Pastoralism: Research, Policy and Practice

RESEARCH Open Access

Exploring pastoralists' perceptions of desertification tipping points in Namibia's communal drylands: An ethnographic case study from Okakarara constituency

Diego Augusto Menestrey Schwieger

Abstract

Most studies and conceptualizations of tipping points in environmental and climatic systems have been conducted using natural science perspectives and approaches. Socio-scientific contributions—including Anthropology—are scarce. This has resulted in a limited understanding of the socio-cultural dimensions of tipping point phenomena at the local level. This paper contributes to ongoing discussion and provides an ethnographic study of local perceptions of desertification tipping points (DTPs) amongst Ovaherero pastoralists in Namibia's semi-arid Okakarara constituency. Following a qualitative approach, this study shows that experienced farmers are aware of these phenomena and have accumulated extensive knowledge enabling them to identify and anticipate DTPs in different, complementary ways. The paper discusses how DTPs are managed in a communally farmed setting and presents the challenges that livestock farmers face in practical prevention of DTPs.

Keywords: Desertification tipping points, Local knowledge, Pastoralism, Ethnography, Namibia

Introduction

Over the past 15 years, the notion of 'tipping point' (TP) has become a scientifically grounded concept epitomizing abrupt, drastic, and nearly irreversible changes in environmental systems ranging from local or regional relevance (e.g. fisheries, rangelands) to major planetary sub-systems (e.g. the Antarctic Ice Sheet, the Amazon Rainforest) (Russill and Nyssa 2009; van der Hel et al. 2018). Current research shows that these changes can be induced by complex combinations of anthropogenic and environmental factors (Lenton et al. 2008; Lenton 2013; Lenton and Williams 2013). As shown by past events in Earth's history, crossing TPs can have far-reaching social-ecological consequences, including the downfall of entire societies (e.g. Janssen et al. 2003; Falkenmark et al. 2019). Similarly, anticipated TPs are likely to effect enormous, if not catastrophic, social and economic repercussions at various scales (Lenton and Ciscar 2013; Renaud et al. 2013; Serrao-Neumann et al. 2016). Nevertheless, identifying and predicting environmental TPs in real-world systems still constitutes a significant cross-disciplinary scientific challenge (Scheffer et al. 2009; Lenton 2011; Dakos and Hastings 2013).

Most pre-existing studies concerning environmental TPs stem from Earth System Science, Ecology, Climate Change Science, and the Social-Ecological Systems approach. Social science contributions, in contrast, have been remarkably few—including Anthropology (cf. O'Riordan and Lenton 2013; Milkoreit et al. 2018). Whilst anthropologists have produced a large body of literature covering a wide range of issues related to environmental degradation and climate change (e.g. Baer and Singer 2018; Crate and Nuttal 2009; Orr et al. 2015), contributions focusing on environmental tipping points, in particular, are scarce. A noteworthy exception,

Correspondence: diego.menestrey@uni-koeln.de
Department for Social and Cultural Anthropology, University of Cologne, Main Building, Albertus-Magnus-Platz, 50923 Cologne, Germany

however, is provided by Nuttall (2012) who advances two major critical arguments directed towards the TP literature: (i) that social change processes have been explained in environmentally deterministic ways whilst ignoring the role that socio-economic and political factors play in causing these changes and (ii) that little attention has been paid to peoples' anticipatory knowledge, practices, and conceptualizations regarding TPs. This, according to Nuttal, has resulted in over-simplistic explanations of human-environment interactions and poor understandings of how people might perceive and adapt to future environmental shifts.

By drawing on Nuttal's points of criticism, this paper contributes to the current discussion by introducing an ethnographic case study focusing on local perceptions of a specific TP, namely, the tipping point at the threshold to desertification (DTP). This TP constitutes one major type of regime shifts in drylands and is usually induced by severe human and environmental pressures (e.g. overgrazing and prolonged droughts). The shift typically involves a switch from a state of dense coverage of perennial grasses to predominantly, almost irreversible, bare soil conditions, thus seriously threatening pastoral livelihoods (Reynolds et al. 2007; Bestelmeyer et al. 2015). This collapse in vegetation production occurs when the loss of dominant perennial plants leads to a reduction in soil water infiltration, loss of nutrients and fertility, and eventually soil erosion (D'Odorico et al. 2013). Recovery of the former state is largely dependent on active restoration (Scheffer and Carpenter 2003). Various efforts have been made to identify and predict DTP from an ecological perspective, but hardly any have assessed local knowledge and perceptions of this phenomenon ethnographically (cf. Briske 2017; Moore 2018; Castillo et al. 2020). This constitutes an important research gap in terms of assessing and understanding how people farming and living in drylands perceive, predict, and manage these critical thresholds.

My research addressing this omission was conducted in Namibia's semi-arid Okakarara constituency as part of a larger inter-disciplinary project (NamTip) aimed at understanding and managing DTP in the broader region[1]. This part of Namibia is representative of other drylands in the country and elsewhere due to the socio-economic and cultural importance of livestock farming for people (mostly Otjiherero-speaking pastoralists) and the multiple factors currently affecting local rangeland conditions, such as climate change, increasing population densities, and overgrazing (see below).

By using a case study approach and qualitative procedures, I explored how farmers from different villages conceptualize and anticipate DTP, including the measures they devise to manage and prevent these critical thresholds in their localities. Based on these analyses, this paper offers the following three principal arguments:

i) Although there is no direct translation of 'desertification tipping point' in Otjiherero, individual farmers are well aware of this phenomenon through lived experience. Moreover, they have different, complementary ways of identifying and anticipating DTP locally.
ii) These ways of predicting DTP include not only identifying marks directly on the rangeland, but also circumstantial indicators in cattle and wildlife, as well as signs of good/bad rain.
iii) Efforts to manage DTPs comprise self-governing institutions that can only operate at the communal level. These aim primarily to avoid the reduction of communal grazing land in contexts where mobility is limited, but resting periods for grazing land are only practicable if cattle post infrastructures are in place.

Against this background, the paper draws attention to environmental TP's socio-cultural and political dimensions by depicting local ways of knowing and predicting DTP in the Okakarara constituency, including the implications of managing this kind of TP in Namibia's communally farmed areas.

The paper is structured as follows: after this introduction, I depict the study area and then present the methods and data collection process used. Next, I elaborate on results obtained from exploring pastoralists' perceptions and ways of anticipating DTP. I discuss the challenges faced by individuals in preventing DTP in their grazing lands and conclude with a short discussion and final remarks.

Study area

Okakarara constituency is located in the western Kalahari Desert, characterized by a semi-arid (between 325 and 350 mm rainfall per year) sandy savannah landscape, where severe droughts occur sporadically (Mendelsohn and Obeid 2002). During South African colonial rule, this area was part of the Waterberg native reserve for Ovaherero pastoralists, later consolidated into the larger Herero 'homeland' under Apartheid (Kakujaha-Matundu 2003). After independence (1990), the homeland was abolished and declared part of the eastern communal areas. The constituency (which includes the same-named town, Okakarara) has ca. 23,000 inhabitants, most of them Otjiherero speakers living in communities of fifteen to fifty households averaging 4.7 members each (Kakujaha-Matundu 2003; Republic of Namibia 2014).

[1]See https://www.namtip.uni-bonn.de/ [last accessed: 02 August 2021].

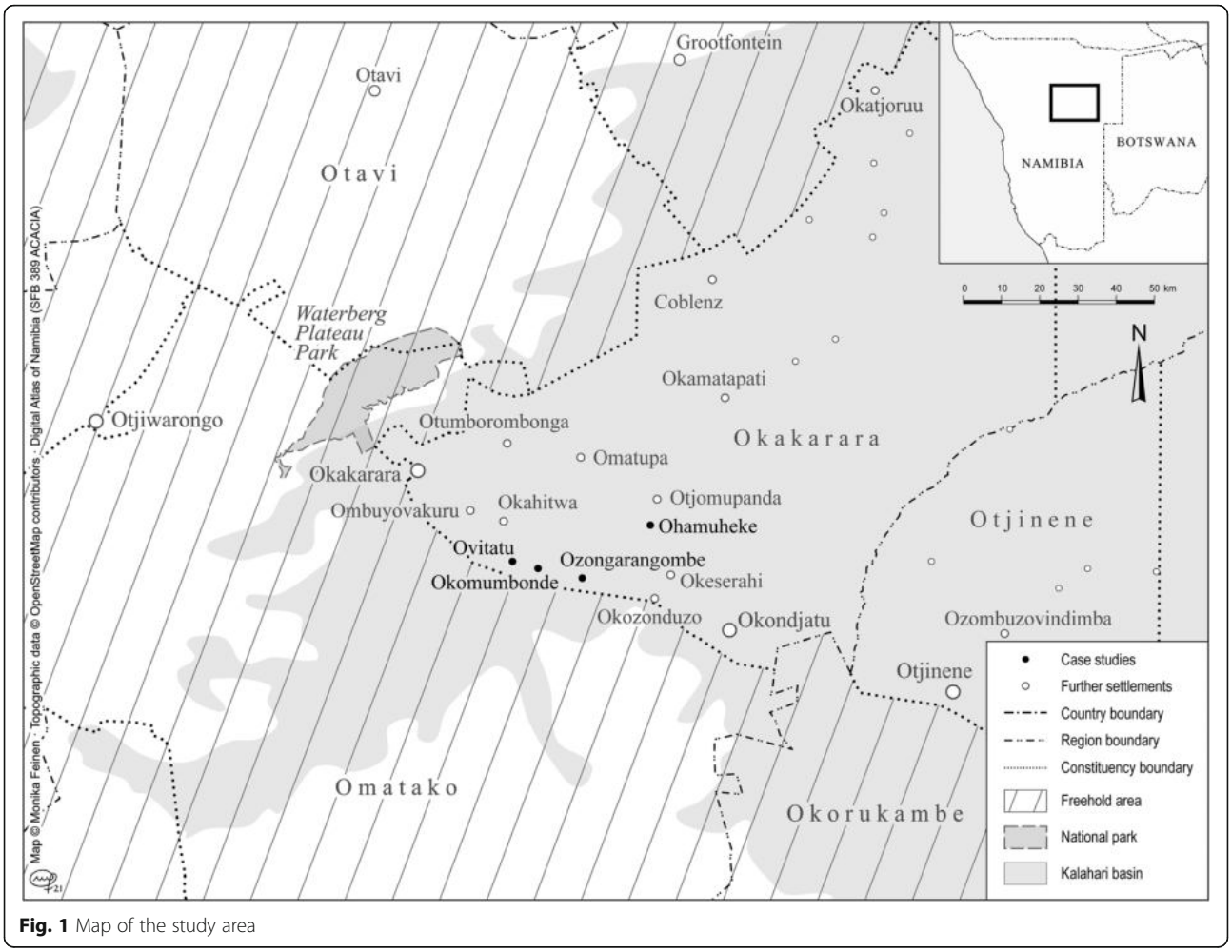

Fig. 1 Map of the study area

Of the four constituencies in the eastern communal areas, Okakarara is the most densely populated—1.6 persons per square kilometre (Republic of Namibia 2014).

Livestock farming constitutes the principal means of subsistence in the region; salaries, remittances, and state pensions provide complementary income sources (cf. Republic of Namibia 2014). Most farmers own between ten to fifty head of cattle and have average flocks of eight sheep and twenty-five goats. Those possessing a hundred head of cattle constitute the minority in each settlement. Many of these are 'weekend' farmers attending jobs in urban centres whilst employing herders or family members to take care of their animals. Horticulture is a minor economic activity, since gardens are only watered by rainwater. The most important water sources are communally administered boreholes around which households comprising a community are located (Mendelsohn and Obeid 2002)[2].

[2]Except for the water pipeline supplying Okamatapati's farming units, where ca. 60 household live (Kakujaha-Matundu 2003).

Communities regard a certain amount of rangeland around their village as their own and these areas are contiguous with the grazing land of neighbouring settlements (Bollig and Gewald 2009:26). Access to, and use, of these commonly 'owned' grazing lands is usually regulated by self-governing institutions (Stahl 2009). Many parts of these communally farmed areas are currently classified as over-utilized and degraded, and annual grass species—typical pioneer or subclimax species—predominate (Strohbach 2014). In this context, colonial re-settlement measures, territorial encapsulation, poor infrastructural development, uncontrolled fencing, and local power relations have influenced current land degradation conditions (Menestrey Schwieger and Mbidzo 2020). Thus, the entire ecosystem is considered extremely fragile and susceptible to desertification (Thomas et al. 2005).

Methods

The data presented here were collected during 12 months of anthropological fieldwork between 2019 and

2020 to assess human factors linked to DTP in the region[3]. To explore the local perceptions and ways of knowing DTP, I implemented a qualitative approach based on open-ended interviews and veld visits with key informants from four different settlements: Ovitatu, Okomumbonde, Ozongarangombe, and Ohamuheke, in the south of Okakarara's constituency (see Fig. 1). Each settlement contained 39, 36, 62, and 34 households respectively during the research period.

Key informants were identified by gathering peer recommendations in each site about persons locally regarded as exceptionally knowledgeable concerning the area's livestock farming practices and grazing lands. However, many villagers were said, or considered themselves, either to be too young, as part-time farmers working intermittently in towns, or simply less knowledgeable than others. I eventually collected the names of fifteen people, seven of them living in Ozongarangombe, two in Ovitatu, and three in Ohamuheke and Ombooronde. Amongst these, twelve were men in their 40s and 50s and three were women in their 60s. All were full-time farmers who had lived and navigated the social-ecological challenges within the area all their lives. None of these fifteen experts could tell me of any other competent sources apart from themselves, thus indicating that other people possessing substantial knowledge in their communities had either died and/or moved to other places[4]. The data collection process for this study was carried out with the help of this small but highly experienced group of people. I was assisted by a local translator since my Otjiherero language skills were limited and none of the informants was proficient in English.

Data collection

The data gathering proceeded in three main steps: (i) initial explorative interviews, (ii) complementary veld visits, and (iii) further in-depth conversations. The first explorative interviews enabled me to learn and discuss vernacular concepts of rangeland degradation and to understand how farmers experienced and interpreted environmental changes regarding DTP. These conversations with key informants were conducted at all four locations and provided the basis on which to assess specific DTP indicators afterwards. This assessment was carried out subsequently within the framework of various veld visits, where my informants showed me areas in their grazing lands that—according to their perspective—were far from, close to, and beyond the DTP. On these spots, we discussed why these sites were in such conditions, how it was possible to recognize a DTP, and whether these places could ever be recovered. In these contexts, I recorded concrete DTP markers on the rangeland's vegetation as indicated by the farmers.

Further circumstantial indicators used for predicting DTP were assessed during supplementary interviews inspired by noticing how livestock owners made inferences about the conditions of their grazing lands by observing the body condition of their cattle. After asking informants if they used other similar ways of knowing and anticipating the state of their rangelands, I recorded a number of additional inferential DTP signs, including farmers' methods for forecasting rain.

After this, all recorded information—including interview transcripts and field notes—was organized using the MAXQDA qualitative data analysis software. Through thematic coding, I established a list of all collected indicators, which were subsequently presented to all fifteen experts one last time for cross-checking purposes. Substantial consensual agreement between their statements became evident during this procedure, and only a few additions were made to the knowledge base[5]. Considering the number of DTP indicators mentioned by my informants, I asked them what they and their communities were doing to prevent DTP in their localities. By these means, I recorded the farmers' strategies and challenges in managing DTP within the social-ecological context in which they make a living.

Results

Local conceptualizations of DTP

None of my informants had heard of a 'desertification tipping point' before, and the phrase cannot be translated into Otjiherero. Therefore, I used the vernacular expression *omakururukiro yokuti* as an opening to explore local conceptualizations of environmental degradation regarding DTP. *Omakururukiro* is a substantive from *kurura*/*kuruka*, which means 'scraped' or 'consumed', and *yokuti* means 'of the field/bush'. Therefore, the sentence literally means 'the deterioration/depletion of the veld', and virtually any Otjiherero-speaking farmer knows the expression. It describes the loss of grazing, including browse trees and shrubs, to the point that no livestock or people can inhabit the area anymore. The phrase captures the state when the rangeland loses its

[3]See https://www.namtip.uni-bonn.de/ueber-das-projekt-2-en [last accessed: 02 August 2021].

[4]This key informant selection followed the guidelines suggested by Davis and Wagner (2003).

[5]Nevertheless, it cannot be ruled out that Ovaherero living in the other regions could have slightly different indicators considering the ecological specificities of the study area.

[6]See the UNCCD definition of desertification (https://www.unccd.int/sites/default/files/relevant-links/2017-01/UNCCD_Convention_ENG_0.pdf.).

biological and economic productivity, as specified in standard definitions of desertification[6].

Omakururukiro yokuti can be caused by multiple inter-related factors, involving *otjiwana tjikura* (population growth), *omarisiro ngahavera oruveze* (overgrazing), *omananeno omavi* (mismanagement), and *ourumbu oure* (extended droughts)[7]. Likewise, *omarundurukiro womuinyo wevaverwa* (literally the change/shift in the weather of the universe[8], or climate change) was also emphasized by my informants as a pivotal contributor to the veld's deterioration. Supernatural factors, or *Mukuru* (usually translated as God), were not ascribed a key role concerning rangeland degradation processes. Unusual personal misfortunes (e.g. sudden illness, cows aborting) were sometimes ascribed to the powers of close ancestors, but these beings could not cause affliction on a grand scale, for example, severe drought (Crandall 1996:336)[9].

To determine if *omakururukiro yokuti* included notions of abruptness and irreversibility—two crucial elements of TP behaviour (cf. Bestelmeyer et al. 2017; Milkoreit et al. 2018)—I asked my informants colloquially: *ehozu rijenena okuzenga tjimanga*? (Can grasses suddenly disappear?). The answers to this question were consistently affirmative and supported with examples. As an illustration, the following two vignettes are extracted from fieldwork conversations, one with 69-year-old Veronika Kasetura and one with 50-year-old Uahungira Tjipe, both from Ozongarangombe.

(i) When Veronika was a child taking care of her father's goats, there was a specific type of local grass that was not only grazed by cattle, but also extensively used by people for roofing their houses. Veronika cannot remember the name of the grass anymore, but she said that it helped keep their homes dry and cool, especially from December to March, the wet-hot summer season. Back then, many village houses were built with on-site materials such as tree branches and a mix of cow dung, sand, and water, but nowadays, most structures are built with shop-bought corrugated iron. Veronika indicated that she had not seen these grasses since the mid-1980s, that is, after 'the year of the rotten carcasses' (*otjo tungava*), as the severe drought of 1981/1982 is known. She inferred that the extreme dryness then must have been the final straw that caused these grasses to vanish, as they were intensively used. The only way to bring them back, she concluded, was to replant them[10].

(ii) Recalling his younger years, Uahungira said his cattle did not have to go too far away from his homestead to find fodder. This was much better for his animals as, then, they had not expended too much energy walking. Now, his cattle have to walk long distances to find enough fodder, especially during the dry seasons. He said, *ozongombe zekondjisa tjinene okupaha ovikuria* (cattle are struggling a lot to find food). Uahungira could not tell precisely when the grasses close by disappeared; only in retrospect, he realized that they had vanished. He was sure that these conditions had to do with the progressive increase of households in the settlement over time. In 1990, for instance, there were ca. forty households in Ozongarangombe, almost one-third less than the current amount. Nevertheless, Uahungira suggested that there was still a chance for these nearby grasses to grow back if their seeds were still in the ground, if animals stopped using the area, and if excellent rains came for two consecutive years. Otherwise, he deduced, the ground would most likely remain bare[11].

Other informants' reports differed little from Veronika's and Uahungira's. They too described the abrupt and almost irreversible loss of specific grasses, or rather, the grazing, in particular areas within their respective communities due to an intensification of adverse weather or disturbance. This suggested that even though there was no equivalent concept in Otjiherero for DTP, key DTP processes were nevertheless known and recognized through lived experience as part of broader dynamics and conceptualizations of *omakururukiro yokuti*. These preliminary insights were further corroborated when we visited the grazing lands of the four case study communities. There, I asked my interlocutors to show me three different types of areas: (i) those that were far from being depleted/consumed; (ii) those close to losing grasses completely; and (iii) those where no grasses grow anymore. According to my informants, the sites presented concrete warning indicators of DTP.

DTP indicators on the rangeland

Areas far from DTP

The areas visited in all four sites regarded by the local informants as far from being depleted/consumed shared common characteristics: (i) visible densities of different grass species, including perennials; (ii) good soil conditions (indicated by rapidly and robustly growing grasses in these spots); (iii) 'openness' with only a few encroaching bush species; and (iv) distance from homesteads and water points (between 2 and 6 km away), thus less

[6]See the UNCCD definition of desertification (https://www.unccd.int/sites/default/files/relevant-links/2017-01/UNCCD_Convention_ENG_0.pdf.).

[7]Mismanagement mostly implies the lack of strategies to leave pastures to rest and failing to exercise group boundaries.

[8]Personal communication with Dr. Jekura U. Kavari, associate professor in the Otjiherero Section of the Department of Language and Literature at the University of Namibia.

[9]For more information on Herero cosmology, see Kavari (2001).

[10]Interview conducted on 14 October 2019 in Ozongarangombe.

[11]Interview conducted on 10 October 2019 in Ozongarangombe.

Fig. 2 Area far from the DTP in Ohamuheke; photographed 29th September, 2020

frequently used for grazing. These traits were pointed out by my interlocutors whilst describing the sites' main characteristics. Figure 2 gives a visual impression of one site, depicting one of the best grazing spots in Ohamuheke as indicated by 60-year-old Erenst Kazenaimue and his 40-year-old cousin Operi, both local residents[12].

Such areas are regarded as particularly valuable due to the presence of two specific perennial grass species: *ongumba* (*Stipagrostis uniplumis*) and *otjisepa* (*Triraphis ramosissima*). Reportedly, these grasses 'hold the ground' (i.e. prevent soil erosion), fatten up the cattle, and considerably increase the cows' milk production. However, all informants concurred that these grasses have virtually disappeared in the settlements' proximities and that annual grass species have become predominant over the years. This coincides with Strohbach's observations, which established that these two perennial grasses are currently found exclusively in cattle posts and areas far from settlements in the region (2014).

Furthermore, although bush encroachment is critical in reducing grass production in these communal areas (De Klerk 2004), a certain degree of woody vegetation was nevertheless seen as beneficial. The usual reason given was that when grass is particularly scarce at the end of the dry period, cattle rely on the browse from various early sprouting trees and bushes, such as *omuvapu* (*Grewia bicolor*), *omupanda* (*Lonchocarpus nelsii*), *omuhe* (*Grevia flavecens*), and *omutijakatjipera* (*Bauhinia macrantha*). Important encroacher species, such as *omusauna* (*Acacia mellifera*) and *omusijasetu* (*Terminalia sericea*), were also regarded as valuable browsers, yet only when young and present in moderate numbers. These accounts resemble the observations made in the neighbouring Otjinene constituency by Katjiua and Ward (2006) who established that bush and trees are vital in sustaining cattle production when grasses are depleted before the arrival of heavy rains from January to March. Therefore, they suggest that rehabilitation of encroached rangelands must consider the role of browse in the region.

Areas close to crossing a DTP

The areas regarded as close to losing grasses permanently also had specific attributes: (i) visibly low grass densities, mostly of annuals; (ii) obvious levels of bush encroachment (especially of *Terminalia sericea* and *Acacia mellifera*); (iii) poor soil conditions (evidenced by fragile and low-growing grasses); and (iv) higher densities of herbaceous plants growing amongst the grasses, especially *ohorotito* (*Sida cordifolia*) and *ohongwe* (*Tribulus terrestris*). Reportedly, all these traits were signs that these areas might be close to becoming bare ground; in other words, they were early warning indicators for DTPs. These sites were proximate to homesteads, near to natural and artificial water points, and/or in areas intensively grazed in the past and/or the present. Figure 3 exemplarily illustrates one of these areas in Omboorronde, as shown to me by a 56-year-old resident, Godlob Kamuserandu. It shows a spot not far from his homestead where grasses have been almost entirely displaced by overgrazing and bush encroachment.

Though these zones were perceived as approaching deteriorated/depleted, my informants generally highlighted the value of the annual grasses still growing in these spots, mentioning species such as *omurondji* (*Schmidtia kalahariensis*), *oruejo* (*Eragrostis porosa*), *ehozu romarindi* (*Urochloa beachyura*), and *otjiramata* (*Setaria verticillata*). Despite their short life cycle, these

Fig. 3 Area close to the DTP in Omboorronde; photographed 12th August, 2020

[12]During fieldwork, signs of under-utilization were, according to informants, obvious, due to the lower number of animals in the place as a result of the 2019 drought.

were said to grow fast after the first rains and fatten cattle quickly. In fact, annual grasses can be essential nutrient suppliers, even though perennials' replacement by annuals is regarded in conventional range management as a bad thing (Scoones 1989:11). However, not all annuals were seen as beneficial, for example, *Aristida rhiniochloa* which can blind cattle with its spikelets, and the animals only eat it when they are extremely hungry[13]. Hence, even though its presence indicates pioneer conditions (Müller 2007:162), the areas where this kind of grass dominates are usually regarded by farmers as worthless for grazing.

In any case, my informants agreed that despite the benefits of various annual grasses, farming in areas where only these short-lived species grow would necessitate purchasing large amounts of fodder to overcome the dry periods. Allegedly, this is especially so in 'old' settlements located on the dry riverbed Omuramba Omatako, for example, at Okahitwa and Orunahi (see Lindholm 2006), where 'harder' arenic Fluvisoils prevail (Strohbach et al. 2004). Such soils were identified as more productive than the region's dominant sandy grounds (i.e. haplic and ferralic Arenosols), which are poor in phosphate (ibid.). However, these hard soils were thought to make the area more prone to DTP because they dry out faster, and so do the grasses, especially if they are annuals. Hence, the strong winds of August might easily erode these soils due to their lower hydraulic conductivity (Strohbach et al. 2004), leaving cattle without fodder until the next rains. Or as 47-year-old Vehonga Kahuure from Ozongarangombe tragically put it: 'it is like farming with a gun pointing at you', implying the constant threat of farming under such circumstances.

In contrast to areas beyond DTP (see below), my informants believed these grazing lands could recover more easily. Less bush removal would be needed here and there were still some annual grasses—a sign that the soil has not lost all its 'power' (*otj. omaza*). Therefore, perennial grasses would be able to return if grazing pressure is reduced and if, in extreme cases, grazers are completely excluded from using the land for a number of seasons.

Areas beyond the DTP

Eventually, the areas that had lost grasses permanently were either (i) completely overrun by *ohorotito* (*Sida cordifolia*) and/or *ohongwe* (*Tribulus terrestris*); (ii) obviously bush encroached, especially by *omusauna* (*Acacia mellifera*) and *omusijasetu* (*Terminalia sericea*); and/or (iii) reduced to bare soil. Such spots were located near to artificial and natural water points, around homesteads with large numbers of livestock, and/or in areas that had been intensively grazed. Figure 4 depicts one of these areas in Ozongarangombe, as indicated by Uahungira Tjipe and Vehonga Kahuure, both previously introduced. The photograph illustrates a spot between the communities' communal water point and two households owning large cattle herds. The grass cover has virtually disappeared, and only *ohorotito* grows between the trees.

Fig. 4 Area beyond the DTP in Ozongarangombe; photographed 2nd August, 2020

Apart from having lost their grass cover, the areas with *ohorotito* and/or *ohongwe* were said to be toxic for livestock. Whilst *ohorotito* causes constipation amongst bovines and sometimes even the animal's death, *ohongwe* can have poisonous effects on sheep, including inflammation of eyes and gums and appetite loss. Furthermore, although *Acacia mellifera* and *Terminalia sericea* may provide browse for cattle when little grass is available, they have displaced grasses entirely in certain areas, making it impossible for cattle to cross the veld. *Acacia mellifera* was said to be the most dominant species encroaching the grazing lands in the area, a claim corroborated by studies in the region (e.g. De Klerk 2004; Hengari 2018).

Nevertheless, my informants were confident that debushing could encourage grasses to return. Godlob Kamuserandu, for instance, substantiated this by showing me a patch where he had cut quantities of *omusauna* for firewood some years before. According to him, barely any grasses were growing on this spot due to the bushes, but they started to return 1 year after *omusauna* was removed. Like Godlob, many other villagers I encountered saw de-bushing as an opportunity to restore local grazing lands and also as a way to improve their livelihoods, for instance, by producing and selling charcoal. However, the Namibian government prohibits large-scale debushing and the commercialization of bush biomass in

[13]All *Aristida* sp. are called *ohoke* (personal communication with Dr. Clara Wellencia Nesongano, lecturer at the Department of Biological Sciences at the University of Namibia).

communal areas. Only a few initiatives for sustainable harvesting and charcoal processing in these parts of the country have been recently implemented[14].

My informants were generally optimistic that grasses could return to barren grounds if certain conditions applied. Forty-nine-year-old Paulus Murumbua, from Ovitatu, showed me an area with hard soils close to a land pan (*omarindi*) where grasses had virtually disappeared due to overgrazing and continuous trampling. Paulus was sorry that his cattle could not graze there anymore; now, he said, they only come to lick the bare ground to absorb the minerals remaining in the soil. When I asked him if the area could ever be rehabilitated, his answer echoed Veronika's and Uahungira's statements. He claimed that if the country was fenced off and good rains came for three consecutive years, the area might recover if grass seeds were dormant in the ground, but if they were not present in the soil, only the wind could help bring seeds, a process implying a much longer recovery period. Otherwise, planting grasses around the pan would be the only option left for restoring the area, he concluded.

Hence, in contrast to areas close to the DTP, areas that have crossed this threshold would require a combination of more drastic interventions to counteract the feedbacks maintaining this degraded state. This would include, for instance, large-scale de-bushing, grazing exclusion for several years, re-seeding, and exceptionally good environmental conditions (good rainfall) over a period of time.

In summary, informants clearly distinguished between areas far from, close to, and beyond the DTP by noticing and identifying physical signs in the rangeland's herbaceous layer, whilst also considering soil characteristics and the degree of bush encroachment. It is essential to highlight that they thought 'tipped' areas were restorable via grazing exclusion and if favourable environmental conditions (good rains) applied, and if active intervention (bush thinning and re-seeding) occurred. That said, some interviews revealed that identifying signs directly in the rangeland was not the only means people used for determining the veld's conditions and anticipating DTP, as I show in the next section.

Further signs of knowing and anticipating DTP

Reading the body condition of cattle

By observing their animals' bodies, many livestock owners make inferences about the conditions of the areas where their cattle graze. Many people do not escort their cattle frequently to the veld due to the lack of herders caused by the outmigration of young people looking for work (Stahl 2009), so instead of conducting direct rangeland assessments, visual inspections inform decision-making regarding buying fodder or ushering animals to other grazing areas. These cattle examinations are usually done when the owners' herds gather to drink at the communal water point or at the homestead, where they rest or are milked before being sent back into the veld.

The most obvious indication that grazing areas are in good condition is if cattle look well-nourished (*zanona tjinene*). This means that the animals' hip bones are not visible, their ribs are well covered, their briskets have evident fat deposits, and their overall outline is smooth. But conversely, if the animal is thin, that is, if their hips and shoulder bones are visible, including their backbone, and if their ribs are faintly noticeable, then it means that animals are struggling to find enough fodder. If the veld is 'clean' (no grasses, no browse), the animals will reach a skeletal body outline (*zarambuka navi*), where backbone, hips, and shoulder bones, including the ribs, are visibly prominent. In this stage, the animals could die unless fed with grass and supplements bought in shops. If cattle are constantly thin even after good rain periods, it means that their grazing areas are becoming chronically depleted/deteriorated—and thus potentially close to a DTP.

Meat fats

An additional way of telling if the veld, especially its soil, is in a good state, is by inspecting the colour of adipose tissue on the animals' carcasses. These assessments are not done regularly, but only when certain opportunities arise, for example, during funeral or wedding feast preparations when at least one head of cattle is slaughtered and cooked[15].

Reportedly, if the fat on a cattle carcass is yellowish, it means that the animal was eating *ehozu ewa romasa* (lit. grass with power; nutritious), that is, grass growing on soils with large amounts of *omongwa* (lit. salt; minerals). Plant carotenoids cause this yellow pigmentation, which also implies that the beef carries a healthier nutritional value, particularly concerning the fatty acid profile and antioxidant content (Dunne et al. 2009). If the colour of the fat is white, it signifies that the grasses the animal ate were 'weak' (*ehozu ereze*), or rather, that the soils where it grazed were poor (*ehi evi*; lit. bad soil)—and thus probably close to a DTP. According to Dunne et al. (2009), the fat might acquire a whitish colour too if the animal is predominantly fed artificial fodder, but this is only done in the study area in times of extended droughts. Otherwise, grass and browse constitute the

[14]See https://www.dasnamibia.org/pilot-on-fsc-certified-charcoal-production-in-communal-areas-kicks-off/ [last consulted on 13 July 2021].

[15]Normally, people prefer to consume goat meat and reserve the bovines (and the sheep) for selling due to their higher monetary value (Katjiua and Ward 2007).

main foodstuff for cattle[16]. My informants agreed that, when cooked, the yellow-fatted meat also tastes better, and 'it does not need any spices, not even salt', as 72-year-old Cornelia Tjaapo, one farmer, assured. The meat with white fat, in contrast, she added, is less tasty and drier after cooking.

Cattle behaviour

Noticeable changes in cattle behaviour are also used to make deductions about the current state of the grazing. For instance, if grazing is abundant (e.g. shortly after the rainy season), cattle will be easily sighted not far from the homesteads and be obviously content, *okutuka ovindondooro* (jumping happily), as my informants said. Also, when the animals come to the kraal after drinking water, they will be noticeably calm, resting on the ground, and ruminating peacefully before leaving for the veld to graze again. By contrast, if the areas where the animals feed are almost depleted, they may stay away for two (and in extreme cases three) days deep in the veld looking for food before returning to the communal water point. They will also be restless when arriving in the kraal (not lying down, but standing) and then not take the usual direction to graze (therefore remaining depleted) after leaving the enclosure. If there is absolutely nothing to eat in the veld, my interlocutors coincided in stating that cattle might not even try to walk away, but will stay and spend the night close to the homestead expecting fodder from their caretakers. If these circumstances prevail even after the rains arrive, then it means the veld is losing fodder productivity and close to crossing the DTP.

Cattle dung and milk

Observable variations in the dung's texture and colour can also reveal the grazing conditions. If the dung is hard, dark, and excreted in the form of pellets, for instance, it means that the grass is dry and that the cattle are lacking green forage. Yet, if the dung is excreted in a more liquid form and noticeably green, the animals are eating fresh grass, meaning that the field is in good condition. Milk production can also be affected by the state of the rangeland: if the cow's yield is low and its udder is small, it means that the animals are not finding enough fodder. But if the opposite applies, then it means that the animal is finding sufficient feed. In this connection, one informant, 45-year-old Matja Tjihenuna from Ovitatu, assured me that if the animals are consuming fresh fodder, the milk might even show a greenish tint; yet no one else corroborated this statement. Otherwise, all agreed that the milk's taste is unaffected by the veld's condition.

[16]Supplements are given to the animals from time to time to compensate for the lack of phosphate in the soil and to reduce their weight loss during the dry seasons.

Cheetah attacks

Livestock depredation constitutes one of the most important causes of livestock loss in the eastern communal areas, followed by drought and livestock theft (Verschueren et al. 2020). In the four fieldwork sites, cheetahs and jackals were reported to be the main culprits for killing livestock. The time and place of cheetah attacks were often connected with the veld's state. Whilst jackals are known to be audacious hunters, killing farmers' animals (especially small goats and chickens) at any time, cheetahs are known to be shy and usually stay far away from homesteads. However, if cheetahs are sighted close to the villages and dare to enter peoples' kraals—which often results in the injury or destruction of several goats or single calves—it is a sign that the veld has seriously deteriorated.

In the interviews, it was emphasized that if there is forage scarcity in the veld (e.g. during extended droughts), the cheetahs' favourite prey (warthog, steenbok, kudus' calves) might migrate or even starve. Therefore, incidents with cheetahs increase at such times because they have no choice but to venture into settlements and attack domestic stock to survive (see Marker-Kraus et al. 1996). This suggests that worsening rangeland conditions have reached a much larger spatial scale and that farmers may, therefore, lose livestock due to imminent DTP and predator attacks occurring simultaneously. This practice-based knowledge is reflected in the observation of Muntifering et al. (2006), namely, that bush encroachment is contributing to an increase in human-carnivore conflicts with changing vegetation likewise affecting the availability of prey. Still, if there are no cheetahs at all, then it points to the possibility of wider ecological destruction.

Antelopes and ostriches at the roadside

Not only are certain antelopes present in the area, such as kudu (*Tragelaphus strepsiceros*; otj. *ohorongo*), duiker (Cephalophinae; otj. *ombambi*), steenbuck (*Raphicerus campestris*; otj. *ombwindja*), but also ostriches (*Struthio camelus australis*; otj. sing. *ombo*). When these creatures are seen beside the main roads, people say they are indicators of veld deterioration. Normally, these animals are infrequently sighted because 'they do not like humans, they prefer to live deep in the veld', as 57-year-old Ngeriuo Kamuingona from Ozongarangombe says. But, according to my informants, if the veld has badly deteriorated, they approach the roads' margins seeking nourishment despite the traffic disturbance. These areas are less intensively grazed and browsed by livestock, so antelope and ostrich visit to feed if the veld is elsewhere depleted/consumed—and probably close to a DTP. These accounts resonate with studies on the distribution of wildlife roadkills in southern Africa which show that

accidents occur more often during the dry seasons because animals experience food scarcity and engage in more exploratory wanderings to acquire adequate food (e.g. Njovu et al. 2019). If these animals are not sighted either close to the roads or deep in the veld, it means that they have probably migrated (or starved) due to the worsening veld conditions.

Rain

Rainfall, or its absence, is a crucial factor influencing rangeland productivity, including DTP. Consequently, signs of good/bad rain can be helpful in predicting forthcoming veld conditions. In the areas covered by this study, one empirical way of forecasting rain is by observing and feeling the direction of the winds. According to my sources, if a chilly wind consistently blows in the mornings from west to east, especially from the hot December month onwards, then it is highly probable that heavy rains will follow in the afternoons. If this pattern manifests consistently, rains might fall up until March–April. Damara communities in northwestern Namibia also recognize and use this wind behaviour as a rain forecast, and it is highly compatible with scientific meteorological predictions (Schnegg 2019). Conversely, if this pattern does not prevail, that is, if winds blow from north to south or vice versa, then the rains might not come. In fact, before the 2019 drought, my informants assured me that the wind was blowing softly, or from different directions, before the rains failed.

Another means to anticipate rain involves observing celestial objects, like the moon (*omueze*). If the crescent moon is shaped like an 'n', it is believed that it pours rain, but if it is 'u' shaped, it holds the rain, my informants explained. Also, when the Pleiades star constellation (*otjose*) arises in September, it signals the start of the spring (*okuni*) and, thus, of the rainy season—an observation also made by Hirschberg (1929) almost 90 years ago. Andean farmers predict that rainfall will be insufficient if this constellation is dim (Orlove et al. 2000), but this idea was not corroborated in the study area. Likewise, if bats (sing. *ondiri*) and/or dragonflies (sing. *oruheranyungu*) are sighted, they are perceived as harbingers of good rainfall. In fact, bats are more active during wet seasons (Laverty et al. 2021), and some dragonfly species migrate with the air masses that bring the rains (Suhling and Martens 2007). People also mentioned the *omumbonde* (*Acacia giraffae*) tree: reportedly, this is one of the first trees to sprout at the end of the dry period, but if this growth is late, rains are expected to be delayed or not arrive at all.

To summarize, apart from identifying specific changes in the veld's vegetation, experienced farmers use complementary ways to know and anticipate (further) rangeland degradation, including DTP. These include empirical weather forecasting methods and detecting a broad range of circumstantial indicators—signs which either imply, or result from, ongoing degradation processes in the veld. In so doing, farmers infer current and near-future rangeland conditions by piecing together different kinds of information perceived both amongst their livestock and within the broader farming environment. These ways of knowing and predicting DTP are primarily experiential and reflect how informants had acquired considerable skills through years of learning and practising livestock farming in their localities (cf. Ingold 2002). But what measures are taken by communal farmers to manage and prevent these critical thresholds?

Managing DTPs in practice

To organize the use of pastures in all four settlements, each livestock owner drives her/his cattle behind the homestead to graze. During good rainy periods, cattle might find fodder closer to the settlement, but as these sources are consumed throughout the dry season, the animals move gradually into the orbits of the villages to find enough fodder. In so doing, they must still walk back to the communal borehole to access water, an activity which considerably increases their energy cost and increases the pressure on grazing areas closer to water points. This is a typical rangeland utilization pattern amongst large communities in the region (cf. Stahl 2009).

In this situation, changing the animals' grazing direction is pointless, as 60-year-old Eva Uahupirapi from Ozongarangombe explained to me[17]. Every year towards the end of the dry season, Eva's cattle noticeably lose weight, so she knows that she should direct her animals elsewhere to feed and allow the exhausted pastures to rest. Nonetheless, 'if I stop sending my cattle behind my homestead, my neighbour's animals would occupy and use those pastures anyways', she said. Once they are in the veld, her animals do not have a delimited area of their own; they inevitably share the open rangeland with the herds of at least five other neighbouring homesteads. Eva said her animals would not have anywhere else to go anyhow because 'the settlement is 'full' (*yeura*), and everybody's animals are grazing everywhere', she complained—circumstances familiar to the rest of my informants. To address the problem, people concentrated on keeping their animals healthy (e.g. giving them vitamins and keeping them free of parasites), so they would remain strong and able to walk far away to find fodder.

In such a setting, managing DTP at the household level is nearly impossible; it becomes a common pool resource management problem (Ostrom 1990; McCabe

[17]Eva was the head of the household I lived in during my fieldwork and one of my key informants.

1990). For this reason, institutions and practices aimed at preventing (further) rangeland degradation in the area operate at the communal level. Regarding this issue, I identified three (partly overlapping) sets of self-governance tactics: one aimed to regulate group and resource boundaries, one to keep and prioritize the use of the land for grazing, and one to allow the pastures around the settlements to rest. The residents of all four villages implemented the first two sets of measures, but the third set was only implemented in Ozongarangombe and Omblooronde in addition to the other two.

Regulations for group and resource boundaries comprised (i) proscribing livestock owners from elsewhere from settling permanently on-site and (ii) restricting the temporal use of local pastures to visitors. The first rule was introduced in the early 2000s in all four settlements and is still in force. The residents complied back then based on the shared perception that their villages were getting 'full', meaning that grazing resources would be inadequate for their children to farm in the future. When visitors want to access local pastures temporarily, they need to ask for permission from the local residents who make a decision depending on the state of the grazing. Moreover, visitors have to pay higher water fees than local residents, a condition aimed at discouraging external users from staying too long in the settlement. Furthermore, over time, all four villages have constructed border fences to avoid their cattle wandering in specific directions and/or to prevent animals from adjacent communities from trespassing onto their grazing lands. However, none of the four case study sites is fully fenced, and large stretches of these inter-settlement boundaries are practically open and unprotected. If cattle from elsewhere are detected crossing these borders, residents try to drive them back the way they came.

The rules aiming to safeguard communal land for grazing comprised (i) preventing new homesteads from being constructed in the village's grazing zone (i.e. behind existing homesteads) and (ii) restricting the size of each homestead's 'camp' (*okamba*); each side must be no longer than 1 km[18]. The first rule was introduced in all four sites around the 2000s; it affects those farmers trying to establish their own households apart from the main homestead. If they wish to do this, they must consult all their neighbours to ascertain whether the site for construction is suitable. The second rule was introduced across all four places much earlier, during the 1970s, when camps were first being constructed (Werner 2009). Those planning to build a new camp are required to negotiate with their co-villagers and ensure that its size conforms to the regulation.

The third type of measures, namely those aimed at allowing pastures around the settlements to rest, is linked to the existence of a cattle post. These rules are only applied in Ozongarangombe and Omblooronde because cattle posts are in place (between 7 and 8 km away from the respective village centres). Ovitatu's and Ohamuheke's residents, in contrast, do not have their own cattle post and depend on other communities to access pastures when the local grazing conditions become acutely depleted. Therefore, it is much more difficult for these communities to effectively reduce the pressure on their grazing lands during the dry seasons, and especially during the extended periods of drought.

The decision to 'open' (*okupaturuka*) the cattle posts is taken collectively amongst all heads of household in the village. The most important criteria for this action are the body conditions of the cattle herds and the state of surrounding pastures. Of all the signs presented in the previous section, these two carry the greatest weight because of their immediate implications: if the animals are thin and without enough fodder, they bring less income, produce less milk, and are prone to get sick or die, thus jeopardizing livelihoods. People usually abstain from taking immediate action when, based on the signs, an extended dry season or limited to no rainfall is anticipated. This is for two reasons: first, they know from lived experience that there is always a margin of chance that the weather might take a different and hopefully better turn; and second, because moving the livestock to the cattle post or buying fodder too hastily can be costly and risky and potentially waste precious resources in a context of scarcity[19]. Therefore, if residents share the perception that their animals are getting too thin and that the veld is nearly depleted, the cattle post will be opened for access.

Once they agree to open the cattle post, residents will decide how many people and livestock from neighbouring villages will be allowed temporary access to these areas (hence regulating group and resource boundaries here as well). The response to neighbouring villagers' requests will depend on the current state of pastures around the cattle post area. When allowed access, these

[18]These are fenced-off pieces of land built behind each homestead to keep the old, sick, weak, and pregnant cattle more easily under guard; to keep the bull separate from other peoples' herds; and to protect livestock from being stolen (Stahl 2009).

[19]Eva, for example, takes care of three of her grandchildren, a 4-year-old toddler and two boys attending primary school in Okahitwa and Okakarara, respectively, both coming every weekend to Ozongarangombe. Three of her adult children occasionally work in the urban centres, and one daughter is completing her technical studies in Okakarara. Therefore, there are not many persons at home to take and oversee her cattle at the post. Moreover, reaching the cattle post is only possible with the donkey-cart which implies leaving the main house and setting up a camp in the veld (i.e. sleep in a tent or an improvised shelter) for weeks. Throughout this period, food supplies need to be organized and transported there as well.

external users must also pay higher monetary contributions to buying diesel and operating the water pump at the cattle post. If they fail to do so, their access to the surrounding rangeland is denied. Eventually, the water pumps are removed, usually when the next rains come, to ensure that no livestock owner uses or stays in these reserved areas without permission, thus preventing their overuse and keeping the DTP at bay.

Discussion and conclusion

The information presented so far shows that experienced farmers possess vast anticipatory knowledge concerning rangeland degradation, including DTP. However, in the context of the research location, individual actions aimed at preventing these phenomena are restricted by the local structures and rules of communal farming. Hence, precautionary measures can only be, and are de facto, taken at the community level. Such measures comprise self-governing institutions to regulate group and resource boundaries, to reserve land for grazing and allow pastures to rest. The latter ones are, or rather can only be, practised if cattle post infrastructures are in place. Other kinds of grazing preservation institutions and practices have not been recorded elsewhere in the region (cf. Mendelsohn and Obeid 2002; Stahl 2009) excepting the community fences in the Aminuis area (Twyman et al. 2001).

If these knowledges and measures have effectively helped avoid DTP at a large scale in the Ovaherero communities I describe, they raise issues that require further research. However, farmers' experiences and my own observations following the 2019 drought might provide some valuable insights. This drought was regarded as the worst for 90 years (Shikangalah 2020), and at least 100,000 head of livestock died country-wide, a figure corresponding to 50% of Namibia's livestock[20]. My informants described the veld as being completely depleted (*okuti kwakururuka*), and no one could move their cattle elsewhere. These circumstances also applied to the people from Ozongarangombe, since the settlement's cattle post was badly affected. In Ombooronde's case, residents could not even access their cattle post due to a problem with the underground borehole. Eventually, most people had to feed their animals in their kraals with fodder bought in shops, which for many was not always possible due to money shortages. Only a few wealthy households could pay for transporting their animals to distant places less affected by the dryness, including commercial farms where they paid a monthly grazing fee per animal, yet, even these people were not spared from losing numerous cattle[21].

Against this background, not only my informants but many other local people had little doubt that many types of grass would never grow back after almost 3 years of drought. No rigorous botanical data assessments of the rangeland conditions before and after the dryness in the settlements exist. However, according to many farmers' perceptions (and surprise), the grazing recovered remarkably well after the good rains between January and March 2020. Based on farmers' rainfall measurements (usually taken with rain gauges), Ovitatu, Ombooronde, and Ozongarangombe received 350 to 380 mm rain, whereas Ohamuheke had almost 450 mm. In all four cases, this exceeded the region's maximum average. Does this mean that communal farmers are managing DTP reasonably well despite the challenges of communal farming? Or are good rainfalls alone sufficient for rangeland recovery and preventing DTP in the region?

Whilst climate variability can be a robust factor linked to desertification (Oba et al. 2001:99, Geist 2005), conceptual models emphasize the intricate interactions between biophysical and socio-economic processes (Reynolds and Mark Stafford-Smith 2002; D'Odorico et al. 2013). On this basis, it cannot be ruled out that local institutions and practices have helped prevent large-scale DTPs despite extreme weather events and the challenges of communal farming. On the other hand, it could also be argued that the rangeland system in the study area is operating according to the non-equilibrium persistent model (e.g. Briske et al. 2020; von Wehrden et al. 2021). This model posits that in regions where annual rainfall is very variable, the herbivore populations (wild and livestock) tend not to grow large enough to cause significant damage to the rangeland vegetation outside certain areas of high impact (e.g. settlements and water sources). In addition, many rangeland grass species are adapted to occasional grazing and to periodic dryness (Müller 2007). These two facts together may help to explain the rapid recovery of grasses following the 2019 drought.

In any case, considering the imminent threats of abrupt and irreversible changes in the earth's climate system (Lenton et al. 2020), higher temperatures and the probability of more regular extreme droughts in this semi-desertic environment might eventually overpower the rangeland's resilience capacities and farmers' already limited agency to cope with these events. In this connection, the Namibian government has made significant steps towards climate change mitigation and adaptation through policies and action plans (Republic of Namibia

[20]'Drought continues livestock carnage', newspaper article in The Namibian published on the 8th of January 2020.

[21]More systematic data collected on people's cattle losses and coping strategies in the studied communities is still being processed. However, some people, like Eva, lost almost the half of her cattle herd (20 animals).

2011; Republic of Namibia 2013). These include identifying and supporting suitable and sustainable land-use practices, including early warning systems (Republic of Namibia 2013). To this end, I hope that this paper's anthropological contribution helps to inform newly emerging strategies and, crucially, that the hitherto underregarded experiences and knowledges Ovaherero communal farmers' revealed during my fieldwork will be considered during ongoing processes of monitoring ecosystems and making structural changes. The local firsthand knowledges documented in this paper may contribute valuably to enabling the prevention of a regional social-ecological collapse in the future.

Acknowledgements
I thank the communities of Ovitatu, Ombooronde, Ozongarangombe, and Ohamuheke for allowing me to conduct fieldwork in their localities. Special gratitude goes to those who provided me with information for this article in particular: Uahungira Tjipe, Vehonga Kahuure, Collin Mbaha, Ngeriuo Kamuingona, Eva Uahupirapi, Veronika Kasetura, Cornelia Tjaapo, Paulus Murumbua, Matja Tjihenuna, Godlob Kamuserandu, Erenst and Operi Kazenaimue, Kaire Katire, Gustaf Veuserua, and Erastus Tjivau. I thank Kapesuva Rutjani for his translation work, Kim Crowder for adjusting my English, Michael Bollig for his guidance, and Elsemi Olwage for her support. The comments of three anonymous reviewers on an earlier version of this text helped enormously to improve the manuscript. To them I am very grateful as well.

Author's contributions
DAMS collected and analysed the data for this study. He was solely responsible for the conceptualization and writing of the original draft. The author read and approved the final manuscript.

Funding
This research was conducted under the NamTip project: Understanding and Managing Desertification Tipping Points in Dryland Social-Ecological Systems – A Namibian Perspective, sponsored by the German Federal Ministry of Education and Research (FKZ: 01LC1821 A-E). Open Access funding enabled and organized by Projekt DEAL.

Availability of data and materials
Most of the data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
The National Commission on Research, Science, and Technology in Namibia approved the research for this paper (Permit Number RPIV00892019). Permission for conducting the study in Ovitatu, Ombooronde, Ozongarangombe, and Ohamuheke was provided to the author in oral form by the respective community councillors (*ozorata*) in consultation with local residents. The study participants took part in the data collection by choice and consented to be mentioned by their names in this publication.

Consent for publication
See above.

Competing interests
The author declares that he has no competing interests.

Received: 21 September 2021 Accepted: 3 January 2022
Published online: 28 January 2022

References

Baer, Hans A., and Merrill Singer, eds. 2018. *The anthropology of climate change*. London: Routledge. https://doi.org/10.4324/9781351273121.

Bestelmeyer, Brandon T., Andrew Ash, Joel R. Brown, Bulgamaa Densambuu, María Fernández-Giménez, Jamin Johanson, Metthew Levi, Dardo Lopez, Raul Peinetti, Libby Rumpff, and Patrick Shaver. 2017. State and transition models: Theory, application, and challenges. In *Rangeland systems: Processes, management and challenges*, ed. David D. Briske, 303–346. Cham: Springer; https://doi.org/10.1007/978-3-319-46709-2_9.

Bestelmeyer, Brandon T., Gregory S. Okin, Michael C. Duniway, Steven R. Archer, Nathan F. Sayre, Jebediah C. Williamson, and Jeffrey E. Herrick. 2015. Desertification, land use, and the transformation of global drylands. *Frontiers in Ecology and the Environment* 13 (1): 28–36. https://doi.org/10.1890/140162.

Bollig, Michael, and Jan-Bart Gewald. 2009. People, cattle and land - Transformations of a pastoral society. In *People, cattle and land: Transformations of a pastoral society in Southwestern Africa*, ed. Michael Bollig and Jan-Bart Gewald, 3–52. Köln: Rüdiger Köppe.

Briske, David D., ed. 2017. *Rangeland systems: Processes, management and challenges*. Cham: Springer. https://doi.org/10.1007/978-3-319-46709-2.

Briske, David D., Layne D. Coppock, Andrew W. Illius, and Samuel D. Fuhlendorf. 2020. Strategies for global rangeland stewardship: Assessment through the lens of the equilibrium–non-equilibrium debate. *Journal of Applied Ecology* 57 (6): 1056–1067. https://doi.org/10.1111/1365-2664.13610.

Castillo, Lucía, César Mario Rostagno, and Ana Ladio. 2020. Ethnoindicators of environmental change: Local knowledge used for rangeland management among smallholders of Patagonia. *Rangeland Ecology & Management* 73 (5): 594–606. https://doi.org/10.1016/j.rama.2020.06.001.

Crandall, David P. 1996. Female over male or left over right: Solving a classificatory puzzle among the Ovahimba. *Africa: Journal of the International African Institute* 66 (3): 327–348. https://doi.org/10.2307/1160956.

Crate, Susan A., and Mark Nuttal, eds. 2009. *Anthropology and climate change: From encounters to actions*. London: Routledge.

D'Odorico, Paolo, Abinash Bhattachan, Kyle F. Davis, Sujith Ravi, and Christiane W. Runyan. 2013. Global desertification: Drivers and feedbacks. *Advances in Water Resources* 51: 326–344. https://doi.org/10.1016/j.advwatres.2012.01.013.

Dakos, V., and A. Hastings. 2013. Editorial: Special issue on regime shifts and tipping points in ecology. *Theoretical Ecology* 6 (3): 253–254. https://doi.org/10.1007/s12080-013-0197-1.

Davis, Anthony, and John R. Wagner. 2003. Who knows? On the importance of identifying "experts" when researching local ecological knowledge. *Human Ecology* 31 (3): 463–489. https://doi.org/10.1023/A:1025075923297.

De Klerk, J.N. 2004. *Bush encroachment in Namibia*. In *Report on phase 1 of the bush encroachment research, monitoring and management project*. Windhoek: Ministry of Environment and Tourism.

Dunne, P.G., F.J. Monahan, F.P. O'Mara, and A.P. Moloney. 2009. Colour of bovine subcutaneous adipose tissue: A review of contributory factors, associations with carcass and meat quality and its potential utility in authentication of dietary history. *Meat Sci* 81 (1): 28–45. https://doi.org/10.1016/j.meatsci.2008.06.013.

Falkenmark, Malin, Lan Wang-Erlandsson, and Johan Rockström. 2019. Understanding of water resilience in the Anthropocene. *Journal of Hydrology X* 2: 100009. https://doi.org/10.1016/j.hydroa.2018.100009.

Geist, H. 2005. *The causes and progression of desertification*. Aldershot: Ashgate.

Hengari, Simeon. 2018. *Final report: Land degradation neutrality pilot project. A project of the Ministry of Environment and Tourism supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)*. Windhoek: Ministry of Environment and Tourism.

Hirschberg, Walter. 1929. Die Plejaden in Afrika und ihre Beziehung zum Bodenbau. *Zeitschrift für Ethnologie* 61 (4/6): 321–337.

Ingold, Tim. 2002. *The perception of the environment: Essays on livelihood, dwelling and skill*. London: Routledge. https://doi.org/10.4324/9780203466025.

Janssen, Marco A., Timothy A. Kohler, and Marten Scheffer. 2003. Sunk-cost effects and vulnerability to collapse in ancient societies. *Current Anthropology* 44 (5): 722–728. https://doi.org/10.1086/379261.

Kakujaha-Matundu, Omu. 2003. *Common pool resource management: The case of the eastern communal rangelands in semi-arid Namibia*. Maastricht: Shaker Pub.

Katjiua, M., and D. Ward. 2007. Pastoralists' perceptions and realities of vegetation change and browse consumption in the northern Kalahari, Namibia. *Journal of Arid Environments* 69 (4): 716–730. https://doi.org/10.1016/j.jaridenv.2006.11.010.

Katjiua, M.L.J., and D. Ward. 2006. Cattle diet selection during the hot-dry season in a semi-arid region of Namibia. *African Journal of Range & Forage Science* 23 (1): 59–67. https://doi.org/10.2989/10220110609485887.

Kavari, Jekura U. 2001. Social organisation, religion and cosmos of the Ovaherero. *Journal of Religion and Theology in Namibia* 3 (1): 116–160. https://doi.org/10.10520/AJA0000013_10.

Laverty, Theresa M., Tara L. Teel, A. Archie Gawusab, and Joel Berger. 2021. Listening to bats: Namibian pastoralists' perspectives, stories, and experiences. *Journal of Ethnobiology* 41 (1): 70–86. https://doi.org/10.2993/0278-0771-41.1.70.

Lenton, T.M., J. Rockström, O. Gaffney, S. Rahmstorf, K. Richardson, W. Steffen, and H.J. Schellnhuber. 2020. Climate tipping points - Too risky to bet against. *Nature* 575: 592-595.

Lenton, Timothy M. 2011. Early warning of climate tipping points. *Nature Climate Change* 1 (4): 201–209. https://doi.org/10.1038/nclimate1143.

Lenton, Timothy M. 2013. Environmental tipping points. *Annual Review of Environment and Resources* 38 (1): 1–29. https://doi.org/10.1146/annurev-environ-102511-084654.

Lenton, Timothy M., and Juan-Carlos Ciscar. 2013. Integrating tipping points into climate impact assessments. *Climatic Change* 117 (3): 585–597. https://doi.org/10.1007/s10584-012-0572-8.

Lenton, Timothy M., Hermann Held, Elmar Kriegler, Jim W. Hall, Wolfgang Lucht, Stefan Rahmstorf, and Hans Joachim Schellnhuber. 2008. Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences* 105 (6): 1786–1793. https://doi.org/10.1073/pnas.0705414105.

Lenton, Timothy M., and Hywel T.P. Williams. 2013. On the origin of planetary-scale tipping points. *Trends in Ecology & Evolution* 28 (7): 380–382. https://doi.org/10.1016/j.tree.2013.06.001.

Lindholm, Karl-Johan. 2006. *Wells of experience: A pastoral land-use history of Omaheke, Namibia*. Sweden: Studies in Global Archeology 9. Department of Archeology and Ancient History. Uppsala University.

Marker-Kraus, L., D. Kraus, D. Barnett, and S. Hurlbut. 1996. *Cheetah survival on Namibian farmlands*. Windhoek: Cheetah Conservation Fund.

McCabe, Terrence. 1990. Turkana pastoralism: A case against the tragedy of the commons. *Human Ecology* 18:81-103. https://doi.org/10.1007/BF00889073.

Mendelsohn, J., and S.E. Obeid. 2002. *The communal lands in Eastern Namibia*. Windhoek: RAISON.

Menestrey Schwieger, Diego Augusto, and Meed Mbidzo. 2020. Socio-historical and structural factors linked to land degradation and desertification in Namibia's former Herero 'homelands'. *Journal of Arid Environments* 178: 104151. https://doi.org/10.1016/j.jaridenv.2020.104151.

Milkoreit, Manjana, Jennifer Hodbod, Jacopo Baggio, Karina Benessaiah, Rafael Calderon Contreras, Jonathon F. Donges, Jean-Denis Mathias, Juan Carlos Rocha, Michael Schoon, and Saskia Werners. 2018. Defining tipping points for social-ecological systems scholarship—An interdisciplinary literature review. *Environmental Research Letters* 13: 1–12. https://doi.org/10.1088/1748-9326/aaaa75.

Moore, John C. 2018. Predicting tipping points in complex environmental systems. *Proceedings of the National Academy of Sciences* 115 (4): 635–636. https://doi.org/10.1073/pnas.1721206115.

Müller, M.A.N. 2007. *Grasses of Namibia*. Windhoek: Ministry of Agriculture, Water, and Forestry.

Muntifering, J.R., A.J. Dickman, L.M. Perlow, T. Hruska, P.G. Ryan, L.L. Marker, and R. M. Jeo. 2006. Managing the matrix for large carnivores: A novel approach and perspective from cheetah (Acinonyx jubatus) habitat suitability modelling. *Animal Conservation* 9 (1): 103–112. https://doi.org/10.1111/j.1469-1795.2005.00008.x.

Njovu, Henry Kenneth, Alex W. Kisingo, Thomas Hesselberg, and Abraham Eustace. 2019. The spatial and temporal distribution of mammal roadkills in the Kwakuchinja Wildlife Corridor in Tanzania. *African Journal of Ecology* 57 (3): 423–428. https://doi.org/10.1111/aje.12608.

Nuttall, Mark. 2012. Tipping points and the human world: Living with change and thinking about the future. *AMBIO* 41 (1): 96–105. https://doi.org/10.1007/s13280-011-0228-3.

Oba, Gufu, Eric Post, and Nils C. Stenseth. 2001. Sub-Saharan desertification and productivity are linked to hemispheric climate variability. *Global Change Biology* 7 (3): 241–246. https://doi.org/10.1046/j.1365-2486.2001.00405.x.

O'Riordan, Timothy, and Timothy Lenton. 2013. *Addressing tipping points for a precarious future*. Oxford: Oxford University Press. https://doi.org/10.5871/bacad/9780197265536.001.0001.

Orlove, Benjamin S., John C.H. Chiang, and Mark A. Cane. 2000. Forecasting Andean rainfall and crop yield from the influence of El Niño on Pleiades visibility. *Nature* 403 (6765): 68–71. https://doi.org/10.1038/47456.

Orr, Yancey, J. Stephen Lansing, and Michael R. Dove. 2015. Environmental anthropology: Systemic perspectives. *Annual Review of Anthropology* 44 (1): 153–168. https://doi.org/10.1146/annurev-anthro-102214-014159.

Ostrom, Elinor. 1990. *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511807763.

Renaud, Fabrice G., James P.M. Syvitski, Zita Sebesvari, Saskia E. Werners, Hartwig Kremer, Claudia Kuenzer, Ad Ramachandran Ramesh, and Jeuken, and Jana Friedrich. 2013. Tipping from the Holocene to the Anthropocene: How threatened are major world deltas? *Current Opinion in Environmental Sustainability* 5 (6): 644–654. https://doi.org/10.1016/j.cosust.2013.11.007.

Republic of Namibia. 2011. *National policy on climate change*. Windhoek: Ministry of Environment and Tourism.

Republic of Namibia. 2013. *National climate change strategy & action plan 2013-2020*. Windhoek: Ministry of Environment & Tourism.

Republic of Namibia. 2014. *Otjozondjupa 2011 census regional profile*. Windhoek: Namibia Statistics Agency.

Reynolds, James F., Fernando T. Maestre, Paul R. Kemp, D. Mark Stafford-Smith, and Eric Lambin. 2007. Natural and human dimensions of land degradation in drylands: Causes and consequences. In *Terrestrial ecosystems in a changing world*, ed. Josep G. Canadell, Diane E. Pataki, and Louis F. Pitelka, 247–257. Berlin, Heidelberg: Springer Berlin Heidelberg.

Reynolds, James F., and D. Mark Stafford-Smith. 2002. Do humans cause deserts? In *Global desertification: Do humans cause deserts?* ed. James F. Reynolds and D. Mark Stafford-Smith, 1–22. Berlin: Dahlem University Press.

Russill, Chris, and Zoe Nyssa. 2009. The tipping point trend in climate change communication. *Global Environmental Change* 19 (3): 336–344. https://doi.org/10.1016/j.gloenvcha.2009.04.001.

Scheffer, Marten, Jordi Bascompte, William A. Brock, Victor Brovkin, Stephen R. Carpenter, Vasilis Dakos, Hermann Held, Egbert H. van Nes, Max Rietkerk, and George Sugihara. 2009. Early-warning signals for critical transitions. *Nature* 461 (7260): 53–59. https://doi.org/10.1038/nature08227.

Scheffer, Marten, and Stephen R. Carpenter. 2003. Catastrophic regime shifts in ecosystems: Linking theory to observation. *Trends in Ecology and Evolution* 18 (12): 648–656. https://doi.org/10.1016/j.tree.2003.09.002.

Schnegg, Michael. 2019. The life of winds: Knowing the Namibian weather from someplace and from noplace. *American Anthropologist* 121(4):830–844. https://doi.org/10.1111/aman.13274.

Scoones, Ian. 1989. *Economic and ecological carrying capacity implications for livestock development in the dryland communal areas of Zimbabwe. ODI Pastoral Development Network paper 27b*.

Serrao-Neumann, Silvia, Julie L. Davidson, Claudia L. Baldwin, Aysin Dedekorkut-Howes, Joanna C. Ellison, Neil J. Holbrook, Michael Howes, Christine Jacobson, and Edward A. Morgan. 2016. Marine governance to avoid tipping points: Can we adapt the adaptability envelope? *Marine Policy* 65: 56–67. https://doi.org/10.1016/j.marpol.2015.12.007.

Shikangalah, Rosemary. 2020. The 2019 drought in Namibia: An overview. *Journal of Namibian Studies* 27: 37–58 Retrieved from https://namibian-studies.com/index.php/JNS/article/view/8635.

Stahl, Ute. 2009. At the end of the day we will fight: Communal land rights and 'illegal fencing' in the Otjozondjupa region. In *People, cattle and land: Transformations of a pastoral society in Southwestern Africa*, ed. Michael Bollig and Jan-Bart Gewald, 319–346. Köln Rüdiger Köppe Verlag.

Strohbach, Ben J. 2014. Vegetation of the eastern communal conservancies in Namibia: I. Phytosociological descriptions. *Koedoe* 56 (1): 1–18. https://doi.org/10.4102/koedoe.v56i1.1116.

Strohbach, Ben J., Marianne Strohbach, Josaphat T. Kutuahuripa, and Heiner D. Mouton. 2004. A reconnaissance survey of the landscapes, soils and vegetation of the eastern communal areas (Otjiozondjupa and Omaheke Regions), Namibia. In *Unpublished report for the Desert Research Foundation of Namibia and the Desert Margins Programme*. Windhoek: National Botanical Research Institute.

Suhling, Frank, and Andreas Martens. 2007. *Dragonflies and damselflies of Namibia*. Windhoek: Gamsberg Macmillan.

Thomas, David S.G., Melanie Knight, and Giles F.S. Wiggs. 2005. Remobilization of southern African desert dune systems by twenty-first century global warming. *Nature* 435 (7046): 1218–1221. https://doi.org/10.1038/nature03717.

Twyman, Chasca, Andrew Dougill, Deborah Sporton, and David Thomas. 2001. Community fencing in open rangelands: Self-empowerment in Eastern Namibia. *Review of African Political Economy* 28 (87): 9–26. https://doi.org/10.1080/03056240108704500.

van der Hel, Sandra, Iina Hellsten, and Gerard Steen. 2018. Tipping points and climate change: Metaphor between science and the media. *Environmental Communication* 12 (5): 605–620. https://doi.org/10.1080/17524032.2017.1410198.
Verschueren, Stijn, Willem D. Briers-Louw, Carolina Torres-Uribe, Annetjie Siyaya, and Laurie Marker. 2020. Assessing human conflicts with carnivores in Namibia's eastern communal conservancies. *Human Dimensions of Wildlife* 25 (5): 452–467. https://doi.org/10.1080/10871209.2020.1758253.
von Wehrden, Henrik, Jan Hanspach, Petra Kaczensky, Joern Fischer, and Karsten Wesche. 2021. Global assessment of the non-equilibrium concept in rangelands. *Ecological Applications* 22 (2): 393–399. https://doi.org/10.1890/11-0802.1.
Werner, Wolfgang. 2009. From communal pastures to enclosures: The development of land tenure in Herero reserves. In *People, cattle and land: Transformations of a pastoral society in Southwestern Africa*, ed. Michael Bollig and Jan-Bart Gewald, 247–268. Köln: Rüdiger Köppe Verlag.

Publisher's Note