Human-wildlife conflicts in Namibia's communal conservancies

MSc thesis

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Abstract

In 1998, Namibia established its "Community-Based Natural Resource Management" programme, which aims to promote the conservation of natural resources, improve the livelihoods of rural communities and protect wildlife and the environment by granting resource rights to members of its communal conservancies. Human-wildlife conflicts (HWC) appear due to overlapping interests in terms of habitats and resources in conservancies for humans and wildlife. By using a time and area-accurate approach, this thesis studied the density of HWC on a regional and conservancy level in Namibia for the period 2001-2017 and the densities for its two main types of conflicts: Crop and livestock damages. It also examined the growing size of conservancies for the same period as a factor influencing the annual total number of HWC. The quantitative data on HWC in conservancies was accessed from the event book of the "Namibian Association of Community-Based Natural Resource Management Support Organizations". The statistical and subsequent geographical analysis using Quantum Geographic Information System revealed a right-skewed distribution of data for the type-based and all-encompassing analysis of HWC. The Zambezi region showed the highest density of crop damage events. Nine out of 15 conservancies in the Zambezi region also faced a high or very high density of livestock damage. In terms of livestock damage, all except two of the conservancies with a high or very high density were located north of the Red Line in the Kunene, Oshikoto or Zambezi region. Furthermore, a very strong positive correlation (r^2 = 0.92) was found between the annual increase in the total area of conservancies and the total HWC. The analysis of the density of HWC revealed that the geographical conditions, which determine the use of land, influence the type of conflict in a region. The stronger distribution of livestock damages in comparison to crop damages was also expected to be due to a higher cultural significance and thus prioritized practice of livestock holding, especially cattle farming, over crop production for farmers in conservancies. The access to adjacent land shaped the distribution of wildlife populations and, thus, consequently influenced the level of risk for HWC. The density of the human population showed a strong positive correlation (r^2 = 0.72) with the occurrence of HWC. The analysis of other variables pointed out that an increased pressure of the Namibian population on wildlife habitats as well as the growth of major wildlife populations until 2012 both are likely to have influenced the increase of HWC. Counteracting measures, such as resettling households from wildlife corridors and the application of chilli-based deterrents were found to successfully mitigate HWC. Future research should include a wildlife-species-specific analysis, investigate agricultural land use patterns, and study the influence of human pressure on HWC to provide even more indications of the occurrence of HWC in Namibian conservancies.

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List of Abbreviations

CBNRM	Community-Based Natural Resource Management
HWC	Human-wildlife conflicts
IRDNC	Integrated Rural Development and Nature Conservation
KAZA TFCA	Kavango Zambezi Transfrontier Conservation Area
MEFT	Ministry of Environment, Forestry and Tourism
NACSO	Namibian Association of Community-Based Natural Resource Management Support Organizations
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental organization
QGIS	Quantum Geographic Information System
SMART	Spatial Monitoring and Reporting Tool

1 Introduction

According to many biologists worldwide, the Earth is currently experiencing the onset of or is in the midst of the sixth major episode of mass biodiversity extinction since life on Earth began (Barnosky et al., 2011; Cowie et al., 2022).[1] Contrary to the five prior mass extinctions, observations of changing species populations suggest that the current biodiversity crisis is caused by human activity, including the unsustainable use of land, excessive use of water and energy, and climate change (Barnosky et al., 2011; WWF, 2023). The endeavours of the international community of states to address the threats to biodiversity and ecosystem services are shown in the adaptations of the Kunming-Montreal Global Biodiversity Framework during the 15th Conference of Parties to the United Nations Convention on Biological Diversity (CBD, 2022). This framework, to which, in November 2023, 196 states are legally bound, foresees primarily the protection of 30% of the planet's land and oceans by 2030 while upholding the rights of indigenous peoples and local communities (CBD, 2011; CBD, 2022; CBD, 2023).

According to the organization Community Conservation Namibia, the total share of all forms of protected land areas In Namibia is estimated to be around 40% in October 2023. More than half of all protected areas, roughly 22% of Namibia's land area, are under communal management by communities, including indigenous peoples, who were granted proprietorship for the management of natural resources (Community Conservation Namibia, 2023a). In addition to the very high proportion of protected areas relative to the national territory in an international context, Namibia is a pioneer in uniting the interests of local communities, including indigenous groups, with national conservation goals (WWF, 2011). Emblematic of this is the fact that "Africa's First-Ever Community-led Conservation Congress" took place in October 2023 in Namibia and provided a platform for indigenous and local community groups, conservation organizations, governments, and policymakers to discuss how communities can play a bigger role in African conservation efforts (Rights and Resources, 2023). The congress was co-hosted by several non-governmental organizations (NGOs), including the Namibian Association of Community-Based Natural Resource Management Support Organizations (NACSO), which is supporting communities within communal conservancies and community forests in Namibia to successfully manage their natural resources sustainably (MEFT & NACSO, 2022; Rights and Resources, 2023).

One example of successful integration of nature conservation with the empowerment of an indigenous community is the *N≠a Jaqna* conservancy in northeastern Namibia where the !Kung San people could secure their land rights through the allocation of management rights by the Namibian government in December 2003. Due to the introduction of many new game animals and the implementation of a sustainable wildlife management system, the *N≠a Jaqna* conservancy has seen resurgences of key wildlife species such as the African savanna elephant (*Loxodonta Africana*) and giraffe (*Giraffa giraffa*). In particular, the strong reproduction of megafauna species promoted trophy hunting and the development of tourism in the area, which in turn generated revenues for the !Kung San people (Equator Initiative, 2012).

[1] Mass extinctions are characterized by palaeontologists as periods in Earth's history when more than 75% of its species are lost in a geologically short interval, which has occurred only five times in the past 540 million years (Barnosky et al., 2011).

Human-wildlife conflicts (HWC) occur “when the needs and behavior of wildlife impact negatively on humans or when humans negatively affect the needs of wildlife” (Mekonen, 2020, p. 1). This thesis investigates the factors that led to a varying regional density and type of HWC in Namibia’s communal conservancies between 2001-2017. In addition, it aims to determine the influencing variables that shaped the total number of HWC within the same period.

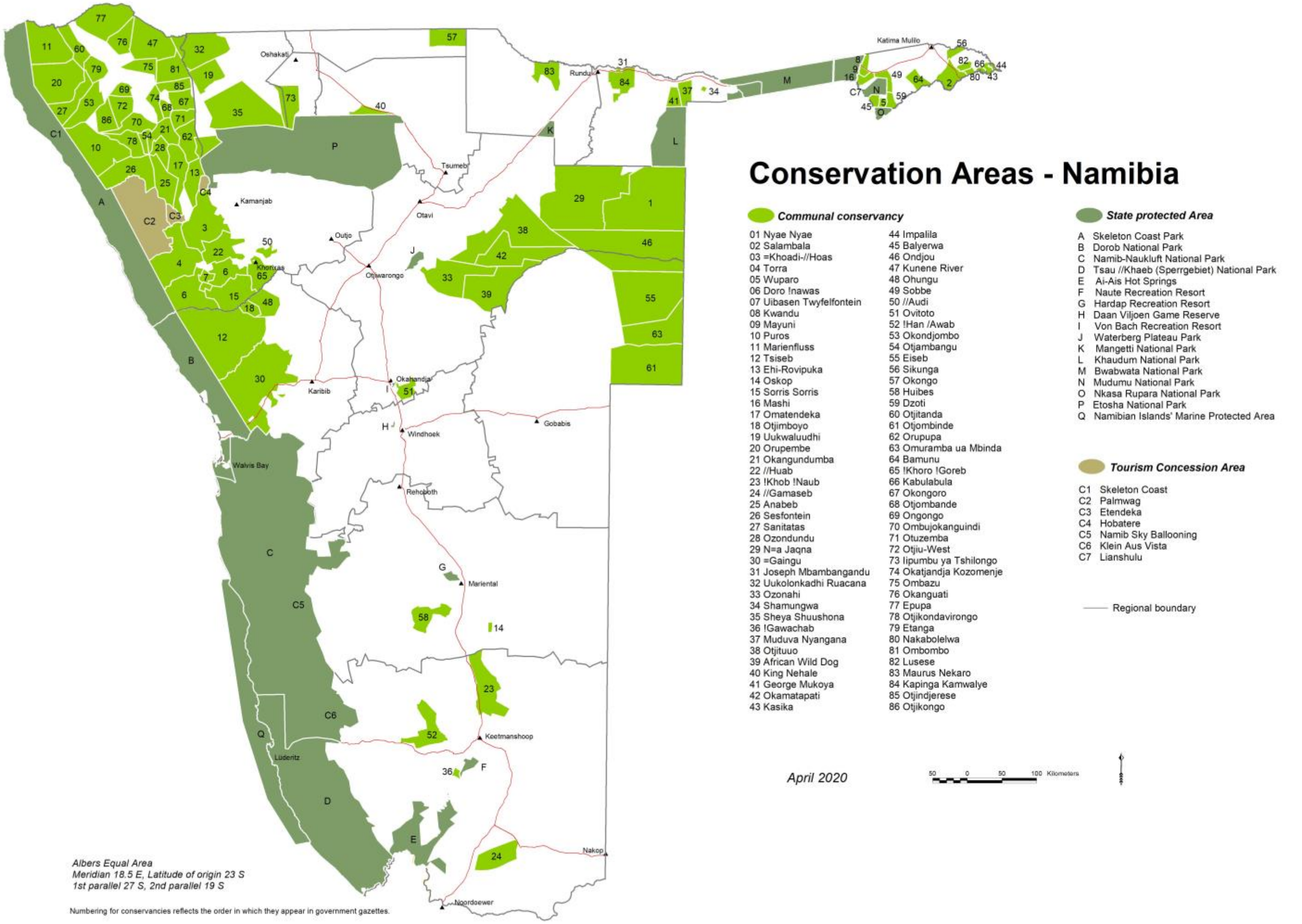
1.1 Community-based conservation in Namibia

Figure 1 provides an overview of the geographical position of all 86 communal conservancies and all other forms of protected areas in Namibia. The conservancies depict the light green, the national parks the dark green areas and the tourism concession areas the brown areas. Overall, in 2022, community conservation including community forests besides conservancies made up a larger proportion (~22%) of Namibia’s land area than the combination of national parks and tourism concession areas (~18%) (Community Conservation Namibia, 2023a). Namibia’s national parks are controlled by the Ministry of Environment, Forestry and Tourism (MEFT) and are linked to game reserves, recreation resorts, transfrontier parks and conservation areas, and tourism concessions. Tourism concessions are also state-owned lands but are overseen by non-governmental entities like conservancies or private sector operators using the area for lodge or campsite-based tourism (NACSO, 2023a).

The communal conservancies and community forests follow a different conservation approach. They fall under the Namibian conservancy programme “Community-Based Natural Resource Management” (CBNRM) which was officially launched in 1998 (Nuulimba & Taylor, 2015). In practice, communal area residents build a “common property resource management institution” (a conservancy) and are given ownership and responsibilities over certain wildlife species (Nuulimba & Taylor, 2015, p. 93). The ultimate ownership, nevertheless, of wildlife and communal land remains with the state of Namibia (Nuulimba & Taylor, 2015). The programme follows its goals to foster livelihood and to provide economic development for indigenous and local communities as well as to conserve their surrounding environment (Nuulimba & Taylor, 2015). The CBNRM approach, which is implemented across different countries in southern Africa, was first applied in Zimbabwe as the “Communal Areas Management Programme for Indigenous Resources” (CAMPFIRE). Namibia succeeded in the establishment of its own CBNRM programme in 1998 through a series of land rights reforms after Namibia gained independence from South Africa in 1990 (Meyer, 2022). In 2022, community conservation within CBNRM in Namibia encompassed more than 240,000 people (Community Conservation Namibia, 2023a).

Figure 1

All conservation areas in Namibia



Note. From *Conservation Areas map A3* by NACSO, 2020, (http://www.nacso.org.na/resources/map)

The CBNRM programme is based on Ostrom's common-pool resources theory, which emerged in the mid-1980s as a serious alternative to Hardin's theoretical solutions to the tragedy of the commons (Machaka, 2022). Hardin (1968) emphasized external regulation and privatization to counteract the depletion of natural resources, whereas Ostrom found through extensive research on commons on different continents that communities effectively self-organize and sustainably manage their common-pool resources (Hardin, 1968; Machaka, 2022). According to Machaka (2022), natural resource management agencies in southern Africa experienced in the mid-1980s a lack of financial and human resources to prevent resource depletion, which in addition to the establishment of the independent Namibian state in 1990, caused an increased urge for an alternative protection concept contrary to the central management of natural resources (Machaka, 2022).

Today, people-centred approaches in nature conservation are applied worldwide and promoted by various international organisations such as the United Nations, which supports through its United Nations Development Programme the integration of the interests of local communities into nature conservation (UNDP, 2023). However, some researchers found challenges and raised doubts about the successful implementation of people-centred conservation approaches. Brown (2003) stated that for well-functioning community-based conservation programmes, a stronger inclusion of all relevant actors in decision-making processes is needed so that community-based conservation would not follow an expert-driven and undemocratic approach (Brown, 2003). Büscher & Fletcher (2020), contrary to Ostrom's bottom-up common-pool resources theory, favour a top-down approach in the governance of natural resources. They argued that actors in superordinate levels are the ones that need to target their actions, which shall then be implemented by the communities. This approach would lift the pressure from local communities and address responsibilities and accountabilities to other actors than the rural poor (Büscher & Fletcher, 2020).

On the Namibian scale, opinions about the success of the CBNRM are divided. While some researchers emphasise the positive outcomes of the programme, others evaluate the programme rather negatively (Mufune, 2015; Naidoo et al., 2011; Nuulimba & Taylor, 2015; Schnegg & Kiaka, 2018). Heffernan (2022) categorised this wide spectrum of opinions into “panaceans, utilitarians, and skeptics”, where “panaceans” regard the programme as successful in terms of achieving its overarching goals, “utilitarians” point out the non-achievement of some objectives and components and “skeptics” perceive that there would not be sufficient support for marginalised groups, which should be prioritised by CBNRM (Heffernan, 2022, p. 55). Despite the discrepancies in the assessment of the success of the CBNRM, the researchers all agree that the livelihood and availability of economic possibilities all depend on wildlife (Mufune, 2015; Naidoo et al., 2011; Nuulimba & Taylor, 2015; Schnegg & Kiaka, 2018).

1.2 The role of wildlife in conservancies

Namibia enjoys global acclaim for its abundant wildlife. While iconic creatures like elephants and lions (*Panthera leo*) are widely recognized, there exist thousands of lesser-known species that all contribute to an ecological balance, which is necessary for intact wildlife populations (Jarvis et al., 2022). Primarily because of these iconic megafauna species, conservancies besides national parks and tourism concessions attract tourists through joint venture cooperatives with private sector actors. In practice, hunting and tourism operators compete over the rights of wildlife-related ecosystem services that include photographic safaris and trophy hunting.[2] In the CBNRM programme, local communities are in this scenario often represented by conservancy committees that are the sellers of ecosystem services and private companies the buyers, which facilitate the tourism experience for the end-users (Naidoo et al., 2011).

In 2022, solely from wildlife-dependent income, including trophy hunting as well as game harvesting for meat, conflict animals and live sales, made up about 26% of all sources of cash income and in-kind benefits for conservancies. Joint venture tourism was the most important source of income for conservancies with about 54% of the total returns (Community Conservation Namibia, 2023b). Since photographic safaris that generate income through joint ventures mainly target areas with fascinating wildlife, one can therefore attribute a considerable importance of wildlife to enabling revenue for conservancies. Matinca (2018) found that the revenues from wildlife have a positive influence on the attitude of some members of communal conservancies. She conducted interviews in conservancies in the Zambezi region that border Mudumu National Park, in which the majority of community members expressed their positive perception of wildlife since their presence provides employment and can deliver positive side effects (e.g. elephants helping in clearing overgrown brush).[3] However, nearly all interviewees stated that they face crop raiding by elephants as negative effects from wildlife each harvesting season, leaving farmers with a smaller or completely failed harvest (Matinca, 2018).

The damage to crops is one out of the following four by NACSO defined types of HWC a community member in a communal conservancy can face (MEFT & NACSO, 2022): (1) Crop damages that are usually caused by feeding or trampling of wild animals, (2) Attacks or predation on livestock by predators, (3) attacks on people, and (4) other incidents, such as damage to infrastructure (Jarvis et al., 2022).

Communal conservancies are requested to report all HWC incidents within their conservancies by community game guards. All game guards within a conservancy meet regularly to compile all events of special interest, such as poaching events, wildfires, sightings of rare species, and HWC. This data, which is collected by the community guards in their so-called "event books", is digitised after being collated with the other game guards and passed on to NACSO. Through analysing this data, NACSO supports MEFT in designing management policies for wildlife at the local, regional and national scales (Community Conservation Namibia, 2023c; MEFT & NACSO, 2022).

HWC have severe impacts on community members in conservancies, which, depending on the type and intensity of the conflict, can have different degrees of impact on the life of an individual, but also on an entire community. Salerno et al. (2020) have shown that crop depredation reduced significantly the household food security of people in the *Mashi* conservancy in the Zambezi region (Salerno et al., 2020). The loss of livestock through predator species is also devastating for communal farmers since they tend to be less wealthy and capable of coping with economic turbulences in comparison to commercial farmers (Rust & Marker, 2014). The most severe form of HWC for a conservancy member is the attack on a human, which in the worst cases can lead to serious injury or even death

[2] "Trophy hunting is hunting of animals with specific desired characteristics (such as large antlers), and overlaps with widely practiced hunting for meat" (IUCN, 2016, p. 1).

[3] Brush is a combination of "shrubs and trees which are considered undesirable to the planned use of the area" (Rollins, 1997, para. 2).

(Community Conservation Namibia, 2023d). Besides visible physical harm and depredations caused by wild animals, Gargallo (2021) emphasized to also not forget about the physical and psychological stress on community members are exposed to by coexisting with wildlife (Gargallo, 2021). The threat to human safety including its vital infrastructure and agriculture can also lead to defensive and illegal retaliatory killing of wild animals (Community Conservation Namibia, 2023d).

The only legal exception for the lethal removal of a wild animal is when many reported and consistent losses can be traced back to a specific animal. While the reporting of all details of an HWC incident must be carried out by the affected person, the judgement if a capture or lethal removal of the problem-causing animal has to be undertaken obliges MEFT and its cooperating stakeholders. This act follows MEFT's policy "Human-Wildlife Conflict Self Reliance Scheme", which aims to partially offset the loss of farmers caused by wild animals. This support to farmers is, however, bound to specific conditions. In the case of livestock death, a farmer in a conservancy only receives financial support if the killing of livestock has not occurred in conservancy-exclusive wildlife zones, when the death of livestock was reported within a day and afterwards verified by MEFT staff and the farmer can prove that reasonable precautions were put in place (MET, 2018).[4]

1.3 Research gap

Since NACSO started publishing data on HWC incidents for communal conservancies in the early 2000's until today, the prevalence of HWC was over time a key pillar of research related to CBNRM (Jones & Barnes, 2006; Mufune, 2015; Lindeque & Dierkes, 2020; Tavolaro et al., 2022). HWC data is provided by NACSO (2023b) on a national scale and, therefore, many studies analysed the number of HWC incidents on a country level (Mufune, 2015; Lindeque & Dierkes, 2020; Stoldt et al., 2020; Tavolaro et al., 2022). However, the analysis of drivers for HWC was limited to administrative regions that received relatively high counts of conflicts. Examples are Jones & Barnes (2006) and Salerno et al. (2021) who both investigated in detail the forces and characteristics of HWC in conservancies in the Zambezi region and Jones & Barnes (2006) additionally in the Kunene region (Jones & Barnes, 2006; Salerno et al., 2021). Furthermore, important works in the research field of HWC within Namibian conservancies, have not shed light on the density of HWC, considering the size of conservancies in relation to the frequency of conflicts (Lindeque & Dierkes, 2020; Tavolaro et al., 2022). Lindeque & Dierkes (2020), Mufune (2015) and Tavolaro et al. (2022) all used the total amount of HWC incidents within their works to conduct their analysis. Also, in these works, there was no integration of the varying amounts of reporting years for the conservancies in their methodology.

In this thesis, the conflict density per area and year was investigated to receive accurate results in terms of area and time. In addition, regional conditions were analysed more closely to gain insight into the presented data on conflict density and the type of conflict.

Regarding the variables that explain the yearly development of the total numbers of HWC, there was little academic research given. MEFT stated in its "Revised National Policy on Human Wildlife Conflict Management" for the period 2018-2027 that the increased level

[4] MEFT emphasized in its active "Revised National Policy on Human Wildlife Conflict Management" (2018-2027) conservancies to relocate households from wildlife corridors to settlement areas to reduce the number of HWC incidents (MET, 2018).

of conflict would be related to rising human and wildlife populations (MET, 2018).[5] An exception for a study that investigated the influence of human population density on the level of HWC poses Tavolaro et al. (2022), who found that the distance to near protected areas and rivers, terrain ruggedness, conservancy size and annual rainfall were greater influencing the prevalence of HWC than the human density (Tavolaro et al., 2022). Both, Jones & Barnes (2006) and Jarvis et al. (2022), examined mitigation measures of communities within conservancies that followed the goal to decrease HWC (Jarvis et al., 2022; Jones & Barnes, 2006).

This thesis investigated by a linear regression model the statistical relationship of the yearly changing total area of communal conservancies and the prevalence of HWC and analysed the most recent studies and available data that provided indications of the occurrence or non-occurrence of HWC.

1.4 Research objectives and research questions

Since former research did not point out the conflict density per area, which is important to faithfully categorise conservancies in administrative regions of relatively higher and lower risk areas for HWC, this thesis aims to investigate the regional differences of the density and type of HWC. The varying number of reporting years for HWC was taken into account to obtain meaningful results without distortions. This thesis also examined the influence of certain variables that determine the occurrence or non-occurrence of conflicts to better understand the data on HWC in Namibian conservancies.

The following two superordinate questions, each with a secondary question were determined to address the thesis' research objectives:

1. How do the density and type of HWC differ depending on the location of a conservancy? What are the influencing factors for variations in conflict density and conflict type?
2. To what extent does the increase in the total area of conservancies explain the amount of HWC over the period 2001-2017? What are other variables that have an impact on the prevalence of HWC?

One objective of this thesis is to find trends and differences in the density and type of HWC on a conservancy and regional level and to provide the reasons for this. The other objective is to identify the drivers for and the impeding measures against HWC in conservancies Namibia-wide.

The approach in this thesis is structured as follows: Chapter 2 presents the methods applied, starting with the explanation of the time and area-accurate approach that served to achieve meaningful results on the geographical distribution of HWC. It then describes the to-be-estimated linear regression model, with which the statistical relationship between the development of the cumulative area of all communal conservancies and the total amount of HWC within the conservancies was investigated. Chapter 3 starts presenting the results of the geographical distribution of HWC on a regional level, proceeds with the distribution of conflicts on a conservancy level and closes with the results of the linear regression. In chapter 4, the analysis of factors influencing the density

[5] MET also stands for the Namibian Ministry of Environment and Tourism (MEFT) because it is the old abbreviation of the ministry. For the sake of consistency, only MEFT is used as the ministry's current abbreviation in the body text of this thesis.

and type of HWC is given as well as the exploration of other variables that influence the prevalence of HWC in Namibian conservancies. The concluding chapter 5 summarizes the overall arguments of this thesis, answers the research questions and gives recommendations for future research.

2 Methodology

The object of the thesis was to investigate the geographical differences and factors that influenced the development of HWC in Namibian conservancies over time. This was achieved by clustering subset data on HWC published by NACSO, understanding it with the help of self-created formulas, integrating it to Quantum Geographic Information System (QGIS) 3.3.2 to gain geographical knowledge and, as a last step, comparing these results with findings from other scholars.

2.1 Data characteristics

The dataset used is publicly available within the event book on NACSO's website which delivers official numbers about the size of communal conservancies and each reported HWC from 2001 until 2017. It also contains additional data such as which animal species was responsible for a specific HWC and the date and conservancy where poaching incidents were reported (NACSO, 2023b). While the given dataset would allow more thorough research with more determinants than the quantity and type of HWC as well as the area over the period 2001-2017, the limited scope of this thesis suggested an analysis of the type and quantity of HWC over the different communal conservancies in Namibia.

In the dataset, each HWC contains information about the year and month of the conflict as well as the type of the conflict given. The event book clusters HWC in four different types: Crop damages, livestock attacks, human attacks and other damages. To understand the nature of the data, one has to consider that an incident that was recorded by community game guards can count as several incidents if it is classified as more than one type of HWC. One example would be that an elephant tramples crops on a maize (*Zea mays*) field and destroys a water tank of a community. Here, this incident would count as one crop damage event and as one other damage event, meaning this hypothetical conflict received two entries in the event book, regardless of the number of crops destroyed and the value lost for the farmer (Lindeque & Dierkes, 2020).

2001 is the first year in which HWC were reported, which is why the years 1998, 1999 and 2000 are neglected in this analysis. Though 10 conservancies were already established before 2001, the event book only delivers reported conflicts from 2001 onwards. For the conservancies that were established later than the first year of reporting (2001) considered in this analysis, there is in consequence data only available after 2001. While for some conservancies wildlife monitoring, which includes data on HWC, found its implementation from the year of establishment onwards, for others it was conducted later (NACSO, 2023b). Section 2.2 describes the method of how the varying years of reporting per conservancy were taken into account in this thesis.

HWC that fall under the category "other damages" or "human attacks" were not analysed in detail in this work since it was calculated using the dataset of NACSO (2023b) that both together displayed only less than 3% of all conflicts reported within the period 2001-2017 (NACSO, 2023b). Moreover, other damages and human attacks provide less scope for geographical analysis in comparison to crop damages and livestock attacks since they occur comparatively rarely and thus are less investigated by other scholars (Community Conservation Namibia, 2023e). An exception was posed by Tavolaro et al. (2022) who formulated geographical differences in the occurrence of human attacks and other damages but their analysis still provided more insights into crop raiding and livestock attacks by wildlife (Tavolaro et al., 2022).

The event book (Status: November 2023) did not include conflicts after 2017 and therefore, there is no data given for the following conservancies that were established during the year 2017 or after: *Maurus Nekaro* (ID: 83), *Kapinga Kamwalye* (ID: 84) and *Otjindjerese* (ID: 85). For the conservancies *Joseph Mbangandu* (ID: 31), *Shamungwa* (ID: 34), *!Gawachab* (ID: 36) and *Ovitoto* (ID: 51) was also no data given on HWC even though all four conservancies were established before 2017. In November 2023, for *Joseph Mbangandu*, *Shamungwa and Ovitoto* there were no wildlife monitoring systems applied, which is the reason no data was delivered by those conservancies in the regarded period. *!Gawachab* has currently an active event book monitoring system but the first year of wildlife monitoring was only in 2021, meaning four years after the end of the period under consideration (NACSO, 2023c). Because of this lack of data for the seven mentioned conservancies, the quantitative and geographical data analysis only considers the remaining 79 of the 86 total registered Namibian conservancies, which are distributed in 12 out of 14 administrative regions in Namibia. Still, in the maps created for the geographical analysis of HWC, those seven conservancies were for the sake of completeness also depicted and colour-coded to separate them from the conservancies with data. The event book did not contain data on HWC in community forest areas outside the communal conservancies. This is the reason this thesis focuses solely on the prevalence of HWC within conservancies.

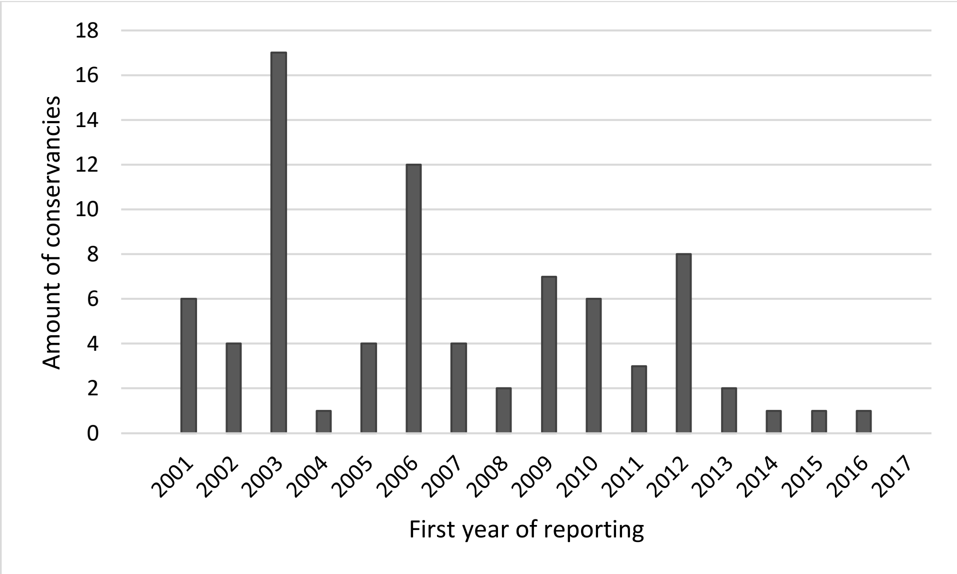
2.2 Geographical data processing

Research question 1 refers to the differences in the prevalence and type of HWC depending on the location of a conservancy. To be able to make statements about the different levels of risks for HWC in the conservancies, the data from all conservancies needed to be processed to make them comparable with each other.

Since the amount of reporting years varies greatly amongst the 79 conservancies, a simple addition of all reported conflicts within a conservancy would bias the results towards conservancies that have a relatively high amount of reporting years compared to conservancies that only provide a few years of data (NACSO, 2023b). In particular, in 2001 only six conservancies reported HWC within the event book, while in 2008, the eighth year of reporting, 29 conservancies were still not providing HWC data either due to a missing wildlife monitoring system or because they were not established yet (NACSO, 2023b; NACSO, 2023c). Figure 2 displays the varying distribution of the first year of reporting for the 79 conservancies considered in this work, which had at least two and a maximum all 17 years (from 2001 to 2017) of reporting.

Figure 2

Distribution of the first year of reporting of human-wildlife conflicts in the conservancies



Note. Own work. Data input by NACSO (2023b).

Besides a time-accurate analysis of HWC, there was a need to further process the data on HWC, so that the varying size of conservancies was also taken into account. The conservancies vary strongly in size, so hypothetically, the same count of conflicts in two different conservancies having two different sizes would signify a higher area-related risk for the conservancy that is smaller in size. While there are many conservancies, especially in the Etosha/Kunene area and Zambezi region that are comparatively small in size, there are relatively large conservancies in Erongo, Omaheke and Otjozondjupa (NACSO, 2023b; NACSO, 2023c).[6] The comparison of the smallest and the largest conservancy in Namibia serves as an illustrating example to demonstrate the immense differences in terms of the size of communal conservancies: *Impalila*, located at the eastern tip of the Zambezi region has a size of 73 km^2, which corresponds roughly to the area of the large medium-sized city of Gießen in central Hesse, whereas *N≠a Jaqna* with 9120 km^2, located in north-eastern Otjozondjupa, is roughly 10 times larger in area than Berlin, the capital of Germany (Hessisches Statistisches Landesamt, 2023; NACSO, 2023c; Statistisches Bundesamt, 2022). Only looking at the total amount of conflicts would, therefore, neglect the major differences in terms of area size.

Considering these two possible constraints of data, namely the disregard of the different amount of reporting years and the varying sizes of the protected areas, a formula was created to process the data by a time and area-accurate approach. First, all conflicts per

[6] The term "Etosha/Kunene" area, which is multiply used in this thesis, describes a specific area within the Kunene region where Etosha National Park makes up the eastern boundary and various conservancies and community forests the west and north of the region (Stoldt et al., 2020; Universität zu Köln, 2022).

type for each conservancy were totalled but also the overall sum of all types of HWC for each conservancy was built. Then, the total number of conflicts was divided by the amount of reporting years for each respective conservancy. As a last step, the quotient was divided by the size of the conservancy to receive the density of HWC per km^2 and year as seen in (1); where D = density of HWC per km^2; C = the total number of conflicts reported since the first year of reporting; t = the individual amount of reporting years for a conservancy and A = the size of a conservancy [in km^2].

$$D = \frac{C/t}{A} \tag{1}$$

The described formula was used for three different inputs for the letter C (total number of conflicts) and their inputs were calculated in Microsoft Excel (2016). First, C_{HWC} included all conflicts by adding up the summation of all four types of conflicts (Crop damages, human attacks, livestock attacks, and other damages) for each conservancy to include every single HWC that occurred between 2001 and 2017 in Namibian conservancies. Second, C_{CROP} considered only the summed conflicts categorised as “crop damage” to determine the frequencies of wildlife damages on crops. Third, only attacks on livestock were included as C_{LIV} to assess the density of livestock attacks in conservancies. The density of conflicts of the types “other damage” and “human attacks” were still calculated and are presented in the appendix together with the densities of the two major types of HWC for all 79 conservancies.

The three computed densities of HWC (D) for all 79 conservancies were then integrated into the open-source software QGIS 3.3.2 as attributes in a shapefile layer that stored the geometric location of all Namibian conservancies.[7] This polygon layer was accessed from the Environmental Information Service Namibia and together with point, line and other polygon layers that display municipal, regional and national boundaries, the capital of Namibia, the so-called “Red Line” and the area of all national parks in Namibia, these features were included to the maps.[8] The shapefile of the national parks was edited by extracting the Namibian Islands’ Marine Protected Area, which is located along the southwestern coast of Namibia. Since the focus of this thesis is on the analysis of communal conservancies that are located on Namibia’s land surface, the marine protected areas were excluded to avoid graphical irritations.

The conflict densities for conservancies in the three datasets were classified into four different categories to rank the degree of conflict density within a conservancy over the period 2001-2017: Low density, moderate density, high density and very high density. The greater the prevalence of conflicts per area in a conservancy the darker red its fill colour

[7] “A shapefile is a simple, nontopological format for storing the geometric location and attribute information of geographic features. Geographic features in a shapefile can be represented by points, lines, or polygons (areas)” (Esri, 2021, para. 1).

[8] The German colonial authorities established in the late nineteenth century a temporary veterinary defence line against rinderpest. About sixty years later, in the 1960s, the South African colonial government constructed a continuous two-metre-high fence that spans 1250 kilometres and separates northern from central Namibia (Miescher, 2012). This fence, the Red Line, is still in place today and it is primarily designed to protect livestock from other livestock and wild ungulates that carry diseases such as foot-and-mouth disease. However, the fences are not selective and can create significant physical barriers for many wildlife species (Gadd, 2012).

is. Since the datasets of the conflict density for all conservancies were right-skewed, meaning the mean was in each case greater than the median, the terminology of the classes needed to take the differing class widths amongst the four classes into account (Siegel & Wagner, 2022). The terminology used to categorise the conflict density was that values in the higher classes were described as "high" or "very high", as the range of the higher classes is significantly wider and thus this terminology represents a realistic classification of the conflict density for the conservancies in the higher classes. The reason for unequal class widths was the selection of a suitable classification mode that considered the skewness of the data.

As there were many data values concentrated near zero, and they decreased the higher one looked at the scale of the density of conflicts, the method of non-equal breaks proved useful for representing the three data sets (Traun, 2023). The applied classification mode was the “Natural Breaks (Jenks)” algorithm by George Frederick Jenks and Fred Caspall (1971) (Jenks & Caspall, 1971). This classification algorithm creates classes that are as harmonious as possible in the set of values. This means that individual clusters are created whose outliers within a class are minimised. This algorithm compares neighbouring classes with each other and, depending on the result, moves the largest element of the lower class to the upper class or the smallest element of the upper class to the lower class. This process is repeated until the algorithm no longer considers a shift to be useful, which creates clusters that classify the data (Bullenkamp, 2020).

Since the data was right-skewed, there was a strong distribution of the data in the different classes regardless of the applied mode of classification. However, the classification of natural breaks delivered maximum differentiated map images by still not distorting the gradient of the data distribution. An even stronger distribution of the data would have been achieved by applying the “Equal count (Quantile)” mode which clusters the same count of features in each class. This would have delivered minimal classes in size for very low values and very high-class widths for higher values. However, the application of this mode of classification would have strongly distorted the real differences of conflict densities of the conservancies and was therefore neglected. Another classification method provided by QGIS 3.3.2, the mode of “Equal intervals”, would have given a simple interpretability of the legend but there would also have been a grouping of data values, which are statistically not similar.

Regarding the rounding of decimal numbers within the three data sets, the conflict density values provided six-digit decimal numbers, which were rounded to two decimal places for better clarity. For example, 0.000834 was the lowest value and 2.406316 was the highest value given for the density of all types of HWC for a conservancy, which were rounded and referred to in section 3.1.2 as < 0.01 and 2.41. The example of the lowest and highest value of conflict densities signifies the large range of values for the three datasets and provides a clear argument against the application of uniform class widths. With widths of classes, the lowest class would, for example, range from 0 to 0.6 and reflect 74 out of 79 values in the dataset for the density of HWC including all types of conflict. By the use of unequal class widths with the “Natural Breaks (Jenks)” mode, 11 values more than with equal class widths lay outside the lowest class, which provided a higher differentiation of the data while still reflecting the density of HWC nationwide realistically, in contrast to “Equal count (Quantile)” method.

After the mode of classification was determined, the symbology of all layers was adapted for an appropriate representation of the data. Last, the three different maps that represent the density of HWC including all types of conflicts, the density of livestock damages and the density of crop damages in communal conservancies in the period 2001-2017 were then exported as image files.

2.3 Regional approach

Since the analysis of conservancies is a strongly insightful strategy to detect geographical differences on a small scale, it was useful to group conservancies from the same administrative region in a Microsoft Excel (2016) file to achieve results on a regional level. By doing so, trends and variations of the density and type of HWC were achieved to be visible on a larger scale. An exception for a clear allocation of a conservancy to a region posed *Ondjou* conservancy, which is the only conservancy that crosses the borders of two different regions: Otjozondjupa and Omaheke. NACSO assigned the cross-border conservancy *Ondjou* to Otjozondjupa, which is why, in this thesis, *Ondjou* was assigned to the same region (NACSO, 2023b). To ensure legibility and quick assignment to a conservancy or a region, the names of regions were set in standard (nonitalic) type and italics for conservancies. To avoid misunderstandings, in sentences in which the Kunene and Zambezi regions were mentioned, the word "region" was added to indicate that the reference was to the regions and not to the rivers of the same name. Other scholars also adopted this approach (Jones & Barnes, 2006; Mufune, 2015; Stoldt et al., 2020).

The additional approach of this thesis to detect overarching trends for specific regions was reasonable since section 4.2 provides references to other scholars, which in many cases also analysed HWC on a regional level with the help of results from specific conservancies (Jarvis et al., 2022; Lindeque & Dierkes, 2020; Stoldt et al., 2020). Furthermore, the conservancies within some regions (e.g. Kunene and Zambezi region) are comparatively well studied in terms of the drivers and the prevailing types of HWC, whereas there is little academic material on conservancies in the majority of Namibian regions such as Erongo, Hardap and Otjozondjupa (Jones & Barnes, 2006; Naha et al., 2023; Salerno et al., 2020). For regions where there was a lack of data on the frequency and type of HWC, interpretations of the data by NACSO (2023b) were supported by studies and figures on rainfall patterns, type of land use as well as human and wildlife population data (NACSO, 2023b).

To receive the densities of HWC for regions considering all their consisting conservancies (*N*), the arithmetic mean of the densities of HWC for all conservancies for each respective region was computed in Microsoft Excel (2016). Thereby, the varying amount of reported years and the respective area per conservancy were included in the calculation, to obtain time and area-accurate results for the overall HWC density, including all types of conflict and the densities of crop and livestock damages.

$$\bar{X}_r = \sum_{i=1}^{N} D \qquad (2)$$

The outputs for the conservancy level (*D*) were further processed as seen in (2) to obtain results for the regional level; where; $\bar{X}_r$ = the density of HWC per km^2 and year within a region; *N* = the number of conservancies within a region and *D* = the density of HWC per km^2 (*A*) and year (*t*) within a conservancy.

As a result, the density of HWC overall ($\bar{X}_r$: HWC), the density of crop damages ($\bar{X}_r$: CROP) and the density of livestock damages ($\bar{X}_r$: LIV) in the period 2001-2017 for the conservancy areas of the 12 regarded regions was calculated and is presented in section 3.1.1.

It is important to mention that the procedure to collect and analyse the dataset obtained from NACSO (2023b) was reversed compared to the presentation of the data on the density of HWC in section 3.1 (NACSO, 2023b). The reason for this is that with a good understanding of the regional differences in the prevalence of HWC (section 3.1.1), the results at the conservancy level (section 3.1.2) can then be better understood.

2.4 Linear regression

To answer research question 2, the summation of all conflicts reported for each year was compared over the cumulated size of all conservancies over the period 2001-2017. Since the total size of all conservancies changed yearly by the establishment of new conservancies over the regarded time and, thus, also the number of conservancies reporting HWC, it was important to closely look at the two parameters over time. Although 10 out of the 79 observed conservancies were established before 2001, the first event book entries were only realized for six conservancies in the year 2001 (NACSO, 2023b). This is the reason the cumulative area in the linear regression only represents the actual size of all conservancies for a specific year that reported HWC in that year. By this procedure, distortions by conservancies that reported later than the year of their actual establishment were avoided. One example of a conservancy that reported in default after its establishment in December 1999 is *Kwandu*, whose game guards started to report HWC only in 2003 (NACSO, 2023b).

In the applied correlation computation and statistical analysis of the two variables, the size of the summed area of conservancies was the independent (*x*-axis) and the summed HWC was the dependent variable (*y*-axis). Since the aim of this computation was to explore the statistical relationship of *x* and *y*, meaning the influence of the yearly changing area (*x*) on the prevalence of HWC within conservancies (*y*), the impact of *x* on *y* was investigated.[9] To examine the statistical significance of this relationship, a linear regression analysis was performed in Microsoft Excel (2016).

As this method only considered one predictor (*x* = cumulative area [in km^2]) for the prevalence of HWC (*y*), other possible predictors, such as the human population pressure and its pressure on natural resources as well as publicly available data on wildlife population and the application of countermeasures by communities in conservancies are analysed in section 4.2.

In this linear regression model, only the statistical relationship of the cumulative area of conservancies and the frequency of HWC were investigated since other parameters such as the human pressure on natural resources are difficult to measure on a national scale. Similarly, wildlife population data is not published uniformly for all regions by NACSO (NACSO, 2023c). Nevertheless, the influence of other predictors for HWC besides the cumulative area in the period 2001-2017 was taken into account by the analysis of the most recent human and wildlife population data as well the findings from different scholars on these parameters.

[9] The only exception was in 2017 when the size of the communal areas did not increase compared to the previous year.

3 Results

The results of the computations of the dataset accessed from NACSO (2023b) are presented in this chapter. Reference to the total area of conservancies or the total number of conflicts was only made for conservancies amongst the 79 conservancies that provided data on HWC for the period 2001-2017.

3.1 Geographical distribution of human-wildlife conflicts

Section 3.1 is divided into two subchapters and presents first, in 3.1.1, the outputs of formula 2, the density of crop and livestock damage as well as all the density of all summed HWC for the 12 regarded regions. Then, in 3.1.2, the outputs of formula 1, the density of crop and livestock damage besides the HWC overall are visualized in figures and further explained in the text.

3.1.1 Regional distribution of human-wildlife conflicts

Table 1 gives information about the total area (column 2) and the human population density of all conservancies within a region (column 3), the total amount of incidents of crop damage (column 4), attacks on livestock (column 6) and all types of HWC (column 8), including other damages and attacks on humans. It further presents the calculated density per km^2 for crop damages (column 5), attacks on livestock (column 7) and all types of HWC (column 9). The statistics for other damages and human attacks are not analysed and reported within its category but are included in the overall HWC counts. Kavango West's only conservancy *Maurus Nekaro* is not represented in the dataset by NACSO, so the 12 remaining regions were compared in terms of the prevalence of crop damages, livestock attacks and HWC overall for the period 2001-2017.

Table 1

Crop damages, livestock attacks and human-wildlife conflicts overall during 2001-2017

Region	Area [in km^2]*	Pop. density [people per km^2]*	Count CROP	Density of crop damages ($\bar{X}_r$: CROP)	Count LIV	Density of livestock damages ($\bar{X}_r$: LIV)	Count HWC	Density of HWC ($\bar{X}_r$: HWC)
//Karas	6,418	0.68	-	0.00	1,110	0.01	1,111	0.01
Erongo	17,303	0.44	24	0.00	1,681	0.02	1,753	0.02
Hardap	1,423	0.59	-	0.00	965	0.17	965	0.17
Kavango East	1,101	1.19	695	0.06	155	0.01	852	0.08
Kunene	60,004	1.20	3,016	0.01	45,745	0.10	50,515	0.11
Ohangwena	1,340	2.31	11	0.00	513	0.05	544	0.05
Omaheke	15,733	0.44	4	0.00	2,110	0.02	2,118	0.02
Omusati	9,496	4.48	1,098	0.01	4,254	0.03	5,584	0.05
Oshana	1,548	1.67	-	0.00	96	0.02	96	0.02
Oshikoto	508	10.49	78	0.01	1,472	0.24	1,677	0.28
Otjozondjupa	43,098	0.80	169	0.00	1,824	0.01	2,107	0.01
Zambezi	4,103	8.24	21,079	0.45	7,125	0.16	28,611	0.63
Total	162,075	-	26,174	-	67,050	-	95,933	-

Note. Own work. Data was computed with the formulas that were presented in sections 2.2 and 2.3, while many of the conservancies were not counted in all the years. The raw data was extracted from NACSO (2023b).

$\bar{X}_r$ stands for the density of conflicts of the respective type or all types of conflicts within a region. "CROP" stands for crop damages, "LIV" for livestock damages and "HWC" for the sum of all types of conflicts. All data for conflicts that are given in NACSO (2023b) were included in the calculations.

* Only the area and population counts of the 79 conservancies that provide data on HWC were included.

For the period 2001-2017, in total 95,933 HWC were reported for all conservancies. Attacks on livestock accounted for the largest share with 67,050 cases (69.9%). Crop damages followed as the second most frequent type of conflict with 26,174 cases (27.3%). Significantly smaller shares were accounted for by other damages with 2,475 cases (2.6%) and, lastly, by attacks on humans with 234 incidents (0.2%).

While the Kunene region holds the largest area of conservancies with 60,004 km^2 out of 162,075 km^2, its region is also accountable for the most HWC with 50,515 cases (52.7%). The Zambezi region follows second with 28,611 cases (29.8%), despite holding only the seventh largest area of conservancies with 4,103 km^2. The third most HWC incidents with 5,584 cases took place in the Omusati region, while holding the fifth highest area of conservancies with 9,496 km^2.

The most crop damages with 21,079 cases occurred in the Zambezi region followed by 3,016 cases in the Kunene region and 1,098 in Omusati. Whereas not a single crop damage conflict was reported for three regions namely //Karas, Hardap and Oshana, in every other region crop damages were reported. However, the counts in the regions vary greatly with seven regions experiencing less than 100 incidents of crop damage over 17 years, while two regions counted conflicts in the four-digit range and the Zambezi region even in the five-digit range (21,079 cases). Contrary to the absence of crop damage in some regions for the regarded period, every region faced livestock attacks. The fewest livestock attacks occurred in Oshana with 96 cases followed by Kavango East (155 cases) and Ohangwena (513 cases). The most livestock attacks, with 45,745 cases, occurred in the Kunene region, followed by 7,125 cases in the Zambezi region and 4,254 cases in the Omusati region.

Considering the conflicts per area and the different amount of reporting years for each conservancy, the Zambezi region faced an average of 0.45 cases of crop damages per km^2 and year. This high prevalence of crop damages per area is followed by 0.06 cases per km^2 and year in the Kavango East region, which accounted for 695 crop damage incidents on a comparatively small total area of conservancies of 1,101 km^2(second smallest summed area for a region including its reporting conservancies). The 10 remaining conservancies showed less than or equal to 0.01 cases of crop damage per km^2 and year. In contrast, on average less than or equal to 0.01 cases of livestock attacks per km^2 and year only applied to three conservancies. Kunene, the region with the most livestock attacks in total, only showed the fourth highest incidents with 0.1 cases per km^2 and a year behind Oshikoto ($\overline{X}_r$: LIV = 0.24), Hardap ($\overline{X}_r$: LIV = 0.17) and the Zambezi region ($\overline{X}_r$: LIV = 0.16).

Similarly, for all summed HWC, including “other damages” and “human attacks”, the Kunene region did not account for the highest conflicts on average per area and year, even though the majority (52.7%) of all conflicts took place in this region. The highest density of HWC with 0.63 cases on average per km^2 and year was calculated for the Zambezi region, followed by 0.28 cases in Oshikoto and 0.17 cases in Hardap. The lowest density of HWC with 0.01 cases on average per km^2 and year was calculated for the regions //Karas and Otjozondjupa. Erongo and Oshana both accounted for the third lowest HWC value with 0.02 cases on average per km^2 and year.

The highest human population density holds Kavango West with its only conservancy *Maurus* Nekaro (11.93 people per km^2), which is not included in Table 1 because of its missing data on HWC. From the remaining 12 regions, Oshikoto’s conservancy *King Nehale* has the highest population density with 10.49 people per km^2, followed by the average of 8.24 people per km^2 of the 15 conservancies in the Zambezi region and an average of 4.48

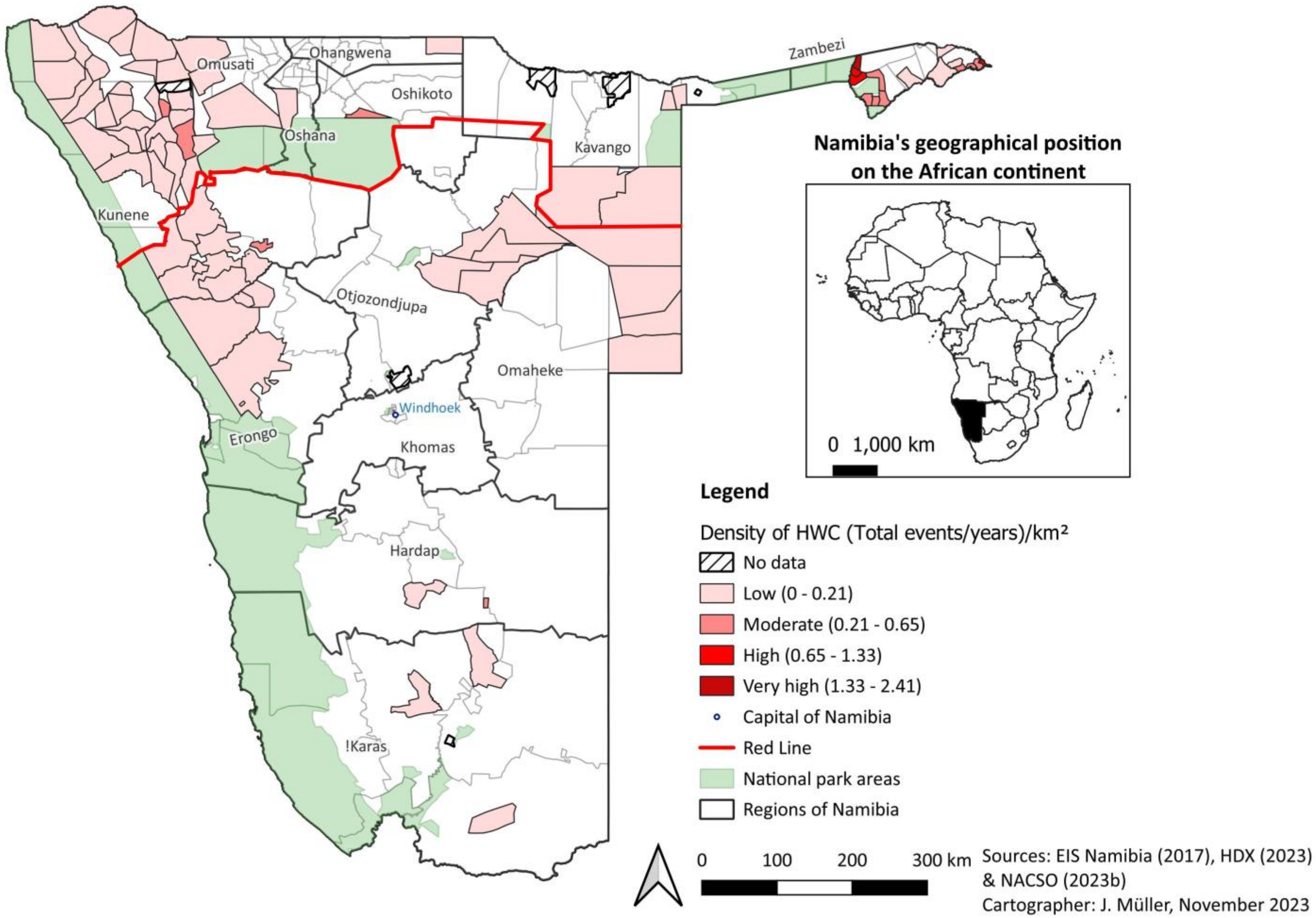
people per km^2 in Omusati's conservancies. In parallel, the Zambezi region and Oshikoto are the two regions with the two highest conflict densities. By comparing the population density [people per km^2] to the conflict density for each of the 12 regions, a strong positive relationship (r^2 = 0.74) was found.

3.1.2 Human-wildlife conflicts on a conservancy level

Figure 3 displays the total number of HWC in Namibian conservancies for the period 2001-2017 divided by the amount of reporting years for each conservancy and its total area [in km^2].

Figure 3

Human-wildlife conflicts in Namibian conservancies (2001-2017)



Note. Own work. Data input for HWC by NACSO (2023b) and sources for layers are given in the figure.

79 conservancies are highlighted in different shades of red reflecting the gradient of the varying density of HWC across Namibia. The seven remaining conservancies without data entries received a hashed black symbol to point out their geographical location. The light green areas depict the Namibian national parks and together with the Red Line, their significance for the occurrence of HWC is analysed in section 4.1.

As explained in section 2.2, the width of the four classes determined by the method of the "Natural Breaks (Jenks)" algorithm varies to deliver a maximum differentiated map image by still not distorting the gradient of the data distribution. The data for HWC over the period 2001-2017 is right-skewed, which is reflected by the class counts: 63 conservancies fall under the lowest (0-0.21 incidents per year and km^2), 12 conservancies in the second lowest (0.21-0.65 incidents per year and km^2), three conservancies in the second highest (0.65-1.33 incidents per year and km^2) and one conservancy in the highest category (1.33-2.41 incidents per year and km^2).

The highest density of HWC faced *Kwandu* conservancy with an average of 2.41 yearly incidents per km^2. The second highest density of HWC was in *Impalila* with an average of 1.33 incidents per year and km^2 followed by *Mayuni* with 1.12 incidents per year and km^2. Those three conservancies are located in the Zambezi region and, overall, nine conservancies out of the 10 conservancies with the highest HWC densities are located in the Zambezi region. The remaining conservancy outside the Zambezi region within this list is *//Audi* (0.45 incidents per year and km^2) in the Kunene region.

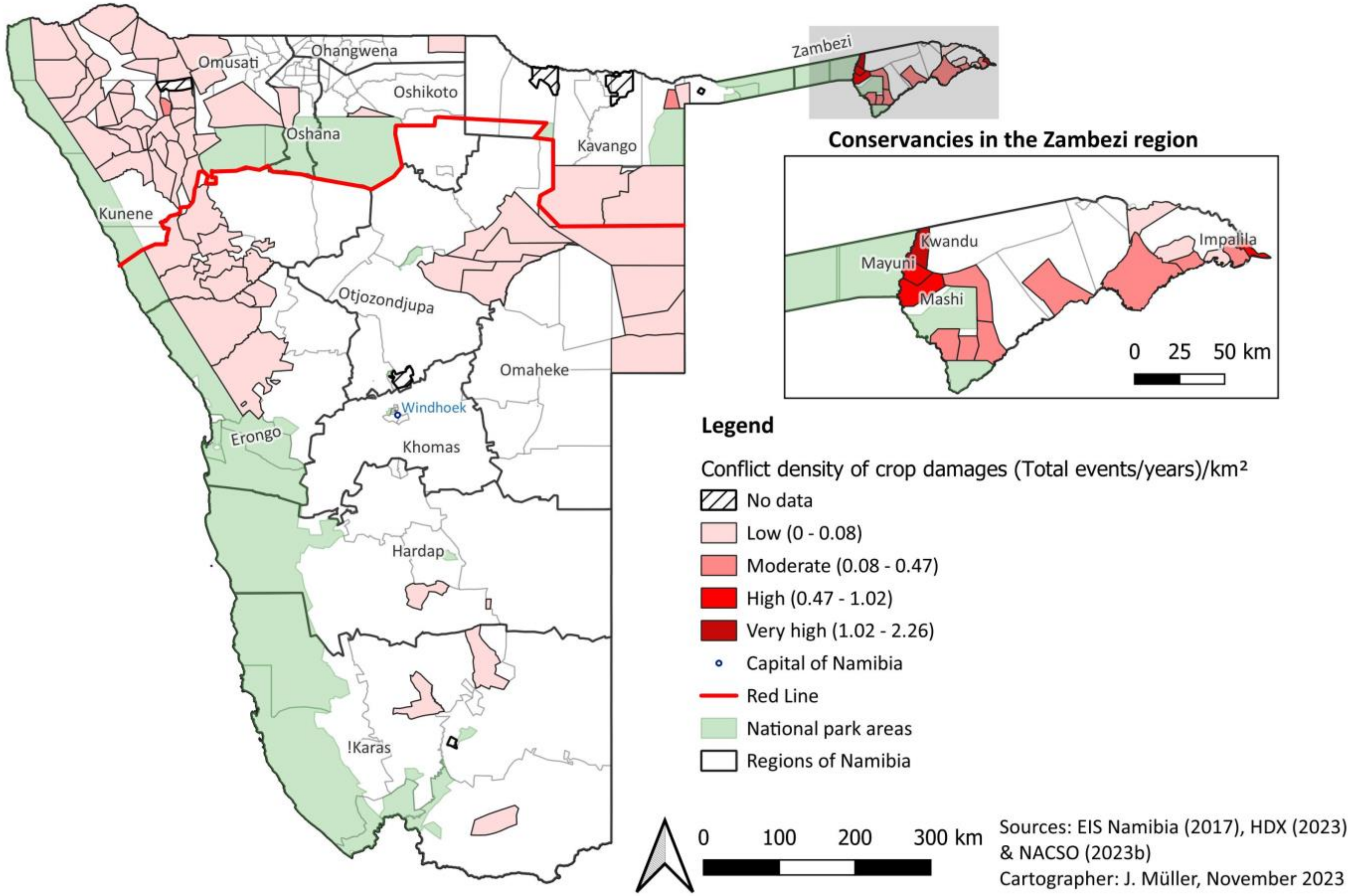
The conservancy with the lowest HWC per area is *≠Gaingu* followed by *Nyae Nyae* and *N≠a Jaqna* with all three of them having a lower value than 0.01 cases per year and km^2. Out of the ten conservancies with the least dense HWC, six are located in Otjozondjupa, two in Erongo and one each in //Karas and Omaheke.

Crop damages on a conservancy level

Figure 4 visualizes the average annual value of HWC broken down to the area with the same method of classification but in this calculation, only the crop damage incidents within the conservancies were considered. The distribution of data is, like for the overall HWC, right-skewed with 65 conservancies falling under the lowest (0-0.08 incidents per year and km^2), 10 conservancies in the second lowest (0.08-0.47 incidents per year and km^2), three conservancies in the second highest (0.47-1.02 incidents per year and km^2) and one conservancy in the highest category (1.02-2.26 incidents per year and km^2).

Figure 4

Crop damages caused by wild animals in Namibian conservancies (2001-2017)



Note. Own work. Data input for HWC by NACSO (2023b) and sources for layers are given in the figure.

The highest density of crop damages in the regarded period faced *Kwandu* with an average of 2.26 yearly incidents per km^2. The second highest density of crop damages took place in *Mayuni* with an average of 1.02 incidents per year and km^2 followed by *Impalila* with 0.92 damages per year and km^2 on average. Similar to the overall HWC, conservancies from the Zambezi region dominate the list with the most dense crop damages per area. For crop damages, all out of the 10 conservancies with the most dense conflicts are conservancies in the Zambezi region.

The map inset in Figure 4 shifts the focus from the main map to the Zambezi region and highlights the four conservancies that fall under the two highest categories with a high or very high density of crop damages: *Kwandu*, *Mayuni*, *Impalila* and *Mashi*. Furthermore, it is striking that proportionally more conservancies in the Zambezi region received a classification in a higher class compared to the 11 remaining regions. This can be seen by the gradient of the different colours of red.

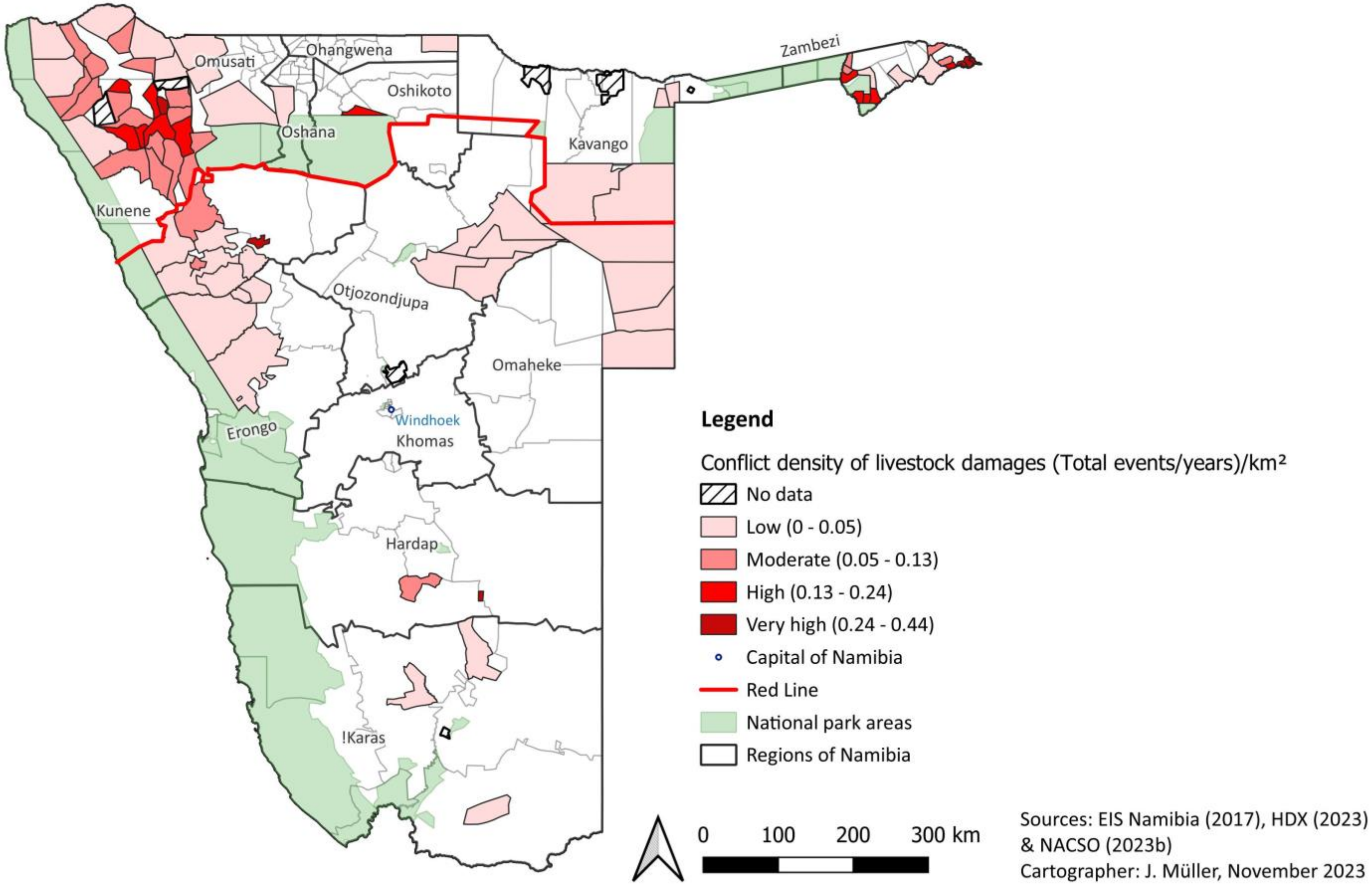
While in every conservancy at least one type of HWC occurred within the period 2001-2017 with the minimum value of 58 cases in *≠Gaingu* conservancy, there were 16 conservancies, in which not a single crop damage was reported over time. Five out of those conservancies are located in the Kunene region, three in //Karas, two each in Hardap, Omaheke and Otjozondjupa and one each in Erongo and Oshana. The conservancies in //Karas (*//Gamaseb, !Han /Awab and !Khob !Naub*), Hardap (*Huibes and Oskop*) and Oshana (*Iipumbu ya Tshilongo*) with no entry for crop damages represent thereby all conservancies that are located within the respective regions. Hence, no crop damages were reported in communal conservancies for the period 2001-2017 in the regions //Karas, Hardap and Oshana.

Livestock damages on a conservancy level

In Figure 5, the average annual values of livestock damages per km^2 in all conservancies are illustrated. As for the overall HWC and crop damage data, the distribution of the data is right-skewed but the data for livestock damages is less dispersed. This is demonstrated by the data distribution in the four categories with the method of “Natural Breaks (Jenks)”: 38 conservancies fall under the lowest (0-0.05 incidents per year and km^2), 22 conservancies in the second lowest (0.05-0.13 incidents per year and km^2), 12 conservancies in the second highest (0.13-0.24 incidents per year and km^2) and six conservancies in the highest category (0.24-0.44 incidents per year and km^2).

Figure 5

Livestock attacks caused by wild animals in Namibian conservancies (2001-2017)



Note. Own work. Data input for HWC by NACSO (2023b) and sources for layers are given in the figure.

The highest density of livestock attacks by wild animals in the regarded period occurred in *//Audi* in the Kunene region with an average of 0.44 yearly incidents per km^2. The second highest density of livestock attacks took place in *Impalila* with an average of 0.34 incidents per year and km^2 followed by *Kabulabula*, both being conservancies in the Zambezi region, with 0.33 damages per year and km^2 on average. Out of the 10 conservancies with the most dense livestock attacks, five are located in the Zambezi region, three in the Kunene region and one each in Hardap and Oshikoto. The regional distribution of the conservancies with a relatively high density of livestock damages is reflected in the comparatively wide distribution of livestock damages. While for the overall HWC and crop damages the 10 conservancies with the densest conflicts per area were either only in the Zambezi region or additionally in the Kunene region, the 10 conservancies with the most dense livestock attacks are distributed amongst four regions (Hardap, Kunene, Oshikoto and Zambezi). Contrary to the density of crop damages in conservancies, conservancies (*//Audi* and *Oskop*) below the Red Line faced a very high density of livestock damages.

The conservancy with the lowest livestock attacks per area was *Nyae Nyae* followed by *≠Gaingu* and *N≠a Jaqna* with all three of them having a lower value than 0.01 cases per year and km^2. Out of the ten conservancies with the least dense livestock attacks, six are located in Otjozondjupa, two in Erongo and one each in //Karas and Kavango East. Overall, every conservancy faced livestock attacks by wild animals between 2001-2017 with *Otjikongo* in the Kunene region having experienced the fewest (32 cases).

3.2 Regression analysis

To answer research question 2 and thus to what extent the change of the total size of conservancies in Namibia explains the occurred conflicts in the period 2001-2017, a linear regression model was estimated in Microsoft Excel (2016). Additionally, other possible predictors (e.g. proximity to other adjacent protected areas) for the occurrence of HWC in communal conservancies are considered in section 4.2. The data input for the regression model is shown in Table 2, which presents the yearly cumulative area in km^2 for all conservancies and the summation of all HWC in Namibian conservancies for each year within the period 2001-2017.

Table 2

Change of cumulative area and the quantity of human-wildlife conflicts during 2001-2017

Year	Cumulative area [in km^2]*	HWC incidents**
2001	12,704	325
2002	15,037	771
2003	53,745	3,019
2004	53,968	2,936
2005	61,528	4,282
2006	87,088	5,713
2007	88,565	5,640
2008	91,384	7,095
2009	118,506	7,689
2010	130,966	7,779
2011	140,858	7,430
2012	156,394	7,277
2013	158,012	9,364
2014	159,560	7,989
2015	161,047	7,117
2016	162,075	6,484
2017	162,075	8,115

Note. Own work. Data was computed by using raw data from NACSO (2023b).

* Only the area of the 79 conservancies that provide data on HWC was included.
** Includes all types of HWC.

For 2001, six conservancies with a cumulative size of 12,704 km^2 reported different types of HWC that summed up to 325 incidents. The biggest jumps in conflicts compared to the preceding year were experienced in 2002 with 137% more incidents compared to 2001 and in 2003, 292% more conflicts in comparison to 2002. In the subsequent years, the rise in conflicts was either smaller and, in seven out of 16 years, the number of conflicts decreased compared to the previous year. The highest amount of reported conflicts was in 2013 with 9,364 over a total size of 158,012 km^2.

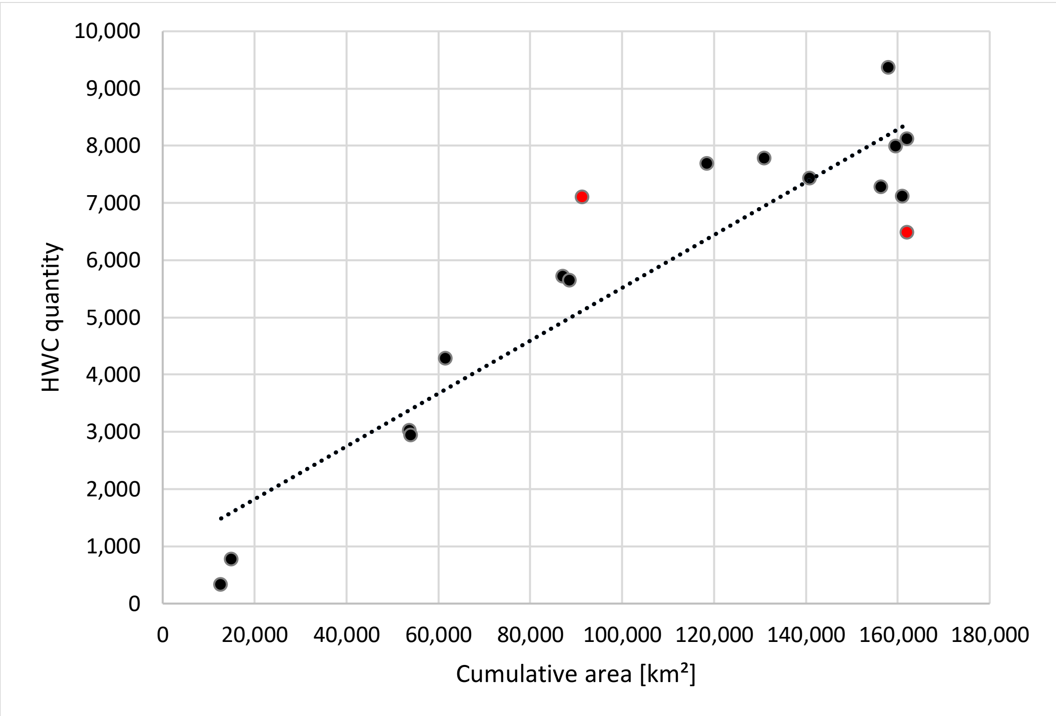
While in 2001, the size of the first six reporting conservancies summed up to 12,704 km^2, it increased to 162,075 km^2 for the 79 conservancies that had at least 2017 an active event book monitoring system. The biggest change in the total size of conservancies took place from 2002 to 2003 with an increase of 257% from 15,037 to 53,745 km^2.

Figure 6 illustrates a scatterplot of the paired values for the years 2001 until 2017 which are shown in Table 2. The cumulative area [in km^2] represents all x-values as the independent variable and the HWC incidents depict all y-values as well as the dependent variable. This association is positively significant at the 1 % level (p = 1.77 * 10^{-7}). The statistical relationship between the two variables is described by the linear function (3):

$$y = 0.0462x + 900.68 \tag{3}$$

Figure 6

Human-wildlife conflicts in comparison to the total size of conservancies (2001-2017)



Note. Own work. Data input by NACSO (2023b).

The scatterplot shows an upward-trending series of points, meaning that with higher x-values, the y-values typically rise. Yet, in six out of 15 consecutive years (2002 until 2016), in which the cumulative area rose in comparison to the previous year, the yearly amount of HWC declined compared to the year before. Nevertheless, a coefficient of determination (R^2 = 0.85) indicates that relatively many of the y-values are explained by the x-values. Most data pairs are either close to or lie on the regression line, while only two data pairs could be seen as outliers: In 2008, there was a relatively high occurrence of HWC (7,095 cases) compared to the total size of conservancies (91,384 km^2) and, in

2016, in contrast, a relatively low occurrence of HWC (6,484 cases) on a size of 162,075 km^2. The two outliers are highlighted with a red fill.

The strong statistical relationship between the size of communal areas and the occurrence of HWC is also affirmed by the very strong positive correlation (r^2 = 0.92) between the two variables.

4 Discussion

This chapter is divided into the analysis of the geographical distribution of HWC (section 4.1) and its two major types of conflicts and the interpretation of the regression results where the influence of the communal size of the area of all conservancies on the prevalence of HWC in the period 2001-2017 was measured (section 4.2). Section 4.1 builds on the results of section 3.1 and the results of 3.2 are analysed in section 4.2.

4.1 Analysis of the geographical distribution of human-wildlife conflicts

Section 3.1 showed that the density of HWC and the type of conflict vary on a conservancy as well as on a regional level. Within the period 2001-2017, slightly more than half (52.7%) of all HWC and the majority (68.2%) of all livestock attacks occurred in the Kunene region. Similarly, with a clear majority (70.1%), most crop damage incidents were reported for the Zambezi region within this period. Considering the varying reporting years and size of conservancies, the Kunene region only ranked fourth of all considered regions for the occurrence of HWC per area. The Zambezi region has the highest conflict density (0.63 cases per km^2 and year) followed by Oshikoto (0.28 cases per km^2 and year) and Hardap (0.17 cases per km^2 and year). Despite facing more than two-thirds of all livestock damages within Namibian conservancies between 2001 and 2017, the conflict density of livestock attacks ranks only fourth highest across the 12 regions. Three conservancies within the Zambezi region (*Kwandu*, *Impalila* and *Mayuni*) accounted both for the highest density of HWC and the density of crop damages in the rank of the three conservancies with the highest conflict density. *Impalila* also was one of the three conservancies with the highest density of livestock damages besides *Kabulabula*, another conservancy in the Zambezi region, and *//Audi* in the Kunene region, where the highest density of livestock damages prevailed. While every region faced livestock attacks, no crop damage incident was reported in the regions //Karas, Hardap and Oshana. By comparing the average human population density of all conservancies within a region over the conflict density, a strong positive relationship (r^2 = 0.74) was found.

To understand the varying patterns across regions one has to consider the different prevailing human population densities, land use forms within conservancies and characteristics of adjacent areas next to conservancies.

4.1.1 Human population density

The coefficient correlation results regarding the relationship between human population and conflict density indicate a strong positive relationship (r^2 = 0.74) over the 12 considered regions, meaning that areas with relatively high population densities also tend to have higher densities of HWC. One must, nevertheless, bear in mind that the values for conflict densities in regions are only described to a certain extent by the population density and may not be a reliable indicator for the occurrence of HWC for all regions. Furthermore, the actual influence of population density in explaining conflict density can also be linked to other variables, such as the amount of livestock in a conservancy or the proximity to wildlife corridors, which were not included in the linear regression. Another indication that population density does not provide a full explanation of the occurrence of conflicts is that for some regions a higher population density did not in turn affect higher conflict densities for the period 2001-2017. For example, Oshana has the fourth highest population density (1.67 people per km^2) across the 12 regarded regions but faced only 0.02 HWC events per km^2 and year over the period 2001-2017. Only //Karas and

Otjozondjupa experienced a lower conflict density. Similar in the statement, but only the other way round, Hardap faced the third highest conflict density with 0.17 events per km^2 and year but represents with 0.59 people per km^2 a relatively low population density.

On the one hand, these two examples strengthen the need for scientific works on the impact of human population increase on the frequency of HWC in Namibia. On the other hand, they point out that the density of the human population alone cannot be the sole indicator for the occurrence of HWC.

In the annual report on the state of community conservation in Namibia, MEFT & NACSO (2022) argue that an increase in the human population density within conservancies in the Zambezi region would lead to rising HWC (MEFT & NACSO, 2022). While there is no publicly available data on the development of human populations in conservancies, this variable could not be compared over the development of HWC in regions over time. Moreover, there is a lack of scientific work on the influence of the relationship between human population density and HWC in Namibia. Tavolaro et al. (2022) pose an exception by analysing 12 different predictor variables for species-specific incident reports for the period 2001-2018. Human population density was one of the 12 predictor variables, for which data from NACSO about the total number of conservancy members in the period 2001-2018 was accessed.[10] They compared the species-specific incidents for cheetah (*Acinonyx jubatus jubatus*), elephant, hyena (spotted hyena [*Crocuta crocuta*] and brown hyena [*Parahyaena brunnea*]), jackal (black-backed jackal [*Lupulella mesomelas*] and side-striped jackal [*Lupulella adusta*]), leopard (*Panthera pardus*), and lion against human population density in conservancies and found amongst all six genera only for jackal a significant influence. Contrary to the presence of other carnivore species, which had a significant positive relationship with human-jackal conflicts, human density had a negative impact on annual HWC reports related to jackals. Overall, Tavolaro et al. (2022) found that other variables, such as the distance to near protected areas and rivers, terrain ruggedness, conservancy size and annual rainfall were of greater influence on the distribution and extent of human-wildlife impact reports than the density of human population (Tavolaro et al., 2022). These results confirm the findings of this thesis that the impact of population density on HWC needs further research and other variables must be considered in addition.

4.1.2 Agricultural land use forms

Figures 4 and 5 show a differing colour gradient with Figure 4 highlighting high-conflict areas almost exclusively in the Zambezi region and Figure 5 depicting a greater distribution of high-conflict areas. It is striking that either the highest or the second highest category or both of livestock damage densities for the period 2001-2017 occurred in Hardap, the Kunene Region, Oshikoto and the Zambezi Region, while for crop damage densities those two categories were only achieved in the Zambezi region. To better understand why the level of crop damage within the Zambezi region is significantly higher than in the other 11 regions and why high levels of livestock damage occur across several regions, a short analysis of geographical variations in terms of agricultural land use forms is needed.

[10] Tavolaro et al.'s (2022) given source on the yearly data of human population in conservancies on NACSO's website is not available any more, which is why this data was not used in this thesis.

Since the annual reports of the conservancies do not provide information on the amount and type of crops produced within conservancies, the prevailing conditions for crop production across Namibia's regions need to be considered (NACSO, 2023c). According to Brouwer & Heibloem (1986), crop growth depends on rainfall, sunshine, temperature and non-climatic factors such as the availability of healthy soils (Brouwer & Heibloem, 1986). In Namibia, especially low and erratic rainfall, as well as inherently poor soils, are the major challenges for crop production (FAO, 2023). While soil conditions vary greatly in Namibia and soil health is dependent on the type of land use and the application of sustainable land management practices by farmers, an overall classification of suitable regions for crop farming is therefore difficult (Prudat et al., 2018). However, the distribution of rainfall and the availability of freshwater provide indications for areas that are more suitable to cultivate crops and, therefore, face in consequence the risk of crop damage by wildlife.

Namibia is the most arid country in southern Africa and 92% of its land area is defined as very arid, arid, or semi-arid. Rainfall varies across the country from 650 mm in the northeast to less than 50 mm in the southwest and along the Atlantic coast (World Bank, 2023). NACSO (2023c) provides information for most conservancies about their received average annual rainfall. For example, the range of average annual rainfall in conservancies in Erongo varies between less than 100 and 200 mm, in the Kunene region between less than 100 and 400 mm, in Otjozondjupa between 300 and 400 mm and in the Zambezi region between 550 and over 600 mm (NACSO, 2023c). This underlines the great variety of precipitation across the country and is best demonstrated by the Kunene region, where the amount of rainfall also varies within regional boundaries.

The Zambezi region is located in the humid northeast of Namibia and is relatively well-suited for crop production because of the favourable climate and surrounding large rivers (Hulke et al., 2021). The Kwando River borders the conservancies *Kwandu*, *Mayuni*, *Mashi* and *Balyerwa* and its tributaries the Linyanti and Chobe River border the conservancies *Dzoti, Bamunu, Salambala, Nakabolelwa, Kabulabula, Kasika and Impalila.* At the "quadripoint", where the four nations Botswana, Zimbabwe, Zambia and Namibia share a unique border, the Chobe River flows into the Zambezi River, which depicts an important surface water resource for the conservancies *Impalila, Kasika* and *Sikunga*. Only three conservancies in the Zambezi region, *Lusese*, *Sobbe* and *Wuparo* are not surrounded by a river. Still, high rainfall in those three regions enables a high vegetation cover, which in turn prevents rainwater from runoff, and an effective use of the soil for crop production within the zoned cropping areas (NACSO, 2023c).

Typical crops that are cultivated in rainfed agricultural systems within the conservancies in the Zambezi region are maize, sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) (Jones & Barnes, 2006; Wanga et al., 2022). Pearl millet and sorghum are the two most cultivated cereal crops in Namibia and they are widely produced under rainfed agriculture in northern regions of Namibia (Wanga et al., 2022). Sorghum is due to its crop water requirement typically grown in regions with 400-600 mm of annual rainfall. These areas are located in the northern regions of the country, such as in the Zambezi region, Kavango East, Kavango West, Otjozondjupa, Oshikoto, Oshana, Ohangwena, Omusati, and the Kunene region (Masaka et al., 2021; Wanga et al., 2022). Pearl millet is grown in conservancies from the western parts of northern Namibia with rainfall conditions from around 300 mm per year to the eastern parts where rainfall reaches an average of 600 mm per year (Matanyaire, 1996; Wanga et al., 2022). It is estimated that only 2% of

Namibia's land receives sufficient rainfall to grow crops, which is further complicated by inherently poor soils that hamper crop production for many farmers (GIZ, 2022). Jones & Barnes (2006), Masaka et al. (2021) and Wanga et al. (2022) made it evident that the dominant cereal crops are grown in northern regions of Namibia, which receive relatively high rainfall and are therefore favourable for cultivation (Jones & Barnes, 2006; Masaka et al., 2021; Wanga et al., 2022).

In regions that receive a relatively low amount of rainfall, such as //Karas, Hardap, Omaheke, Otjozondjupa and the Kunene region, there was still a significantly higher share of agricultural households that were active in livestock farming alone in comparison to solely crop-producing households (Namibia Statistics Agency, 2019). While livestock also depends on the availability of water and good grazing conditions, which are rare because the large majority of Namibian land receives insufficient rainfall, only two regions (Khomas and Erongo) in 2013/2014 had households that were not solely focussing on livestock herding (GIZ, 2022; Namibia Statistics Agency, 2019). One reason for the high dependency on livestock could be the high value of herds for communities. Researchers of the research project "Adaptation at Scale in Semi-Arid Regions" found in 2018 that many farmers in the Omusati region refused to sell their cattle (*Bos taurus*) despite drought warnings. By conducting interviews with farmers, they discovered that for many farming households in Omusati, there is a strong cultural attachment to their herds and that cattle are seen as a valuable asset (Iita, 2018). A similar pattern of results in the Omusati region was obtained by Davies et al. (2019) who found in their study that cultural factors such as religious belief and the symbolic significance of certain agricultural practices (e.g. cattle farming) are negatively impacting the uptake of climate-smart agriculture practices, including the application of new crops and cultivars (Davies et al., 2019).[11] Förster (2005) investigated the role of cattle for the Herero people, an ethnic group in Namibia, which engaged in the establishment of several Herero communal villages within Namibia's CBNRM programme since the late 1990s (Förster, 2005; Hoole & Berkes, 2010). She found that Herero-speaking Namibians view cattle farming as both a source of income and a symbol of wealth and status (Förster, 2005).

These findings demonstrate the importance of livestock especially cattle for farming households across different regions in Namibia. The great significance of cattle for communal conservancies is supported by the finding of Lindeque & Dierkes (2020) who analysed the type of livestock affected by HWC within the period 2010-2018 across 11 regions (Lindeque & Dierkes, 2020).[12] Cattle as an affected type of livestock by HWC was in eight out of 13 regions the major type of livestock affected. Only in //Karas, where geographical conditions make cattle breeding extremely difficult, cattle were not among the types of livestock affected by HWC (EIS, 2006; Lindeque & Dierkes, 2020). The small-stock farming systems which consist of sheep (*Ovis aries*) and goat (*Capra hircus*) herds in the southern regions demonstrate the flexibility of farmers to shift the type of livestock in areas where the amount of rainfall and grazing conditions are not sufficient for cattle production (Aschenborn et al., 2022; EIS, 2006). The great meaning of livestock for farming households in Namibia as well as the geographical variation of different types of

[11] Climate-smart agriculture is an approach for developing agricultural strategies that help to sustain food security under climate change by considering local contexts as well as the cultural and social sensitivities of local communities (UNFCC, 2021).

[12] Hardap and Omusati, which both hold communal conservancies, were not included in the analysis (Lindeque & Dierkes, 2020).

livestock might indicate to some extent why domestic animals are across the 12 regarded regions more consistently kept than crops cultivated and, therefore, livestock damages were spread over more regions than crop damages in the period 2001-2017.

For the decision of farmers to cultivate crops, the difficult growing conditions for the large majority of Namibian land seem to have a higher influence than on the husbandry of animals. The latest Namibia census of agriculture for the years 2013 and 2014 has confirmed that within regions with typically more rainfall, more agricultural households relied on crop production only (Namibia Statistics Agency, 2019). For example, 21% of all agricultural households in Kavango East, in whose conservancies the average rainfall ranges between 500 and 600 mm, were in 2013 active in crop farming as their only farming activity, while in //Karas, whose conservancies face between 100 and 150 mm rainfall on average, only 0.1% of all agricultural households could rely on crop farming only (NACSO, 2023c; Namibia Statistics Agency, 2019). The findings of the Namibia Census of Agriculture 2013/2014 underline the importance of favourable crop farming conditions for agricultural households to invest in crop cultivation instead of solely relying on livestock production. The census' findings on participating households in crop cultivation per region also provide indications for the low occurrence of crop damages in regions, such as //Karas, Erongo, Hardap, Omaheke and Otjozondjupa, where the share of households focusing only on crop production was comparably low (Namibia Statistics Agency, 2019).

However, regions such as Kavango East, Ohangwena and Omusati in 2013/2014 all had a higher share of agricultural households that were active in crop farming as their only agricultural activity than the Zambezi region. Their conservancies additionally faced rainfall above the nationwide mean of 269.2 mm, thus one might wonder why only conservancies in the Zambezi region were classified with the two highest density categories for crop damages (NACSO, 2023c; Namibia Statistics Agency, 2019; World Bank, 2021).[13]

4.1.3 Adjacent land next to communal conservancies

Although for the causes of the prevalence of HWC researchers often consider the behaviour of humans and the accompanied protection for livestock, crops, infrastructure and themselves, it is also important to look at the adjacent land next to communal areas (Community Conservation Namibia, 2023d; Jarvis et al., 2022; Montgomery et al., 2022). Aindongo (2023) emphasized in his research the importance of investigating the impact of HWC on resettled freehold farms and communal lands outside of communal conservancies. Aindongo (2023) conducted interviews with farmers in three different study sites in the Kunene, Kavango East and Zambezi regions that were in proximity to national parks. The communal land in Kavango East was located close to Bwabwata National Park, the area in the Zambezi region in proximity to Mudumu National Park and the study site in the Kunene region was south of the Etosha National Park. According to the farmers in the three study sites, the reported losses from HWC increased over the past years, so Aindongo (2023) (Aindongo, 2023). While this thesis investigates the prevalence of HWC in conservancies, the research by Aindongo (2023) still delivers important findings by demonstrating the impact of abundant wildlife populations on communities near protected areas. Tavolaro et al. (2022) obtained similar results for the

[13] 269.2 mm is Namibia's average annual precipitation for the latest climatology (1991-2020) (World Bank, 2021).

influence of the distance to protected areas on the frequency of HWC in conservancies. They found that within the period 2001-2019 for 79 conservancies that provided data on HWC, there were increased reports of crop damages the closer the incident was to other protected areas (Tavolaro et al., 2022).[14] They neglected in their methods the different amount of reporting years and the strongly varying size of the area of the communal conservancies. Their results showed an even greater concentration of livestock damage in the Kunene region, a concentration of livestock damage in the Omaheke region and, overall, a significantly weaker concentration for smaller conservancies, especially those in the Zambezi region (Tavolaro et al., 2022). The application of the two different methods, in Tavolaro et al. (2022) and in this work, clarify that the results for HWC differ greatly when using either the total amount of conflicts or the density of conflicts that considers the different amount of reporting years for conservancies.

The connectivity of protected areas supports wildlife populations to move freely between national parks and conservancies in the search for water and grazing (Community Conservation Namibia, 2023e). The largest transfrontier conservation area in the world, the "Kavango Zambezi Transfrontier Conservation Area" (KAZA TFCA), which covers protected areas in Angola, Botswana, Namibia, Zambia and Zimbabwe, is aiming at the improved movement of wildlife (WWF, 2022). According to Stoldt et al. (2020), the increasing roaming of wildlife is expected to positively support ecosystem functioning and promote biodiversity (Stoldt et al., 2020). For conservancies in the Zambezi region and in the northern Kunene region west of Etosha National Park, Community Conservation Namibia found in 2017 a relatively high species richness of large wildlife species compared to other regions in Namibia. The species richness was calculated by comparing wildlife population estimates in the past with current counts and it was found that in the majority of the conservancies within the two regions described above, the wildlife species richness is at least 80% of previous estimates. In regions such as Kavango West, Otjozondjupa, Hardap and //Karas, the majority of conservancies had a species richness of large wildlife of only 50% or less compared to past populations (Community Conservation Namibia, 2023e).

This may be due to the poorer connectivity of protected areas compared to regions in the Etosha/Kunene area and the Zambezi region, where species have vaster areas to roam between protected areas. In the Etosha/Kunene area, wildlife populations can migrate freely between many communal areas and the adjacent Skeleton Coast and Etosha National Park. This allows wildlife to move to adjacent protected areas when rainfall is scarce in a specific region and, thus, enables many wildlife populations to survive in the long term (NACSO, 2021). Despite the positive impacts of the connectivity of protected areas, especially since the start of establishing communal conservancies within CBNRM, many wildlife populations in the Kunene region declined because of severe droughts in the years 2013, 2016 and 2019 (Liu & Zhou, 2021; NACSO, 2021).

In the Zambezi region, many wildlife species including elephants, African buffalos (*Syncerus caffer*) and lions could roam freely across international boards even before the establishment of the KAZA TFCA in 2011, but they were more prone to poaching events since no formal protection in the form of a transfrontier conservation area was in place

[14] Since the HWC within conservancies, which also count as protected areas, were investigated, the proximity to other protected areas (e.g. national parks and concession areas) was taken as a measure (Tavolaro et al., 2022).

(Mulonga et al., 2003; Peace Parks Foundation, 2023). Since the establishment of the KAZA TFCA, anti-poaching measures have been enforced to prevent wildlife crime (Peace Parks Foundation, 2023). The emphasis on conserving wildlife led to a stricter implementation of wildlife protection measures over time (Stoldt et al., 2020). The KAZA elephant survey which was conducted from August until October 2022 revealed in its 2022 census that the elephant population in Namibia amounts to approximately 21,000 (WWF, 2022). In contrast, in 1995, five years after Namibia gained independence from South Africa, there were only approximately 6,000 elephants in Namibia since elephant numbers were heavily decimated by poaching by South African military personnel between 1980 and 1990 (Said et al., 1995; Stoldt et al., 2020). Estimates from 1990, 1995 and 1998 obtained from partial aerial and ground surveys revealed a clear upward trend in the elephant population within Namibia, which was further boosted by wildlife protection measures along the establishment of communal conservancies from 1998 onwards (CITES, 2000; Jones & Barnes, 2006).

Besides the wildlife-favouring connectivity of protected areas in the Etosha/Kunene area and the Zambezi region, the so-called “Red Line” or “veterinary cordon fence” has also influenced the unbalanced distribution of wildlife in Namibia (Stoldt et al., 2020). The Red Line has especially affected large-bodied migratory ungulates (e.g., gemsbok [*Oryx gazelle*], plains zebra [*Equus quagga*] and buffalo) and elephants, who, in comparison to small ungulates are not able to slip under fences or between wires. The Red Line often denies large-bodied ungulates in their search for water, which could be determined by the observations that their carcasses were often found along the fence lines on paths to water. Especially in years of drought, the migratory movement of wild animals to dry season destinations was often restricted by fences, which led to unnaturally high concentrations of animals. In this environment, animals are more prone to exhaustion, dehydration and predation (Gadd, 2012). During the decade 2012-2022, Namibia received below-average rainfall and severe droughts in 2013, 2016 and 2019, and the gemsbok population in North-West Namibia, besides other large-bodied migratory ungulates, declined heavily by 90% (Liu & Zhou, 2021; NACSO, 2023c). In this context, several scientists agreed that the movement restrictions of the Red Line played a significant role in the decline of populations, especially in years of drought (Gadd, 2012; Martin, 2005; Stoldt et al., 2020).

Stoldt et al. (2020) found by comparing occurrence patterns of the elephant, lion, blue wildebeest (*Connochaetes taurinus*), zebra and buffalo in the years 1934, 1975 and 2020 that the Red Line and other bordering fences restricted heavily the range of the wildebeest, the zebra, the buffalo and the elephant. The range of lions seems to be less influenced by the Red Line since populations occur on both sides, north and south of the fence (Stoldt et al., 2020). The comparison of the range of the lion and the elephant showed that both populations increased their range between 1934 and 1975, a period in which at least until the 1960s their populations could roam more freely than after the veterinary cordon fence was erected (Schneider, 2012; Stoldt et al., 2020). In recent years, the range of lions and elephants was significantly smaller than it was in 1975, and they were increasingly limited to protected areas located in the Namibian section of the KAZA TFCA and around the Etosha/Kunene area (Jarvis et al., 2022; MEFT & NACSO, 2022; Stoldt et al., 2020).

Naha et al. (2023) collected the movement behaviour of 36 lions and seven spotted hyenas along the Etosha fence over 14 years with the help of GPS collars and found that hyenas had an 18% likelihood of crossing the fence when moving in the vicinity of the fence while lions were less likely (9%) to cross (Naha et al., 2023). Although large-bodied migratory ungulates are denied to cross fences along the Red Line, small ungulates and, as Naha et al. (2023) have shown, especially hyenas and lions can do so (Gadd, 2012; Naha et al., 2023). The possibility for apex predators, such as hyenas and lions, which have their largest population in Namibia in the Etosha National Park, to cross fences along the Red Line explains the occurrence of predators south of the fence in the Kunene region (Weise et al., 2021). Thus, this may also indicate the classification of conservancies in the Kunene region south of the Red Line (e.g., *//Audi, =/=Khoadi-//Hôas and Uibasen Twyfelfontein*) in the third highest or highest category of the density of livestock damages.

Another conservancy close to Etosha National Park that faced a high livestock damage density (0.24 cases per year and km^2) was *King Nehale* in Oshikoto. *King Nehale* is also amongst the 12 regarded regions the conservancy with the highest human population density (10.49 people per km^2). A high population density is positively correlated with a higher HWC density, which might explain the relatively high level of conflict in this conservancy. Another factor that influenced the prevalence of HWC in *King Nehale* is the connectivity with Etosha National Park with the conservancy, which allows wildlife movement between the two protected areas. A survey with 115 randomly selected participants conducted by Nakanyala et al. (2022) revealed that the community members agree that a major proportion of HWC can be traced back to wildlife movement from Etosha National Park to *King Nehale* (Nakanyala et al., 2022).

Since elephant is the wildlife species that were within the period 2001-2019 the most involved in HWC in conservancies, this explains a high conflict density of crop damages in the Zambezi region since elephants find more foraging opportunities in the Zambezi conservancies compared to the rugged north-western regions (Tavolaro et al., 2022). The connectivity of protected areas in the Etosha/Kunene area enabled the long-term survival of predator species such as hyena (spotted and brown) and cheetah, which were responsible for the second and fourth most incidents in Namibia within the period 2001-2019 (Community Conservation Namibia, 2023e; Tavolaro et al., 2022). Although the conservancies in the Zambezi region and in the Etosha/Kunene, which are located above the Red Line and have a relatively well-established wildlife favouring habitat connectivity, the findings of this thesis demonstrate that there are also conservancies south of the Red Line and with poorer connectivity at protected areas with a relatively high conflict density. *//Audi* in the Kunene region and *Oskop* in Hardap pose exceptions within the list of conservancies that fall under the highest livestock damage density category, being the only conservancies south of the Red Line.

Overall, the analysis of geographical differences in Namibia suggests that the population density as well as the type of agricultural land use and the adjacent land conditions next to a communal conservancy all were proven to have an impact on the frequency and type of HWC in the period 2001-2017. Since areas north of the Red Line with high connectivity of protected areas tend to have a higher density of HWC, conservancies south of the Red Line with lower connectivity of surrounding protected areas, which is the case for *//Audi* and *Oskop*, need further research. Other scholars are advised to look closer at predominant species regarding HWC to understand the density of HWC outside the well-studied regions of the Etosha/Kunene area and the Zambezi region.

4.2 Analysis of variables influencing the occurrence of human-wildlife conflicts

To answer research question 2, to what extent does the increase in the total area of conservancies explain the amount of HWC over the period 2001-2017, one has to analyse the statistical measures in section 3.2 and consider other influencing variables besides the size of the area. As presented in the regression analysis, 85% of the *y*-values (HWC counts) are explained by the *x*-value (cumulated size of all conservancies) within the applied linear regression model. It is important to mention that one must not reduce the explanation of the increase in conflicts to this determined percentage. This approach would neglect other external influencing factors that, taken together, may provide more insight into the number of HWC incidents. The high value of a coefficient of determination ($R^2 = 0.85$) and the very strong positive correlation ($r^2 = 0.92$) of the two variables prove that a large share of the increase of HWC of the period 2001-2017 can be explained by the rising cumulative area.

While this regression analysis considered the total numbers only, Jarvis et al. (2022), who investigated the yearly change of HWC on a conservancy level, found by processing NACSO's data on HWC that the average counts of conflicts per conservancy were relatively stable over the period 2004-2019. Emblematic of this trend is that they discovered, that the average number of incidents increased maximally for the following year but decreased again in the subsequent year (Jarvis et al., 2022). The findings of Jarvis et al. (2022) go along with the results presented in 3.2. When the cumulated size of conservancies between 2012 and 2017 changed by a maximum of 1.0%, the total HWC also lost, almost without exception, the trend of an increase in the total number. This up and down in the total HWC without a clear trend is illustrated by the data points on the right in Figure 6, which represent the more recent years over the period 2001-2017. The findings by Jarvis et al. (2022), as well as the results of this thesis, are based on the event book system of NACSO, which is maintained and updated by the game guards in each conservancy and delivers trustful data to entities such as MEFT, which derives specific policies and actions regarding the management of HWC (Community Conservation Namibia, 2023c).

Since Jarvis et al. (2022) proved that the average number of conflicts per conservancy was relatively stable over the period 2004-2019, one might question how the average amount of conflicts per conservancy did not significantly rise. Thus, in the next sections, the role of other parameters such as the development of the human and wildlife population and the application of counteracting measures to HWC are studied.

4.2.1 Namibian population increase

The 2011 census showed that the annual population growth rate diminished from 2.6% in 2001 to 1.4% in 2011, meaning the Namibian population still grew between 2001 and 2011 but at a slower pace than in the initial decade (Namibia Statistics Agency, 2011). The trend of an ongoing growing Namibian population after the 2011 census is expected by non-governmental sources but also by a policy brief dated 2015 by the National Planning Commission in Namibia (Mulama, 2015; World Data, 2023).

Mulama on behalf of the National Planning Commission projected in 2015 that until 2030 the fertility rate in Namibia continues to decline, while women in rural areas would have an average of 4.6 children compared to an average of 3.2 children for women in urban areas. After Mulama (2015), this would be due to differing socioeconomic characteristics between the two groups, which are defined by the level of education and income additionally to the access to family planning information and services. He predicted that a large share of youth and the working-age adult population will move to aspiring towns such as Windhoek, Walvisbay and Swakopmund and thus there will be an amplified rural-urban migration to the regions of Khomas and Erongo (Mulama, 2015). An amplified rural-urban migration would also include communal land within Namibia's conservancies, which give a home to approximately 244,587 people (Estimation from 2022) (Community Conservation Namibia, 2023a). The latest census from the Namibia Statistics Agency**,** which is expected to be conducted from September until November 2023, will deliver more insights about the population development in Namibia since 2011 (Namibia Statistics Agency, 2023). The 2023 census will also clarify if Mulama (2015) predicted trends of an intensified rural-urban migration for the period 2015-2030 are accurate for the move from communal land in rural areas to urban areas.

4.2.2 Human pressure on natural resources

Since humans including its livestock and wild animals share similar interests over natural resources such as grazing areas and water, one might wonder why the conflicts per conservancy did not rise from 2004 to 2019 even though Namibia's population grew within the same period and, therefore, pressure on wildlife's habitats was exerted (Jarvis et al., 2022; Mulama, 2015; Namibia Statistics Agency, 2011). For the Zambezi region, which has the third highest population density (8.1 people per km^2) in its conservancies compared to all other regions, NACSO and MEFT evaluated in its annual conservancies report 2021 that the increase in human population would lead to encroachment in wildlife habitats, which result in turn to more HWC (MEFT & NACSO, 2022; NACSO, 2023b). It is striking that many researchers who are active in the field of HWC within Namibian conservancies referred in their works to the observations of other scholars that investigated outside of Namibia the relationship between an increasing human population and a more strongly associated occurrence of HWC (Gargallo, 2021; Kahler & Gore, 2015; Salerno et al., 2020). Besides the overall observations by NACSO and MEFT, there is a lack of scientific work about the influence of human expansions on the frequency of HWC in Namibia.

One exception depicts the study from Meyer et al. (2021) who analysed classified satellite images within a social-ecological framework and found that CBNRM increased elephant presence but decreased woodland cover. By applying a heterogeneous treatment effect analysis, they have shown that CBNRM has a positive effect on woodland cover if communities are located in or around wildlife corridors. As a side result of the study, no negative correlation between human population density and elephant presence for the period 1999-2009 could be found, while on the contrary, the population density was found to influence negatively the presence of woodland (Meyer et al., 2021). Since the results of Meyer et al. (2021) are only related to one species and lack comparable results of other researchers, it is indicative that there is a need for further studies that investigate the influence of the increasing human presence in Namibian conservancies. To investigate the emerging struggles human population causes with the encroachment into wildlife habitats, three studies beyond the Namibian scale were examined.

These studies have found that within areas, which underwent landscape expansion to create space for human dwellings and infrastructure, the frequency of HWC increased (De Stefano & De Graaf, 2003; Mekonen, 2020; Narayan & Rana, 2023). De Stefano & De Graaf (2003) have investigated the role of various wildlife species including white tailed deer (*Odocoileus virginianus*), beavers (*Castor canadensis*) and Canada gees (*Branta canadensis*) that occur in Northern America. They found that humans came in closer contact with wildlife by expanding urban areas further into wildlife habitats who then replied by increasing its numbers and distribution. This resulted in an overabundance of adaptive species such as deer, beavers and gees, which grew beyond many region's cultural carrying capacity by eating shrubbery and defecating prolifically.[15] With rising numbers of "problematic" wildlife species hunting and trapping of those species increased (De Stefano & De Graaf, 2003). Narayan & Rana (2023) demonstrated comparable experiences of habitat fragmentation and wildlife repression on the European continent, where apex predatory wildlife species are in decline. They provided examples of keystone species for their respective ecosystem such as the brown bear (*Ursus arctos*) and the Iberian lynx (*Lynx pardinus*), which are impaired in their recolonization through the human pressure on habitat availability (Narayan & Rana, 2023).

While Mekonen (2020) defines HWC as occurring when "the needs and behavior of wildlife impact negatively on humans or when humans negatively affect the needs of wildlife", which represents the dilemma of shared interests from both sides, he focuses in his listing of causes for HWC solely on activities that can be controlled by humans (Mekonen, 2020, p. 1). By interpreting data from a survey questionnaire covering 95 participants from two of the five districts surrounding the Bale Mountains National Park in Ethiopia, Mekonen (2020) found that agricultural expansion (30%) and human settlement (24%) are the major causes of HWC in and around the study area while poaching (4%) was the lowest cause of HWC. According to Mekonen (2020), the frequency and intensity of these conflicts are expected to further increase with a rising human population and demand for resources (Mekonen, 2020).

4.2.3 Shifts in the Namibian wildlife populations

As rendered in section 3.2, MEFT's active "Revised National Policy on Human Wildlife Conflict Management" for the period 2018-2027 claimed there would be a prevailing "wildlife population growth" besides a growing human population, which would in combination, aggravate HWC in Namibia (MET, 2018, p. 8). While many works by scholars correctly referred to CBNRM's positive impact on increasing wildlife populations, particularly as the previous period (1960s-80s) was characterized by widespread poaching and warfare, as well as a severe drought in the 1980s, which resulted in declining wildlife populations, one has to examine the most recent wildlife population trends in Namibia to understand the level of pressure from wildlife on humans (Gargallo, 2021; Naidoo et al., 2011).

The measurement of Namibian wildlife populations follows different regional approaches that suit local conditions. In the eastern conservancies, an annual moonlight waterhole count is performed, while in the northeastern conservancies, counts are conducted on foot along fixed transect lines. These counts sum up to 2,500 kilometres walked annually. All census methods are designed to work together with other existing census methods, such as aerial censuses conducted by MEFT and daily event book data collection, to complement and enhance their effectiveness (Community Conservation Namibia, 2023g).

In the past years, along with technological progress in the use of unmanned aerial vehicles, the application of drones to assess the numbers and distribution of wildlife gained also more and more significance in the count of Namibian wildlife populations

[15] Cultural carrying capacity reflects the number and type of species that people tolerate over time. The carrying capacity is dynamic because it can change from season and year (TPWD, 2023).

(Etosha National Park, 2014; Hua et al., 2022). Hua et al. (2022) have demonstrated in their study the potential of a drone-based artificial intelligence pipeline model to detect free-ranging megafauna in remote settings in Namibia. While the model was successful in identifying larger animals, notably black rhinos (*Diceros bicornis*) and giraffes, it had difficulties in identifying smaller objects including ostriches (*Struthio camelus australis*), springboks (*Antidorcas marsupialis*) and humans (Hua et al., 2022). The management of Etosha National Park has used unmanned aerial vehicles for the surveillance of its park since 2009 because they are a relatively cheap alternative in comparison to a fixed-wing plane and pilot. Drones can assist in the fight against poachers by detecting pending poaching activities without directly risking the lives of park rangers in the national park (Etosha National Park, 2014).

Despite the help of emerging technologies, Namibia's game counts are challenging for three main reasons: First, in large open areas where animals roam freely, animals can move into or out of the areas being monitored and hamper the counting. Second, animal numbers are largely influenced by good and poor rainfall seasons in certain regions, particularly in desert conditions, leading to cycles with ups and downs in wildlife populations (Community Conservation Namibia, 2023g). Third, the movement of species in transboundary protection areas, such as elephants which cross-border within the KAZA TFCA can also be a reason for significant changes in game count numbers. Elephants in the KAZA TFCA move across international borders to diverse landscapes in Angola, Botswana, Namibia, Zambia and Zimbabwe in search of water and food, and in response to various pressures such as competition with other animals, fire, drought, habitat loss or human-elephant conflict (WWF, 2022). The frequent crossing of elephants over international borders is underlined by the finding of Lindsey et al. (2017) that between 2006 and 2015 76% of all African savanna elephants, including elephants statistics for the KAZA TFCA were found in populations spread across one or more national borders (Lindsay et al., 2017; Thouless et al., 2016). Besides elephants, there are estimated 100 other species of mammals including buffalo, hippopotamus (*Hippopotamus* amphibious), lion and endangered antelope species such as lechwe (*Kobus leche*), roan (*Hippotragus equinus*), sable (*Hippotragus niger*), puku (*Kobus vardonii*) and sitatunga (*Tragelaphus spekii*) that move across international borders and, therefore, hamper precise Namibian wildlife population counts (MEFT & NACSO, 2022).

The combination of these three factors that challenge especially the data analysis over the short term suggests a consideration of the long-term perspective of wildlife populations (Community Conservation Namibia, 2023g). Figures for game counts in conservancies across the different geographical regions in Namibia are provided by NACSO (2023c). NACSO (2023c) subdivided the wildlife population counts into four interregional divisions: South, including Hardap and //Karas; North-West, including Erongo and the Kunene region; North-Central, including Ohangwena and Omusati region; and Zambezi, including the eponymous region. The conservancies within Omaheke, Oshana, Oshikoto and Kavango West and East are neither included in the aforementioned interregional divisions, nor separate game counts were uploaded by NACSO on their website. In Otjozondjupa only for the conservancies *Nyae Nyae* and *N≠a Jaqna* wildlife population counts were reported, while for the remaining five conservancies within the region, there were not (Status: November 2023) (NACSO, 2023c).

In the North-West, most species experienced stable or growing population trends in the period 1996 and 2012. NACSO (2023c) explains a steady decline of many game species with prolonged dry phases since 2012 (NACSO, 2023c). Liu & Zhou (2021) found that the Normalized Difference Vegetation Index (NDVI) decreased significantly during the period 2011-2020 due to lower precipitation in the growing season while it increased from 2001 to 2011 as a result of higher precipitation.[16] The continued extreme drought over the past decade with its extremes in 2013, 2016 and 2019 had profound impacts on many ecosystems across Namibia, forcing the Namibian government to declare national emergencies in those years. Besides humans and livestock, wild animals suffered particularly badly from the drought and the degradation of ecosystems (Liu & Zhou, 2021). Another factor that might have led to a decline in wildlife populations is the illegal harvesting of trees which also has severe impacts on the health of ecosystems (NACSO, 2023c).

While the populations of many predator species in the North-West, such as the black-backed jackal and cheetah have levelled off or dropped slightly, the three antelope species gemsbok, the greater kudu (*Tragelaphus strepsiceros*) and springbok faced severe declines in the past decade. For example, the gemsbok population is estimated to have declined by a staggering 90%, the kudu population by 88% and the springboks by 79% in North-West Namibia from 2012 to 2022 (NACSO, 2023c).

Namibia, including the North-West in Namibia, received 2022 nationwide with precipitation of 280.78 mm above average rainfall compared to the latest climatology, 1991–2020, during which the country experienced a mean annual precipitation of 269.2 mm (NACSO, 2023c; World Bank, 2021; World Bank, 2023). This led to a slight recovery in vegetation production in the eastern part of the North-West. If the next rainy seasons have average or above rainfall then wildlife populations are expected to recover (NACSO, 2023c). However, over the long term within the current climatology (2020-2039), the annual average rainfall is predicted to shrink by 1.2 mm compared to the previous climatology (World Bank, 2021).

Regarding the other interregional divisions classified by NACSO (2023c), the nationwide game counts in the conservancies confirm the statement by the organization Community Conservation Namibia that since 2012 game numbers were reduced across Namibia (Community Conservation Namibia, 2023g; NACSO, 2023c). Most species within the other classified interregional regions have also either experienced a slight or major decline in their population numbers. Only a few species could keep their population stable in individual regions or increase it only within a few exceptional years within the period 2012-2022. Examples of positive exceptions are the gemsbok population in *Oskop* and the eland (*Taurotragus oryx*) population in the *Okongo* conservancy in Ohangwena (NACSO, 2023c).

Thus, considering the wildlife population counts for the period 2012-2022 one can declare the statement by MEFT (2018) that there would still be a prevailing wildlife population growth as false or at least out of date since at least 2012 (MET, 2018). This gives rise to the assumption that until around 2012, increasing wildlife populations led to more conflicts in terms of area compared with 2008 as the peak year. Except for 2013, after 2012, all data pairs in Figure 6 can be found below the regression line, which reinforces

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[16] The Normalized Difference Vegetation Index (NDVI) is a measure of vegetation that quantifies the difference between near-infrared light (which vegetation reflects strongly) and red light (which vegetation absorbs). A high NDVI indicates dense and healthy vegetation, while a low NDVI is an indication of less or no healthy vegetation (GIS Geography, 2023).

the statement that the presence of wildlife populations had a positive influence on the prevalence of HWC. However, there was no particular evidence found for the relatively low amount of HWC in 2016.

4.2.4 Measures and technologies assisting in conflict mitigation

An explanation to Jarvis et al. (2022) that the average counts of HWC per conservancy did not significantly increase despite an increasing population pressure might be given by the application of assisting technologies and measures applied by the communities, which helped in mitigating conflicts with wildlife (Jarvis et al., 2022; MEFT & NACSO, 2022). Jarvis et al. (2022) found that the amount of incidents of crop damage has decreased since 2010 and they presume the mitigation measures by communities within conservancies played a significant role here (Jarvis et al., 2022). Using the event book data on HWC by NACSO (2023b), it was calculated that 80.5% all of reported crop damages in conservancies occurred in the Zambezi region (NACSO, 2023b). While elephants are the species of wild animals that cause the highest amount of crop damage in the Zambezi region, one needs to consider especially mitigation measures that target the prevention of human-elephant conflicts to understand the decrease of crop damages in Namibian conservancies (Community Conservation Namibia, 2023d). However, mitigation measures against predators that tear livestock must also be looked at since within the period 2004-2019 livestock attacks increased slightly (Jarvis et al., 2022).

Jones & Barnes (2006) analysed in their study the effectiveness of different HWC prevention methods across multiple conservancies in the regions Otjozondjupa, Kunene and Zambezi. One mitigation measure that worked successfully in reducing HWC was the re-location of people that lived in the floodplains of Kwando River located in *Mayuni* conservancy- an area that is to date regularly visited over years by elephant populations- neighbouring Bwabwata National Park (Bollig & Vehrs, 2021). As described in section 3.1, *Mayuni* is also the conservancy with the second highest crop damages (1.02 incidents) per year and km^2, which underlines the high density of crop damages for farmers in this area. Before the implementation of the first zonation plan in the early 2000s in *Mayuni*, many farmers lived and farmed in wildlife corridors due to the abundance of resources available for livestock and farming (Jones & Barnes, 2006; Kansky, 2022).[17] According to Jones & Barnes (2006), the resettlement of households from the floodplains of Kwando River, which serve wildlife as a facilitator of migration to other habitats, decreased the total number of HWC incidents (Jones & Barnes, 2006). This finding is supported by the event book's data on HWC, whose statistics reveal that within the period 2002-2017, 2002 and 2003 are the years with the highest amount of crop damages in *Mayuni* (NACSO, 2023b).[18] It can therefore be assumed that the introduction of a zoning plan and thus the re-location of households from wildlife corridors to settlement areas played a decisive role in reducing the number of crop damages in *Mayuni* conservancy. Another argument in favour of the success of implementing zonation plans and dividing conservancies into wildlife management and settlement areas is the fact that in 2022 60 out of 86 were

[17] A zonation plan is a management technique employed in Namibian conservancies to partition the land into distinct zones based on their ecological, social, and economic attributes. The zones are then managed differently according to their specific characteristics. For instance, areas with high wildlife populations may be designated as wildlife management areas, while areas with high human populations may be designated as settlement areas (Community Conservation Namibia, 2023h).

[18] 2002 was the first year of HWC reporting for *Mayuni* (NACSO, 2023b).

actively implementing a zoning plan and 68 conservancies maintain a wildlife management plan (Community Conservation Namibia, 2023h).

Two other widely in the Zambezi region applied prevention measures of HWC are chilli pepper fences and chilli bombs to deter elephants from damaging field crops (Jarvis et al., 2022; Jones & Barnes, 2006). Chilli bombs contain a mixture of ground chilli and elephant dung, which are compacted into a brick mould and dried. By burning the bricks at the edge of a field, the smoke serves as a deterrent to elephants. Chilli bombs are relatively simple and inexpensive to produce by community members themselves since chilli peppers (*Capsicum annuum*) grow well in the Zambezi region. For setting up chilli pepper fences a mixture of chilli peppers with grease (e.g. from diesel oil) is needed, which is then applied on cloths and ropes that hang between poles (Jones & Barnes, 2006; NACSO, 2023d). Those two methods were effective for households to deter elephants within the case study of Jones & Barnes (2006) in *Kasika* conservancy even though the fences need regular maintenance to keep their functionality in scaring elephants away (Jones & Barnes, 2006). The NGO Integrated Rural Development and Nature Conservation (IRDNC) conducted two case studies within the Zambezi region in 2016 concerning the application of mitigation strategies such as chilli bombs and chilli pepper fences. By conducting informal interviews with community members in conservancies they found that those two methods were successful and relatively inexpensive (Matinca, 2018). The efficacy of the use of chilli to deter elephants on an international scale was tested by Montgomery et al. (2022) amongst other intervention methods to protect crops from raiding elephants. Montgomery et al. (2022) conducted an extensive review including studies published over 31 years and found that interventions involving chilli peppers (i.e. fences, spray and briquettes) were most effective in scaring away elephants (Montgomery et al., 2022). These findings underline the importance of the two measures, chilli bombs and chilli pepper fences, and their application suggests that the two measures have had a significant impact in reducing crop damages in Namibian conservancies within the period 2001-2017.

In comparison with chilli pepper fences, electric fences that are installed as a barrier, especially against elephants, to prevent them from leaving protected areas or getting access to crops and settlements delivered mixed results. Jones & Barnes (2006) found in their case studies that electric fences deterred elephants in some events but at other times elephants either broke or walked around fences to enter crop fields or settlement areas (Jones & Barnes, 2006). Besides the fact that they are considerably more expensive and, therefore, for many communities not affordable, electric fences also require regular maintenance, for which often no one takes care within conservancies according to NACSO (Jones & Barnes, 2006; NACSO, 2023d).

Other measures to mitigate HWC that are applied and taught by NACSO trainers within conservancies are for example simple alarm systems (e.g. string or cowbell that alerts a farmer of animal presence) and elephant trip alarms linked to a battery-operated car siren to scare the elephant away (NACSO, 2023d). While alarm systems have been observed to work in some cases, they pose, firstly, a disturbance of community members and are secondly limited in their effect when elephants become habituated to the sound (Jones & Barnes, 2006). Modern technologies that are less disturbing for communities in comparison to loud sirens have been evolving in the past years. One example is early-warning systems that consist of early-warning towers and collars, which alert farmers when lions with collars are nearby, allowing them to safeguard their livestock (IRDNC, 2023). In April 2018, the first early-warning tower was erected in *Torra* conservancy, which was followed by the collaring of several lions and the erecting of further early-warning towers (IRDNC, 2023; The Lion Rangers, 2018). According to IRDNC, the application of early-warning systems that targeted the mitigation of human-lion conflict led to a decline in reported lion incidents in the northwest of Namibia (IRDNC, 2023). Another modern technology that assists community members in avoiding HWC is the "Spatial Monitoring and Reporting Tool" (SMART), which provides real-time information on the movement and behaviour of animals. This data can then be used in the development of an early-warning system by collecting and evaluating data on wildlife (SMART, 2021). While SMART is primarily known for its contribution to conservation to protect wildlife from poaching, it is also applied by communal conservancies to track the movement of wildlife and thus help in mitigating HWC (MEFT & NACSO, 2022; SMART, 2021).

These modern technologies are besides the proven methods also assisting in mitigating HWC in Namibian conservancies and their application is expected to intensify in the future. However, since the first early-warning tower was established in 2018 and SMART-technologies found its application only in recent years, their effect on the dataset of this thesis (2001-2017) is therefore presumably very low and can therefore be neglected.

5 Conclusion

This thesis aims to investigate the geographical differences in the type and density of HWC as well as the impact of the cumulative size of conservancies on the amount of HWC in Namibia, both for the period 2001-2017. Beyond that, the factors for variations in conflict density and type as well as other variables besides the area that influenced the prevalence of HWC were investigated.

By applying a time and area-accurate approach, variations on a regional and conservancy level in the density and type of HWC were found. A strong positive correlation (r^2 = 0.72) between the density of HWC and the human population density was found but not all regions confirmed this relationship of a higher conflict density in areas with a high population density. The data pairs of conservancies in Hardap and Oshana showed a contrary picture, which made it necessary to consider further factors to explain the varying density of HWC depending on the geographical location.

The Zambezi region was the region with the highest density of HWC since the majority of its conservancies received a moderate, high or very high density of crop and livestock damages. Regarding crop damages, no conservancy outside the Zambezi region faced a high or very high density of crop damage events. The only two exceptions that received a moderate density of crop damage were one conservancy in Kavango East and one in the Kunene region. The fact that three regions (//Karas, Hardap and Oshana) had no reported crop damage and the majority of regions had a significantly lower density of crop damage than the Zambezi region is estimated to be due to the prevailing limiting arable farming conditions for the majority of Namibian land. However, a lack of data on the type of land use by farmers in conservancies across regions prevented a more comprehensive explanation of the type-specific HWC density.

The distribution of areas with a high or very high density of livestock damages was wider as besides the Zambezi region, Hardap, Oshikoto and the Kunene region all had at least one conservancy that was classified within the two highest classification categories. Livestock holding, especially cattle farming, was found to have a higher cultural significance than crop production for communities across several regions, which might in combination with rainfall as a limiting factor for crop production in the majority of land, explain to some extent the stronger distribution of livestock damages in Namibian conservancies.

The relatively high density of HWC in the Etosha/Kunene area and the Zambezi region is expected to be due to a prevailing wildlife-favouring connectivity of different protected areas. The survival of wildlife populations, especially in years of drought, south of the Red Line and in areas with low connectivity of protected areas was hampered, which might explain the comparatively lower occurrence of wild animal populations and thus lower conflict densities in these areas. *//Audi* in the Kunene region and *Oskop* in Hardap posed exceptions for a comparatively very high density of livestock damage despite being located south of the Red Line and in a less well-connected network of different protected areas.

The results of the linear regression indicated a very strong positive correlation (r^2 = 0.92) between the annual increase in the total area of conservancies and the total HWC. Since there is a lack of data on the impact of communities on the prevalence of HWC within Namibian conservancies, a changing gradient of influence by community members on the number of HWC within the period 2001-2017 could thus not be identified. The frequently mentioned increase in wildlife populations as a factor for the increase in HWC could be denied at least from 2012 onwards, as wildlife populations have declined drastically in some cases, particularly due to droughts. The successful realization of measures to decrease HWC incidents, such as the resettlement of households from wildlife corridors to settlement areas in conservancies and the application of chilli bombs and chilli pepper fences were found to have contributed to the reduction of HWC.

This thesis illustrates by its time and area-accurate approach a realistic representation of the varying levels of HWC and its two major types of conflict across the different conservancies and regions in Namibia. For more insights into the background and the drivers of HWC and its types, a wildlife-species-specific analysis is recommended for other scholars. Areas outside the Etosha/Kunene and Zambezi region need further research to better understand exceptions and overall patterns of the varying density of HWC. Future studies that analyse the agricultural land use across regions and the influence of human pressure on HWC would help to provide more insight into the density and type of HWC in Namibian conservancies.

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Appendix

Table appendix

Density of human-wildlife conflicts and all its types on a conservancy level

ID *	Conservancy	Region	Area [in km²]	Repor -ting years	D_{CROP}	D_{HUM}	D_{LIV}	D_{OTH}	D_{HWC}
1	*Nyae Nyae*	Otjozondjupa	8,992	15	0.00	0.00	0.00	0.00	0.00
2	*Salambala*	Zambezi	930	17	0.11	0.00	0.05	0.00	0.16
3	*≠Khoadi-//Hôas*	Kunene	3,364	15	0.00	0.00	0.06	0.01	0.07
4	*Torra*	Kunene	3,493	17	0.00	0.00	0.03	0.00	0.03
5	*Wuparo*	Zambezi	148	17	0.34	0.01	0.24	0.00	0.58
6	*Doro !nawas*	Kunene	3,978	15	0.00	0.00	0.05	0.00	0.05
7	*Uibasen Twyfelfontein*	Kunene	286	12	0.00	0.00	0.08	0.00	0.08
8	*Kwandu*	Zambezi	190	15	2.26	0.01	0.13	0.01	2.41
9	*Mayuni*	Zambezi	151	16	1.02	0.00	0.10	0.00	1.12
10	*Puros*	Kunene	3,562	15	0.00	0.00	0.02	0.00	0.02
11	*Marienfluss*	Kunene	3,034	15	0.00	0.00	0.02	0.00	0.02
12	*Tsiseb*	Erongo	7,913	17	0.00	0.00	0.01	0.00	0.01
13	*Ehi-Rovipuka*	Kunene	1,980	15	0.01	0.00	0.11	0.00	0.12
14	*Oskop*	Hardap	96	7	0.00	0.00	0.27	0.00	0.27
15	*Sorris Sorris*	Kunene	2,290	15	0.00	0.00	0.04	0.01	0.05
16	*Mashi*	Zambezi	297	16	0.68	0.00	0.19	0.00	0.87
17	*Omatendeka*	Kunene	1,619	13	0.01	0.00	0.08	0.00	0.09
18	*Otjimboyo*	Erongo	448	16	0.00	0.00	0.05	0.00	0.05
19	*Uukwaluudhi*	Omusati	1,437	16	0.03	0.00	0.02	0.00	0.05
20	*Orupembe*	Kunene	3,565	15	0.00	0.00	0.02	0.00	0.02
21	*Okangundumb a*	Kunene	1,131	15	0.04	0.00	0.17	0.01	0.21
22	*//Huab*	Kunene	1,817	12	0.00	0.00	0.02	0.00	0.02
23	*!Khob !Naub*	//Karas	2,747	13	0.00	0.00	0.02	0.00	0.02
24	*//Gamaseb*	//Karas	1,748	13	0.00	0.00	0.01	0.00	0.01
25	*Anabeb*	Kunene	1,570	15	0.00	0.00	0.07	0.00	0.07
26	*Sesfontein*	Kunene	2,465	15	0.00	0.00	0.07	0.00	0.07

ID *	Conservancy	Region	Area [in km^2]	Repor-ting years	D_{CROP}	D_{HUM}	D_{LIV}	D_{OTH}	D_{HWC}
27	*Sanitatas*	Kunene	1,446	13	0.00	0.00	0.13	0.00	0.13
28	*Ozondundu*	Kunene	745	15	0.01	0.00	0.09	0.01	0.11
29	*N≠a Jaqna*	Otjozondjupa	9,120	12	0.00	0.00	0.00	0.00	0.00
30	*≠Gaingu*	Erongo	7,731	9	0.00	0.00	0.00	0.00	0.00
32	*Uukolonkadhi Ruacana*	Omusati	2,993	12	0.01	0.00	0.03	0.00	0.04
33	*Ozonahi*	Otjozondjupa	3,204	9	0.00	0.00	0.01	0.00	0.01
35	*Sheya Shuushona*	Omusati	5,066	12	0.00	0.00	0.04	0.00	0.05
37	*Muduva Nyangana*	Kavango East	615	11	0.02	0.00	0.01	0.00	0.03
38	*Otjituuo*	Otjozondjupa	6,133	9	0.00	0.00	0.00	0.00	0.00
39	*African Wild Dog*	Otjozondjupa	3,824	9	0.00	0.00	0.01	0.00	0.01
40	*King Nehale*	Oshikoto	508	12	0.01	0.00	0.24	0.02	0.28
41	*George Mukoya*	Kavango East	486	11	0.10	0.00	0.02	0.00	0.12
42	*Okamatapati*	Otjozondjupa	3,096	9	0.00	0.00	0.01	0.00	0.01
43	*Kasika*	Zambezi	147	17	0.12	0.01	0.28	0.02	0.44
44	*Impalila*	Zambezi	73	17	0.92	0.02	0.34	0.05	1.33
45	*Balyerwa*	Zambezi	223	14	0.47	0.00	0.17	0.01	0.65
46	*Ondjou*	Otjozondjupa	8,729	7	0.00	0.00	0.01	0.00	0.01
47	*Kunene River*	Kunene	2,764	12	0.00	0.00	0.05	0.00	0.05
48	*Ohungu*	Erongo	1,211	9	0.00	0.00	0.02	0.00	0.02
49	*Sobbe*	Zambezi	404	12	0.27	0.00	0.05	0.00	0.32
50	*//Audi*	Kunene	335	5	0.00	0.00	0.44	0.01	0.45
52	*!Han /Awab*	//Karas	1,923	9	0.00	0.00	0.01	0.00	0.01
53	*Okondjombo*	Kunene	1,645	10	0.00	0.00	0.07	0.00	0.07
54	*Otjambangu*	Kunene	348	12	0.01	0.00	0.16	0.00	0.16
55	*Eiseb*	Omaheke	6,625	8	0.00	0.00	0.02	0.00	0.02
56	*Sikunga*	Zambezi	287	11	0.03	0.00	0.09	0.01	0.13
57	*Okongo*	Ohangwena	1,340	8	0.00	0.00	0.05	0.00	0.05
58	*Huibes*	Hardap	1,327	8	0.00	0.00	0.07	0.00	0.07
59	*Dzoti*	Zambezi	287	15	0.23	0.00	0.20	0.00	0.44
60	*Otjitanda*	Kunene	1,174	10	0.00	0.00	0.06	0.00	0.06
61	*Otjombinde*	Omaheke	5,891	6	0.00	0.00	0.02	0.00	0.02

ID *	Conservancy	Region	Area [in km²]	Repor -ting years	D_{CROP}	D_{HUM}	D_{LIV}	D_{OTH}	D_{HWC}
62	*Orupupa*	Kunene	1,234	15	0.04	0.00	0.19	0.01	0.24
63	*Omuramba ua Mbinda*	Omaheke	3,217	6	0.00	0.00	0.01	0.00	0.01
64	*Bamunu*	Zambezi	556	12	0.09	0.00	0.04	0.01	0.14
65	*!Khoro !Goreb*	Kunene	1,283	5	0.00	0.00	0.03	0.01	0.04
66	*Kabulabula*	Zambezi	89	11	0.08	0.01	0.33	0.00	0.42
67	*Okongoro*	Kunene	956	12	0.03	0.00	0.07	0.00	0.11
68	*Otjombande*	Kunene	329	6	0.10	0.00	0.27	0.01	0.37
69	*Ongongo*	Kunene	501	6	0.00	0.00	0.20	0.00	0.20
70	*Ombujokangui ndi*	Kunene	1,160	8	0.00	0.00	0.09	0.00	0.09
71	*Otuzemba*	Kunene	742	12	0.01	0.00	0.10	0.01	0.13
72	*Otjiu-West*	Kunene	1,100	8	0.00	0.00	0.09	0.00	0.09
73	*Iipumbu ya Tshilongo*	Oshana	1,548	4	0.00	0.00	0.02	0.00	0.02
74	*Okatjandja Kozomenje*	Kunene	656	6	0.00	0.00	0.15	0.00	0.15
75	*Ombazu*	Kunene	871	6	0.00	0.00	0.11	0.00	0.11
76	*Okanguati*	Kunene	1,159	6	0.00	0.00	0.09	0.00	0.09
77	*Epupa*	Kunene	2,912	6	0.00	0.00	0.05	0.00	0.05
78	*Otjikondaviron go*	Kunene	1,067	7	0.00	0.00	0.14	0.00	0.15
79	*Etanga*	Kunene	908	8	0.00	0.00	0.11	0.00	0.11
80	*Nakabolelwa*	Zambezi	114	15	0.15	0.00	0.17	0.00	0.32
81	*Ombombo-Masitu*	Kunene	1,487	3	0.01	0.00	0.04	0.01	0.06
82	*Lusese*	Zambezi	207	15	0.03	0.00	0.09	0.00	0.12
86	*Otjikongo*	Kunene	1,028	2	0.00	0.00	0.02	0.00	0.02

Note. Own work. Data was computed with the formulas that were presented in the section 2.2. The raw data was extracted from NACSO (2023b).

D stands for the density of conflicts of the respective type or the density number of conflicts summed for all types. “CROP” stands for crop damages, “HUM” for human attacks, “LIV” for livestock damages, “OTH” for other damages and “HWC” for the sum of all types of conflicts. All data for conflicts that are given in NACSO (2023b) were included in the calculations.

* Only the 79 that provided data on HWC are presented in this table.