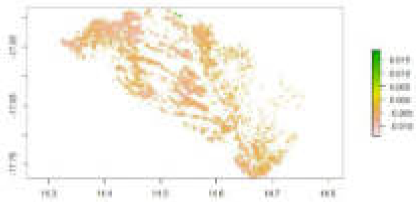

Figure 11. NDVI range 10% filtered

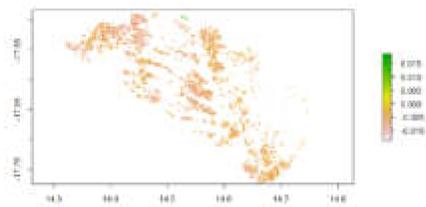

Figure 12. NDVI range 5 % filtered

3.4 Perception of Non-Climatic Factors

Apart from the climatic factors, human activities seemed to indicate a greater influence on the availability of mopane worms. The research revealed that deforestation, overharvesting, urbanisation and burning of mopane veld (Table 2). Looking at the table, the majority of participants (57.5%) from Okahao indicated that deforestation is the major contributing factor to the decline of mopane worms, compared to 36.7% from Tsandi who felt the same (see also figures 13 and 14). Most of the participants (36.6%) from Tsandi indicated that overharvesting contributes to the decline, compared to 20% from Okahao who indicated the same. Urbanisation as a cause of the decline was indicated by 15% of participants from Okahao, and 10% from Tsandi. The burning of mopane veldts was indicated by 16.7% of the respondents from Tsandi, and 7.5% from Okahao.

Figure 13. A mopane tree in Tsandi

Figure 14. Mopane wood fence and structure

Table 2. Results of human activities

Variables	Okahao	Tsandi
Deforestation %	23 (57.5%)	11 (36.7%)
Overharvesting %	8 (20 %)	11 (36.6%)
Urbanisation %	6 (15%)	3 (10%)
Burning of mopane veld %	3 (7.5%)	5 (16.7%)

Overharvesting and urbanisation are some of the known human activities that have historically contributed to the decline of mopane worms (Makhado, 2012). This research has revealed the same, as shown in the figures below, whereby mopane trees had to be cleared, which are habitats of mopane worms. In addition, overharvesting, as shown in Figure 16 below, is another activity done by humans to destruct habitats of mopane worms, that lead to habitat loss, which eventually causes a decline in the availability of mopane worms.

Figure 15. Results of urbanisation

Figure 16. Overharvesting of mopane worms

4. Discussion

4.1 Impact of Climate Change on the Availability and Distribution of Mopane Worms

The findings of this study indicate that climatic factors have a major impact on mopane worms' availability, distribution and livelihood options of the harvesters and traders, compared to the non-climatic factors. This is in agreement with the findings by Mataboge *et al*. (2016), whose study revealed a link between the availability of mopane worms and the impact of climate change, rainfall, and change in weather patterns on the mopane woodlands. Poor rainfall distribution and high temperature were found to be contributing factors to the decline of mopane worm, as revealed by a study by Senkonya (2016). A further explanation to this is the fact that lack of rainfall causes poor egg-laying by the emperor moth, while high temperature causes the eggs to burst, ultimately leading to the declining in the mopane worm population which has greatly affected the food and income source of the respondents (Boon & Ahenkan, 2012; Stack *et al*., 2003). Although abundant rainfall is good for mopane worm abundance, our research revealed a significant reduction of the mopane worm population, mainly experienced during the flood and drought events. For example, during heavy rainfall, mopane worms easily fall off trees and burrow faster, or drown in water, which increases their mortality rate (Thomas, 2013).

4.2 Impact of Non-Climatic Factors on Mopane Worm Availability and Distribution

Apart from the climatic factors, non-climatic factors also indicated a greater influence on the availability of mopane worms (Mogomotsi *et al*., 2016). Among others, deforestation seems to be the worst result of human activities, which plays a major role in the decline of mopane worms through clearing the land for crop production. These results can be supported by the findings by Senkonya (2016), that cutting down of trees leads to deforestation, which further leads to the decline of mopane worms as they feed on mopane leaves. Due to the high human population pressure on the environment, the north-central areas of Namibia have suffered from deforestation (Sithole, 2016; Senkonya, 2016). This environmental catastrophe is a threat to the mopane worm populations, as it can lead to their decline. Other human activities found by this study that lead to the decline of mopane worms are overharvesting, urbanisation and burning of mopane veld. These are also a result of increasing human pressure on the environment, which may completely wipe off the mopane worm habitats, further leading to their population decline.

Moreover, commercial harvesters are accused of destructive practices such as climbing trees, cutting off branches and cutting down whole trees to get at the caterpillar. They also have a tendency of harvesting all the caterpillars, which lowers the population levels of the following generation to the extent that harvesting is no longer feasible.

4.3 Economic Value of Mopane Worms

Although mopane worms were traditionally harvested for subsistence, their economic value has led them to become commercial (Stack *et al*., 2003; Ghazoul, undated). This study revealed that the trade of mopane worm is an important form of employment for the unemployed rural people in the 2 constituencies. The respondents indicated that unemployed people depend on mopane worms for economic empowerment, as they have the potential to generate higher income levels that can improve their livelihoods. Sadly, the production of mopane worms is seasonal, thus they cannot be relied on if not harvested in substantial amounts (Stack *et al*., 2003). Nevertheless, mopane worms remain an important food source for the local people in Okahao and Tsandi constituencies. This, and the need to trade mopane worms often results in overharvesting, which has a high potential to affect yield in the following season (Stack *et al*., 2003).

4.4 Regulation of Mopane Worm Harvesting

Given the current rate of mopane worm harvesting in Namibia, it is essential that regulations are put in place to ensure quality and acceptable standards of supply. Such will be necessary because through them, sustainable harvesting levels will be set that will seek to control overharvesting and ensure the maintenance of natural mopane populations. At the moment, the harvesting of mopane worms in Namibia does not appear to be strictly regulated but is largely based on local knowledge, beliefs and local institutional frameworks of control. Consequently, the development of policies guiding the harvesting of mopane worms is essential.

The Namibian Government is managing the forestry resources through various Acts and policies administered by the Ministry of Agriculture, Water and Forestry (MAWF). Specifically, the Forest Act No. 12 of 2001, amended as the Forest Act No. 13 of 2005, provides for general direction for the management of Namibia's forestry resources (GRN, 2005). This includes protecting and making the forests productive to improve the economic welfare of rural communities. In addition, the Environmental Management Act No. 7 of 2007 promotes the sustainable management of the environment and the use of natural resources by establishing principles for decision-making on matters affecting the environment (GRN, 2008). This applies to the harvesting of mopane worms, as observed in the two constituencies that the government does not have specific rules and regulations on the harvesting of mopane worms. The contributing factor may be the perception by the government that mopane worms have low economic value.

In an effort to ensure sustainable mopane worms harvesting in the two constituencies and prevent overexploitation and collecting of immature worms, the Traditional Authorities of the Ongandjera and Uukwaluudhi have set up in-house guidelines (by-laws) governing the harvesting in the outbreak sites. Other regulations governing the harvesting of mopane worms include the control of illegal cutting down of trees such as *Colophospermum mopane* for building and fencing material and the prohibition of setting fires in the forest.

5. Conclusions

Mopane worms are an important source of food and income for households in Northern Namibia. These worms are a beneficial trading commodity, which creates employment opportunities for unemployed people. However, climatic factors such as rainfall and temperature, and non-climatic factors, mainly human-induced (deforestation, overharvesting, urbanization) threaten their survival and populations, as they significantly contribute to their decline. Vegetation cover also contributes to their availability. Overall, non-climatic factors have a great effect on the decline of mopane worms compared to the climatic factors. There is a greater need to control of harvesting of mopane worms in order to avoid their overexploitation. In essence, deforestation should be avoided by all means, as it is the major contributor to the decline of mopane worm populations. Therefore, cutting down trees should be controlled, which should also be seen as a mitigation measure for climate change, which has a devastating effect on the production of mopane worms and their availability. For this reason, it is recommended that harvesters should always obtain permission (permits) before harvesting mopane worms. In addition, the mopane worm population should be left to recover for at least 1 to 2 years without any harvesting being allowed. It is also advisable that communities should practice agroforestry, and avoid cutting trees at all costs. Generally, when cutting trees, people have a tendency to keep trees such as Berchemia discolor and *Sclerocarya birrea* (marula), however, they should perhaps consider leaving mopane trees as well. Our study further recommends collaboration between traditional leaders, harvesters and the local government to address the management of forests and forestry resources, in efforts to reduce overharvesting and deforestation.

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Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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