Transhumant pastoralism in a changing world

Nedup Dorji

2020

Transhumant pastoralism in a changing world:

challenges and opportunities to sustainable yak farming in Bhutan

Nedup Dorji

Propositions

1. To sustain yak farming, stimulating the interest and motivation of successors is more important than supporting current herders.
   (this thesis)

2. Socioeconomic developments are the biggest threat to yak faming in Bhutan.
   (this thesis)

3. Venturing into social research as an animal scientist is like riding a bicycle for the first time in a crowd.

4. As long as scientific publications are the holy grail, the societal impact is minimal.

5. Increasing the quantity of students decreases the quality of education.

6. The quality of an animal production system should be expressed in gross animal happiness.

Propositions belonging to the thesis, entitled

'Transhumant pastoralism in a changing world: challenges and opportunities to sustainable yak farming in Bhutan.'

Nedup Dorji

Wageningen, 21 October 2020

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Thesis

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Abstract

In the high altitude of Bhutan, yak farming is the main livelihood of transhumant pastoralists. However, yak farming is under pressures because of external factors such as socioeconomic developments, policies and climate change. Little is known about the impact of these factors on yak farming, and what policies and interventions might be required to sustain yak farming. Therefore, the aim of this thesis was to assess the impact of external factors and management on yak farming in Bhutan, with a focus on past developments, the current situation (including the health and welfare of yaks) and future perspectives in yak farming. Overall, increasing yak predation by predators, decreasing forage availability in the rangelands, and decreasing number of successors are the major threats to yak farming, while the market to sell yak products is the least threat. The factors causing forage shortage are specific to certain regions, e.g. competition with the horse population (west), cordyceps collection (central and west) and prohibited burning of shrubs around rangelands (east and central). In three regions (east, central, west,) the health and welfare of yaks was assessed using an adapted welfare protocol. In the visited yak herds, clinical issues, such as dirty body areas, integumentary lesions, ocular and nasal discharge, sings of diarrhoea, lameness and subclinical mastitis were virtually absent. A few instances of agonistic behaviour and flehming behaviour were observed. Yaks in the central and western regions exhibited more scratching and rubbing behaviour than did those in the eastern region, which may be associated with limited treatments against ectoparasites. Moreover, the traditional bull castration without use of analgesics was identified as a prominent welfare issues that calls for attention. Aside from several potential risk factors, the health and welfare status of yaks living in various regions of Bhutan was assessed as good at the time of visit. Although concerns around yak farming have increased over the years due to external factors, most herders (82%) wish their children to continue yak farming in the future. Nonetheless, over half of the herders (58%) and most livestock professionals (96%) think that the number of yak farming families will decline in the future. To get insight into how different stakeholders perceive the challenges and opportunities related to yak farming, six focus group interviews were organised with different stakeholders (herders and representatives of governmental bodies). Most problems and solutions identified in the focus group interviews differed between, and sometimes within, the stakeholder groups. There is a need for a multi-stakeholder dialogue aiming to discuss problems and solutions together with different stakeholders. The government should streamline socioeconomic development by supporting and improving basic facilities in yak farming villages (e.g. better access to communication, animal health services), pay attention to human-wildlife conflicts and forage shortage, and explore sustainable income based on yak farming (e.g. payment for ecosystem services, tourism associations, providing better market opportunities).

Contents

Chapter 1

General introduction

1. Mountain pastoralists

High altitude areas of the Himalayas have one of the harshest climatic conditions in the world, yet humans, mainly transhumance pastoralists, also have capitalised the available natural resources there. Pastoral transhumance communities are defined as families remaining in a permanent settlement growing crops and raising animals, while herders migrate with their livestock during part of the year (Allen et al., 2011). Transhumance pastoralists are recognised to play a role in contributing to the mountain landscape and ecosystem (McVeigh, 2004, Bhasin, 2011, Jurt et al., 2015). Mountain ecosystems offer various benefits for humans such as food, water, air, fuel and cultural identity (FAO, 2011, Oteros-Rozas et al., 2014). In the Himalayas, the highland pastoralists have a livestock-dependent economy of keeping yaks, cattle, cattle-yak hybrids, equine, sheep and goats that graze on rangelands.

Bhutan, a country in the Himalayas covering altitudes from 150 up to 7570 meter above sea level (masl), has both cattle-based and yak-based transhumant communities. The cattle-based communities practice seasonal migration of cattle herds between subtropical (500 masl) and subalpine rangelands (around 4000 masl) (Namgay et al., 2014), whereas the yak-based communities practice seasonal migration of yak herds between temperate (2500 masl) and alpine rangelands (5000 masl) (Ura, 2002). Traditional routes and patterns are followed for this migration (Wangdi, 2016). For both systems, the main reason to migrate to lower altitudes are the harsh climatic conditions and forage shortage in the winter season (Acharya et al., 2014, Dong et al., 2016, Wu et al., 2016).

Although cattle- and yak-based communities are important, yak-based communities own very little agricultural land to grow crops and they have limited livelihood options besides their yaks. Yaks therefore play a crucial role in these communities (Gyamtsho, 2000, Wiener et al., 2003, Wu et al., 2016). They provide food, fuel, fibre, draft power, and products to sell. Herders in Bhutan mainly process the yak milk manually to butter and cheese (Gyamtsho, 2000). Although officially not allowed in this Buddhist country, some adult yaks are slaughtered every year before the onset of winter when the animals are in the best body condition, and the meat is also sold (Wiener et al., 2003). Yak hair is harvested between April and June during the time of moulting (Wiener, 2013, Mizuno and Tenpa, 2015), and is used for making garments and blankets, tents, bags and ropes (Wiener et al., 2003, Joshi et al., 2020). In some regions yak dung is collected and used as fuel where there are no trees (Rhode et al., 2007, Wiener, 2013). Animal skins (hides) are used to make leather objects (e.g. mats, bags, saddle strap). Also in other countries yaks are kept for economic reasons.

In China, milk is the most important product, while in Mongolia it is their meat (Wiener et al., 2003).

Besides economic importance, yaks also are interwoven in the socio-cultural traditions and rituals of yak-based communities. In Bhutan, a special mask dance, called yak *chham* is performed to honour *Theopa Gali*, the man who is said to have discovered a yak (Dompnier, 2007). In Tibet, the two popular deities *Yama*, the god of death, and *Yamantaka*, the slayer of the god of death have similar yak-headed forms (Olsen, 1990) and yaks are given as a dowry when a woman marries a herder (Wiener et al., 2003). In the Mustang district of Nepal yak blood is fed to sick and weak people because it is believed to have medicinal properties (Wiener et al., 2003, Acharya et al., 2014). In general it can be said that yak-based communities have a unique culture and together with the mountainous landscape in which yaks are kept they are potentially attractive for tourists from all over the world. In Bhutan however, tourism is restricted and as it is only allowed to stay in the country for one to two weeks against a fee. Together with the remoteness and poor road conditions, it discourages tourists from travelling to these communities (Suntikul and Dorji, 2016).

2. Yaks and their distribution in Bhutan

Yaks (*Poephagus grunniens* or *Bos grunniens*; Linnaeus, 1766) are thought to be domesticated from the wild yak (*Bos mutus*; Przewalski, 1883) by ancient Qiang people of Tibet (Wiener et al., 2003). Domestic yaks are home to the highlands of central Asia, i.e. in China, Mongolia, Nepal, Bhutan, India, Pakistan, Afghanistan, Kyrgyzstan, Russia, and Tajikistan (Wiener et al., 2003, Wu et al., 2016, Joshi et al., 2020). Later, yaks were introduced to European, North American and other Asian countries (Wiener et al., 2003).

Yak is the only bovine species that is suitably adapted anatomically and physiologically to survive in a cold, harsh mountainous environment. They are found between annual ambient temperatures of −40 to +13 °C (Wiener et al., 2003). The adaptive features of yak include: i) a few functional sweat glands, accumulated subcutaneous fat prior to winter, wool with a thick long outer coat and fine and dense undercoat in order to survive the cold environment and minimize heat dissipation (Wiener et al., 2003); ii) larger chest capacity, bigger heart, larger lung surface area, larger trachea and lower haemoglobin counts but higher affinity as compared to cattle for the presence of low atmospheric oxygen at higher altitude (Wiener et al., 2003); iii) a broad mouth, a broad and blunt cutinized tongue, and flat incisors allow this animal to graze a wide variety of plant species. They graze like cattle on long grasses and like sheep on short grasses up to 2–3 cm (Leslie and Schaller, 2009).

Yaks are found in 10 northern districts of Bhutan (Gyamtsho, 2000, DoL, 2013, Phuntsho and Dorji, 2016) (Figure 1), and can be differentiated genetically into a western-central and an eastern population (Dorji et al., 2002). Yak-based communities in the western districts practice pure line breeding. In these districts the yak population often suffers from inbreeding because a single breeding bull is used for many years (Wiener et al., 2003, Acharya et al., 2014). Besides pure yak breeding, hybridization of yak with local cattle is practiced in the eastern districts. These cattle-yak hybrids are superior in milk production compared to pure bred yaks and in adaptation to harsh conditions compared to cattle (Mizuno and Tenpa, 2015, Paudel and Parajuli, 2016). Cattle-yak hybrids can take advantage of rangelands at high altitude inhospitable to cattle and at the same time migrate at lower altitude where yaks cannot survive (Wangchuk, 2011). Hybridization, however, is only useful for one generation due to fertility problems in hybrid males (Wiener et al., 2003). Hence, herders of the eastern region have to keep purebred yaks as well.

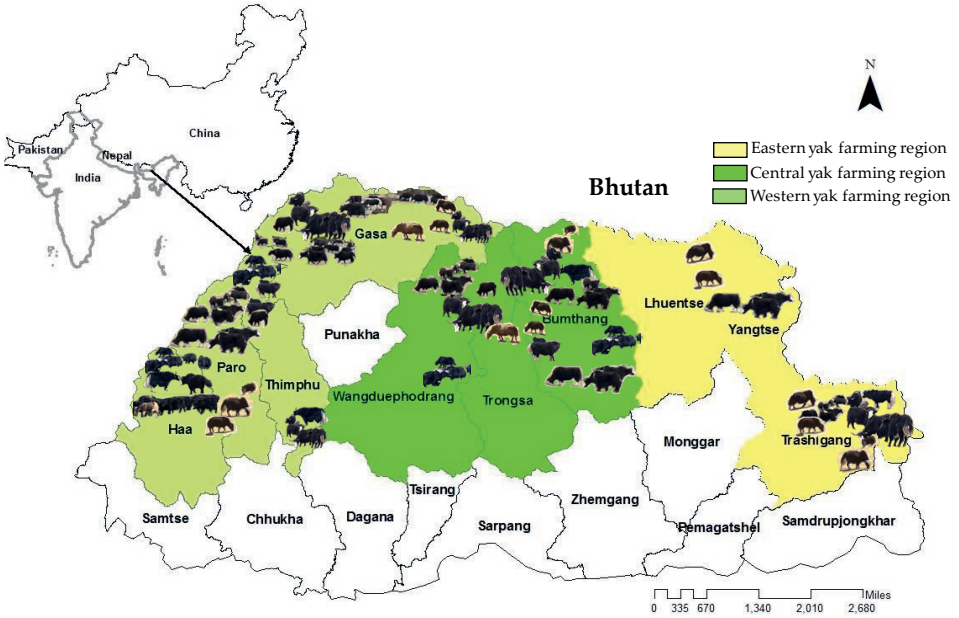

Figure 1. Map of Bhutan with its districts and the identification of yak farming districts (shaded colour) and distribution of yaks.

Yaks are fertile around 3 years of age. Bulls reach their mating peak around 6 years of age (Gyamtsho, 2000, Wiener et al., 2003, Paudel and Parajuli, 2016). Cows produce usually one calf every two years (Wiener et al., 2003). The gestation period ranges from 240–270 days (Gyamtsho, 2000, Wiener et al., 2003). The majority of calving occur from May to July (Degen et al., 2007,

Paudel and Parajuli, 2016, Wangdi and Wangchuk, 2018). Generally, herders start milking the cows 10–30 days after calving (Wiener et al., 2003) depending on health and body condition of calf and cow.

In Bhutan yak cows are generally milked manually one to two times per day and the average milk yield is approximately 1 kg per day (Wangdi and Wangchuk, 2018). Milk yield depends on factors such as forage quality and milking frequency (Dong et al., 2007a).

3. Yak-based transhumant communities under pressure

Although yak based communities have a long history, recently there are several external factors these communities have to deal with, of which the most important ones are socioeconomic developments, policy, and climate change. Socioeconomic development has prompted changes in the yak-based communities. With the introduction of modern education systems, most children are sent to school in order to improve the living standards of the community. As an unforeseen consequence, many young and literate pastoralists prefer to leave their villages and move to towns where they hope to achieve an easier and better life (Wangdi, 2016). On top of that, young adults, especially men, prefer to be involved in tourism or collect invaluable fungi called cordyceps (*Cordyceps sinensis*) in the mountains and trade the harvest with mainly China (Derville and Bonnemaire, 2010, Wangdi, 2016) instead of herding yaks. These socioeconomic developments put pressure on labour availability, e.g. for yak herding or for production and selling of yak products, which in itself might affect viability of the yak-based communities. Although outmigration and a lower interest in yak farming is assumed to have an impact on the yak-based communities, its effect has not been studied yet. Yak farming, in this thesis is referred as all activities related to herding, processing milk to butter and cheese, selling of yak products, making hay, shearing animals, and feeding.

A second pressure for the livelihoods of the yak-based communities are the strict environmental and conservation policies in place. The *Forest and Nature Conservation Act* 1995 of Bhutan, for example, declare that all forests including rangelands are "Government Reserved Forest", and prohibits the traditional method (burning) of rejuvenating the rangelands and clearing shrubs around the rangelands to control shrub proliferation (Phuntsho and Dorji, 2016). The increased shrub coverage has receded available rangeland and as a consequence reduced forage availability for yaks. Furthermore, most of the highland rangelands located in subalpine and alpine zones are declared protected areas (wildlife sanctuaries and national parks). The protected areas are home to wild endangered predators such as tiger (*Panthera tigris*), snow leopard (*Panthera uncia*), Asiatic wild

dog (*Cuon alpinus*), and Himalayan black bear (*Ursus thibetanus*), and also wild herbivores such as Himalayan blue sheep (*Pseudois nayaur*), Himalayan musk deer (*Moschus chrysogaster leucogaster*) and takin (*Budorcas taxicolor*). Consequently, yaks are lost to predators leading to human-wildlife conflicts. Herders try sometimes to prevent predation by either tethering young yaks near settlements or construct night shelters for young yaks (Wangchuk et al., 2013a), but herds are also often left alone for a while and therefore becoming more prone to be predated. Hence, the policies and regulations seem to impact the yak-based communities, but a clear view on the effects are lacking so far.

A third major pressure on yak-based communities is the effect of global warming. In the eastern Himalayas, a rapid rise in surface temperature has been found, which is more than the global average increase of 0.74 °C over the last century (1906–2005) (IPPC, 2007). Shrestha and Aryal (2011) even predict that the average temperature will rise with 3.5–4 °C in Nepal. This increase in temperature will probably also happen in neighbouring countries such as Bhutan and the northern parts of India, and will have a prominent effect on the fragile mountain ecosystem (IPPC, 2007). The grasses on the rangeland are temperature-sensitive (Klein et al., 2007, Haynes et al., 2014). Global warming therefore reduces grass diversity and can have an effect on forage availability at high altitudes as observed on the Tibetan plateau (Klein et al., 2007), while new ecosystems with woody plant species will establish in rangelands, which may be a threat to the present ecosystems (Archer et al., 2001, Archer et al., 2017). A positive effect of global warming might be that snow disappears sooner in spring and more forage will be available for yaks and other herbivores. A direct negative effect is that due to high temperatures and less precipitation, the shrub litter decomposition rate decreases that will affect nutrient cycling in rangelands (Bernard et al., 2019, Steinwandter et al., 2019). Another negative effect is that due to higher temperatures cyanobacterial bloom can occur in water reservoirs, as for example observed in Lake Taihu, China (Ma et al., 2016). Also in Bhutan, yaks were poisoned due to intake of such contaminated water by cyanobacteria algae (Phuntsho and Dorji, 2016). To our knowledge, limited information is available on the exact effects of global warming on yak farming practices.

4. External and management factors affecting yak health and welfare

In the previous paragraph mentioned external factors do not only impact yak-based communities, but may also impair the health and welfare of yaks (Figure 2). Indirect effects of the socioeconomic development and legislation are, for example, labour and forage shortage. Less labour force means less people to take care of the yaks and proliferation of shrubs and competition with wild herbivores and horses used for cordyceps collection means less feed for the yaks. Furthermore,

yaks are adapted to low temperatures and the increase of ambient temperature due to global warming might urge herder to move up higher in the mountains and leave the lower areas. Moreover, forage scarcity especially in winter and early spring may result in loose of body weight and even lead to mortality. Herders do not keep records of morbidity and mortality rates of their herd, but death rates are generally high especially among young stock during winter (Gyamtsho, 2000). Although herders are very experienced and probably know their animals as the best, they are not trained other than following traditions and their own and ancestors experiences. This all might often be effective, but not always the best way to ensure a good health and welfare of the animals. For example, shelter is only occasionally provided and then only to young animals, preparing hay as a winter feed is done only in some yak farming regions (central and west), sharp pins stitched through the nose are used to wean calves, and bulls are castrated at a late age without anaesthesia (Gyamtsho, 2000). Skills and knowledge on restraining and handling animals for milking and other actions are essential factors which may influence the welfare of animals (Waiblinger et al., 2006). Furthermore, a lack of proper veterinary and health services due to remoteness, makes that diseases are mainly treated in traditional ways using indigenous knowledge and ethno-veterinary medicines (Derville and Bonnemaire, 2010, Dhendup, 2015). However, parasite-related diseases, such as, for example, gid (*Coenurus multiceps multiceps*) infestations are common. Gid is a parasitic disease that infects yaks below three years of age and may result in death. Furthermore, ticks, fleas, lice and mites infestations can contribute to mortality in early spring when yaks are in poor health condition (Gyamtsho, 2000).

This highlights that all kind of external and management factors have an impact on the health and welfare of yaks. Yet, no information is available on the current status of the health and welfare of yaks under existing management practices (Figure 2). Although yak health and welfare might not be the first thing yak herders might think of, knowing the underlying issues that impair health and welfare will give benefit to the yak-based communities. Therefore, obtaining this knowledge would provide a first step to examine potential relationships between external and management factors and health and welfare of yaks in order to be able to improve the living conditions of yaks in a changing environment.

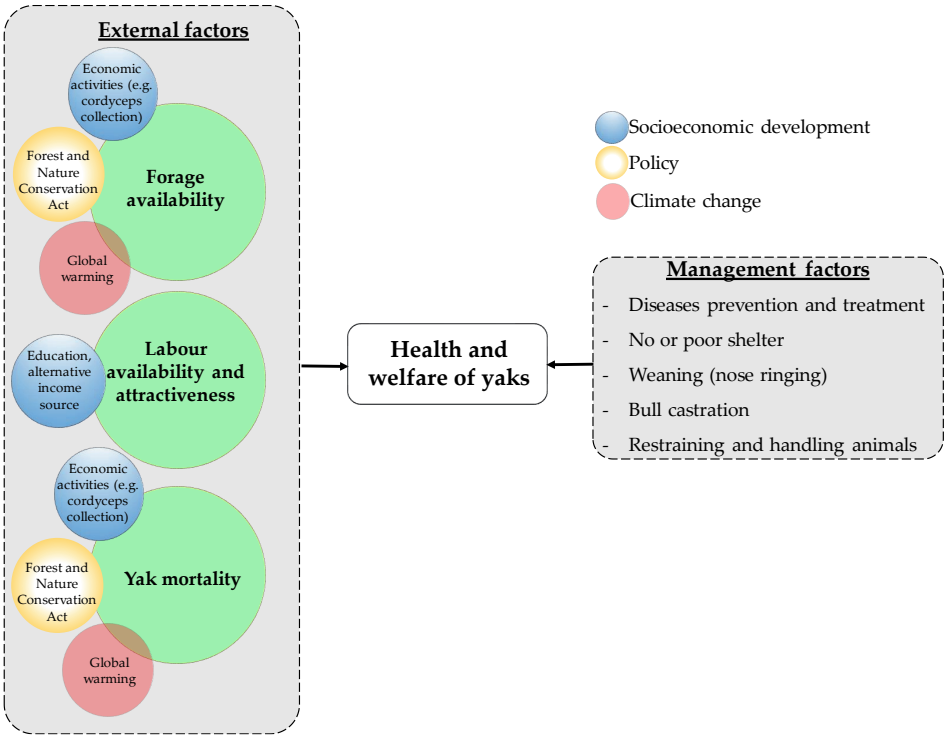

Figure 2. Overview of the potential external factors (left side; related to socioeconomic development, policy and climate change) and management factors (right side) associated with health and welfare of yaks.

5. Aim and structure of thesis

The future of yak farming in Bhutan is unsure or even at risk because of external factors such as socioeconomic development, environmental and conservation policy, and climate change. However, the impact of these external factors on the yaks and yak-based communities are largely unknown. Therefore, the aim of this thesis was to assess the impact of external factors and management on yak farming in Bhutan, with a focus on past developments, the current situation (including the health and welfare of yaks) and future perspectives in yak farming (also see Figure 3 below).

It is hypothesised that the decision of transhumant families to continue yak farming is associated with livelihood options, which differ from one region to another. These livelihood options are expected to be influenced by socioeconomic development, policy and climate change affecting local conditions. It is also hypothesised that due to cultural and local environmental differences, perceived level of concerns of factors related to yak farming will differ. In addition, the exact health

and welfare conditions of yaks is unknown and is presumably at risk due to external and management factors. Since the perceptions, opinions, traditions and beliefs of herders on how to manage yaks may vary, it is hypothesised that health and welfare of yaks will be different in different yak farming regions. To this end the current situation and developments in yak farming over the last 10 years as perceived by the herders and the current health and welfare situation of the yaks were assessed in three different yak farming regions of Bhutan (Chapter 2 and 3). Subsequently, Chapter 4 focused to identify factors that determine the future prospects of yak farming in Bhutan. Having gathered in-depth information on important factors that influenced yak farming practices, in Chapter 5 the most important factors and challenges (or issues) for future sustainable yak farming in Bhutan were identified and prioritised by different stakeholders.

In Chapter 6, the findings of four chapters are brought together where the main constrains to yak farming as experienced by yak herders and other stakeholders, and strategies to support yak farming in Bhutan are discussed.

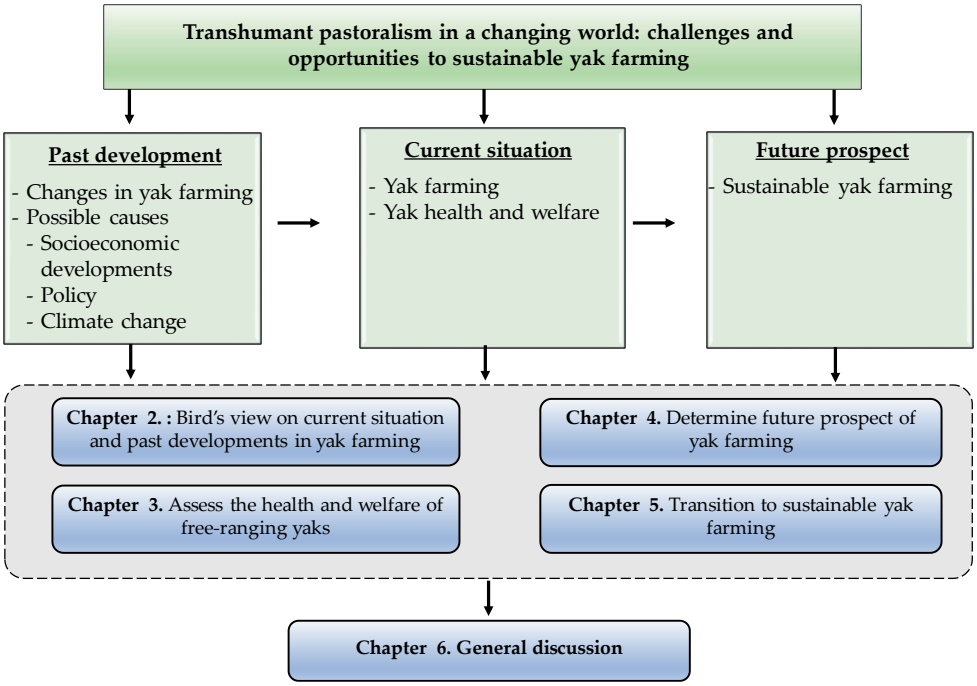

Figure 3. Working scheme of the research process used to conduct this thesis.

Chapter 2

Herders and livestock professionals' experiences and perceptions on developments and challenges in yak farming in Bhutan

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Abstract

The yak-based transhumant system is influenced by socioeconomic developments, regulations and environmental changes. Little is known about the impact of this on yak farming practices among different regions in Bhutan. The experienced changes in yak farming practices over the years and perceptions on developments were assessed through interviews with yak herders in three regions (west, n = 22; central, n = 20; east, n = 25) and with livestock extensionists (n = 28). At present, forage shortage in the rangeland, yak mortality mainly due to (endangered) wild predators and, to a lesser extent, labour availability are the main concerns in all yak farming regions. These concerns have increased due to socioeconomic developments (e.g. education and other sources of income) and strong conservation policy, which affects the living environment of the yaks. Overall, the market to sell yak products and livestock extension services has improved, but forage shortage and yak mortality has increased over the years. However, some factors causing forage shortage are more specific to certain regions, e.g. competition with the horse population (west), cattle and cattle–yak hybrids (east), cordyceps collection (west and central) and prohibited burning of rangelands (central and east). Family labour available to herd yaks has slightly decreased, and the number of young family members (successors) to take over yak farming has decreased over the years. On the basis of the experiences and perceptions of yak herders and extensionists, we conclude that increasing forage shortage in the rangelands, decreasing numbers of successors, and increasing yak predation by wild animals are the major threats to yak farming.

Keywords: yak-based communities; external forces; livelihoods; perception

1. Introduction

Highland pastoralists in the northern region of Bhutan highly depend on their yaks because these animals provide several products such as food and fur and are also used as pack animals. The arid and semiarid environment has one of the harshest climatic conditions, yet pastoralists have capitalised the available natural resources there. In Bhutan, yak-based communities are considered transhumant pastoralists because they practice seasonal migration between alpine and cool-temperate zones in response to forage availability (Gyamtsho, 2000), while the families remain in a permanent settlement (Allen et al., 2011). Yak-based communities are important for Bhutan because they preserve a rich culture and tradition, which is one of the four main pillars of the Bhutanese development philosophy. Yak-based systems have an effect on the landscape and ecosystem (McVeigh, 2004). For instance, grazing and trampling by animals control grass species diversity in the rangelands, while allowing young plants to grow and develop. Nevertheless, ~30 households leave yak farming every year (Phuntsho and Dorji, 2016).

Yak-based communities are affected by socioeconomic developments (e.g. access to education) and regulations (e.g. *Forest and Nature Conservation Act* 1995). Education results in literate youth who might view yak farming as an old-fashioned way of supporting livelihood, and they may seek better opportunities and scope in towns (Wangdi, 2016). Additionally, access to other livelihoods might strongly affect the interest in yak farming. For instance, both young and adults of many yak-based families of central and western regions collect cordyceps (*Cordyceps sinensis*, a mushroom for which medicinal effects are assumed and which is mainly sold to Chinese people) on the rangelands from May to July (Wangchuk and Wangdi, 2015). Both developments might lead to a labour shortage for herding yaks and selling yak products, which might affect viability of yak-based communities.

There are three important factors related to policy that are assumed to have influenced decisions of families to continue yak farming. The first is the *Forest Act* established in 1969, which prohibits the traditional method (burning) of rejuvenating rangelands and controlling shrub proliferation, thereby negatively affecting forage availability for the yak. Second, most rangelands at a high altitude are within protected areas (national parks and wildlife sanctuaries), which also are home to wild endangered and protected predators such as the tiger (*Panthera tigris*), snow leopard (*Panthera uncia*), bear (*Ursus thibetanus*) and Asiatic wild dog (*Cuon alpinus*), and may lead to increased yak predation and human–wildlife conflicts. Third, the *Land Act* established in 2007 states that the rangelands will be nationalised and leased back to yak herders and livestock farmers by 2017. This may have led or may lead to conflicts among different rangeland users (yak herders, horse farmers,

cattle farmers). To what extent these policies affect yak farming practices has never been studied from the perspective of herders and livestock professionals.

Since Bhutan is a mountainous country with large regional differences in the capacity to adapt to challenges, development might differ among regions. Regions in Bhutan have been, for a long time, isolated from each other due to the mountainous landscape, low population density and poor infrastructure (Derville and Bonnemaire, 2010), and also more recent developments differ among regions, such as establishment of farmer shops and dairy farmer groups in the central region. Therefore, the present study assesses the past experiences and current perceptions of yak herders and livestock professionals from different regions on challenges and developments in yak farming.

2. Materials and methods

2.1. Study sites

Bhutan has 10 districts where yak farming is operated (DoL, 2008). These districts can be stratified in a western, central and eastern regions. These three regions were chosen because they differ substantially in culture and traditions, which affect yak farming practices (Wangchuk et al., 2013a), specific types of yak products produced, the practice of cattle–yak hybridisation, source of income, and agricultural land (Derville and Bonnemaire, 2010). Within a district, a *geog* (block) functions as the local administrative unit and contains several villages.

For the present study, we selected one representative block per region. Laya (western region), Saephu (central region) and Merag (eastern region) are all located more than 3000 m above sea level and safely reachable within 1 day of traveling. Selected blocks were representative of each region, and certain characteristics were specific for each region. (i) In the western region, only purebred yaks are kept and milk is processed to butter and cheese (dried and fresh). Besides, family members are involved in cordyceps collection and tourism. They own small areas of land in the village and they cultivate buckwheat, barley, mustard and vegetables. (ii) In the central region, mainly purebred yaks and a few cattle–yak hybrids are kept and milk is processed to butter and cheese (dried and fresh). Family members are involved in cordyceps collection. They mainly grow potatoes and vegetables to sell. (iii) In the eastern region, approximately an equal number of purebred yaks and cattle–yak hybrids are kept, while milk is processed to butter and fermented cheese. Herders trade yak products with the local community as well as with people in Arunachal Pradesh, India. They are not involved in cordyceps collection. Generally, they do not grow crops. A detailed description of the differences among the regions is given by Derville and Bonnemaire (2010). In the results, regions are used instead of the name of yak farming blocks: western for Laya, central for Saephu, and eastern for Merag.

2.2. Data collection

Data were collected from herders by conducting face-to-face interviews, and from livestock professionals (local livestock extensionists, yak researchers) who were working with yak-based communities through face-to-face interviews and a self-administered computer questionnaire sent via email. The two data-collection methods were used for livestock professionals because the respondents were working in different areas, and they were not all accessible in person. Data from livestock professionals were collected to verify and supplement the information on the current situation of yak farming practices obtained through the interviews with the herders.

A verbal consent was obtained from the respondents to participate in the interview, and to audio-record the interview. The purpose of the study was briefly explained to the respondents and they were assured that the participation in the study was voluntary and their identity would be protected (Corti et al., 2000). For example, when a livestock extensionist and local health worker escorted the investigator to a yak campsite or house, the interview was conducted in a private setting to ensure a safe environment for interviewee and interviewer. All interviews were conducted in the Bhutanese national language (western and central regions) and the local dialect called *sharchopkha* (eastern region). Hence, the questions constructed in English were translated to the national language. Each translated question was verified by a qualified translator. Because the interviewer was a native speaker of the local dialect, the translated questions were used and, where needed, adapted to the local dialect to interview the herders in the eastern region.

The questionnaire was tested with three yak herders located in the Tsento block (which was not selected for the study) to check the level and length of questions and questionnaire. Similarly, two Bachelor of Science students studying Animal Science at the College of Natural Resources, who worked with yak-based communities, were used to test the questionnaire on livestock professionals. The questionnaire was revised and adapted after testing, and the final version was then used to interview the yak herders.

Interview of yak herders

A purposeful sampling method was used to identify and select yak herders for an interview. In the first meeting with the livestock extensionist and the local health worker, yak herders to be visited were identified on the basis of current proximity of the yak herds to the permanent village, and the number and location of the yaks. Sixty-seven yak herders (Laya, 22; Saephu, 20; Merag, 25) from

16 villages (Laya, 5; Saephu, 8; Merag, 3) were interviewed. The interview was constructed as a semi-structured questionnaire, and it consisted of the following four main topics:

- Basic respondent information (age, sex, education level, years of yak herding), and source of income and livelihood for current and past situations (based on the number of years of herding experience).
- Practices related to yak herd migration (start date of migration between the rangelands, migration route, which family member migrates with yak herds) for current and past situation.
- Current yak farming practices to sell yak products, market situation for yak products, labour situation, forage availability, yak mortality, and coping strategies to challenges.
- The opinion of yak herders on the level of changes experienced over the years on the market for selling yak products, labour availability, forage availability, mortality, access to veterinary and health services, and prevalence of diseases and parasites.

Interview of livestock professionals

Two local livestock extensionists from two regions were interviewed face to face during the visit. In addition, the questionnaire was sent to 26 other local livestock extensionists working with yak-based communities at present or who had worked until a maximum of 12 months ago, and to six yak researchers in Bhutan. Twenty-four livestock extensionists and two yak researchers returned the questionnaire. This semi-structured questionnaire included the following three sections:

- Respondent basic information (sex, education level, number of years working with yak-based communities).
- The opinion of livestock professionals on the current yak farming practices (market situation for yak products, labour situation, forage availability and yak mortality).
- The opinion of livestock professionals on the level of changes that yak herders might experience on the market situation for yak products, labour situation, forage availability and mortality, access to veterinary and health services, and prevalence of diseases and parasites.

Interview of non-yak farmers

Non-yak farmers (farmers who did not keep yaks) were interviewed face to face. A snowball method was used to reach the target farmers through a respondents' network (Heckathorn and Cameron, 2017) because there was no prior information on non-yak farmers. Twenty-six non-yak

farmers (Laya, 7; Merag, 10; Saephu, 9) from the same villages visited for yak herds were interviewed about previous involvement in yak farming and the reason for abandoning yak farming.

2.3. Data analyses

Data were entered into Excel and then analysed in R Studio (R Team Core, 2018). Two-sided Fisher exact tests were performed to check whether the current situation of livelihood, yak products for sale, yak product customers, and money spent from sale of yak products differed from those in the past. A Kruskal–Wallis test was performed to compare herd size and mortality among the regions.

Herder characteristics (age, gender, education, yak herd size and region) were treated as explanatory variables in a logistic regression. The education level was coded as 'attended school' and 'did not attend school'. A binomial logistic regression model was used to assess the association between the explanatory variables and the experience on the problem to sell yak products, labour shortage, forage shortage and yak mortality. A Hosmer-Lemeshow goodness-of-fit test was used to check whether the explanatory variables were correctly specified in the model by using the packages 'generalhoslem' in R. Also, the model accuracy was evaluated by calculating a confusion matrix. A Hosmer-Lemeshow test results ($P > 0.05$) and the confusion matrix (75%) indicated no evidence of poor model fit. Furthermore, Mann–Whitney U tests were performed to check whether the view of livestock professionals on the cause and developments in yak farming practices differed from the experience of yak herders.

3. Results

The results are presented as an overview of yak farming practices in Bhutan; however, distinctive features in different yak farming regions are also mentioned.

3.1. Respondent characteristics

Table 1 shows some basic characteristics of the respondents. The yak herders were mainly male in the eastern region, and female in the western and central regions. Most of them were illiterate and the average age (mean ± s.e.m.) of the herders was 39.7 ± 3.1 years for western, 41.9 ± 2.8 years for central and 49.1 ± 3.1 years for the eastern region. More than half of the herders had been herding yaks for more than 15 years. The average yak herd size was 49.8 ± 8.6 for western, 47.4 ± 4.7 for central and 54.6 ± 5.8 for the eastern region. The livestock professionals were mainly male, literate and had more than 6 years of working experience with yak-based communities.

Table 1. Respondent characteristics (%).

Characteristic	Yak herders			Livestock professionals (n = 28)
	Western (n = 22)	Central (n = 20)	Eastern (n = 25)	
Gender				
Male	34	40	76	85
Female	56	60	24	14
Education				
Illiterate	73	80	88	
Primary school	19	20	0	
Non-formal education	9	0	12	
Diploma				77
Undergraduate				15
Others				8
Yak herding experience				
≤5 years	14	20	12	41
6 to ≤10 years	18	0	0	37
11 to ≤15 years	9	25	12	7
≥16 years	59	55	76	15

3.2. Yak-based transhumant livelihoods

Yak-based communities depended on more than one source of livelihood (Table 2). In the western and central regions, yak farming has become less important for livelihood over the years, while cordyceps collection has become more important ($P < 0.05$). Tourism was also a source of livelihood in the western region.

Although there were different livelihoods, yak farming was the preferred choice of livelihood in all three regions. The herders indicated that yak farming was a reliable source of livelihood because yaks have multiple functions (provide food and fur, draft power, insurance, cultural identity) and yaks have been reared for centuries, while cordyceps collection is seen as unsustainable due to overexploitation of the resources. The preferred choice of livelihood for yak herders was not associated with the number of years of yak herding ($P > 0.05$). More than 25% of the herders in the western and central regions preferred cordyceps collection as their livelihood because it generated high revenues. Likewise, farming cattle–yak hybrids was the preferred livelihood source for a large group of herders in the eastern region, because these hybrids were more productive than were purebred yaks (Table 2).

Table 2. The most important source of livelihood at present and in the past years, and preferred choice of livelihood in three yak farming regions (%).

Livelihood activity	Western region (n = 22)		Central region (n = 20)		Eastern region (n = 25)	
	At present	Before	At present	Before	At present	Before
Main source of livelihood to your family						
Yak farming	26	86	19	81	68	50
Cordyceps	52	5	81	14	0	0
Cattle–yak hybrid farming	0	0	0	0	24	50
Other (horse, shop, sheep)	22	9	0	5	8	0
Preferred choice of livelihood						
Yak farming	65		71		54	
Cordyceps	26		29		0	
Cattle–yak hybrid farming	0		0		38	
Other (horse, shop)	9		0		8	
Reason for the preferred choice of livelihood						
Yak farming is reliable source of livelihood	52		60		47	
Yak farming is tradition and culture	13		15		7	
Yak farming is easy compared with cattle–yak hybrid farming	0		0		13	
Cordyceps fetch high income	26		30		0	
Cattle–yak hybrids fetch high income	0		0		38	
Other (easy work)	9		0		8	

3.3. Sales of yak products and market situation

Small-sized dry cheese (4 × 1.5 × 1 cm) was the most valuable yak product to sell in the western and in the central regions (Table 3), and this dry cheese had become more popular to sell than in the past. In contrast, meat used to be the most important product for sale in the past, but its popularity has declined over the years. Herders mentioned that the slaughtering of yaks began to decline ~10–15 years ago because of increasing religious sentiment among yak herders. When a herder slaughters a yak, a herder can experience societal pressure and is often stigmatised. Overall, the most important yak products produced to sell have changed over the years ($P < 0.05$). These changes in sales of yak products may be explained by a change of customers. In the past, more than half of the herders bartered their yak products with lowland farmers, while, nowadays, citizens in towns are also an important group of customers.

The money earned through selling yak products was said to be mainly spent on daily household requirements, investments in yak farming (purchase wheat or maize flour, oil, salt), purchase of clothes, and sending children to school (Table 4). Herders (east, 27%; central, 35%) answered that the money invested in yak farming had increased compared with the past, while, in the western region, the money invested had not changed. About 44% of the herders spent at least 40% of the total revenue from selling yaks and yak products in yak farming.

Table 3. The economic most important yak products at present and the past years in three regions (%).

Most important yak product to sell	Western region (n = 22)		Central region (n = 20)		Eastern region (n = 25)	
	At present	Before	At present	Before	At present	Before
Butter	21	25	28	23	34	40
Big-sized dry cheese	36	29	12	8	0	0
Small-sized dry cheese	39	14	52	23	0	0
Fermented cheese	0	0	0	0	58	50
Meat	4	32	8	46	0	5
Other (hair, sell live yaks)	0	0	0	0	8	5

Table 4. Customers of yak products and spending of money earned by yak products at present and the past years.

Parameter	At present (%)	Past years (%)	Fisher exact test
Most common customers for yak products			
Lowland farmers	44	72	$P < 0.05$
Citizens in towns	30	8	
Citizens of India	4	9	
Others (yak farmers, non-yak farmers)	22	11	
Most common usage for money earned from sales of yak products			
Daily household requirements	61	75	$P > 0.05$
Yak farming	32	23	
Purchasing clothes	1	2	
Education of children	6	0	

None of the age, gender, level of education, yak herd size or region was significantly related to the herder's experience regarding ease of selling yak products ($P > 0.05$). However, differences were observed in the herders' experience regarding ease of selling yak products and the regions ($P < 0.05$).

More than half of the herders interviewed (76%) responded that they were able to sell their yak products, which was confirmed by 68% of the livestock professionals ($P > 0.05$). However, some herders (west, 36%; central, 30%; east, 8%) indicated they had experienced problems mainly in selling yak butter, because of competition with butter from dairy cows and from cheap imported margarine from India. For example, the cheap margarine has replaced often the use of yak butter in making ritual cakes and burning butter lamps during religious festivals in the western and central region. Other reasons that were mentioned were the unhealthy image of yak butter and transport problems (poor road conditions, long distance). For these reasons, some herders of the central and western regions perceived that the market for selling yak products had deteriorated over the years. Those herders who were not able to sell their yak butter, often offered it to illuminate the butter lamps in the temples and monasteries.

3.4. Yak herd migration

Except for 12% of the herders in the eastern region that did not migrate, herders practiced moving from cool temperate (winter campsite) to subalpine and alpine zones (summer campsite) to take advantage of forage availability on the basis of seasons. Herders still followed the traditional migration routes.

Most of the herders (95%) began to migrate from summer to winter rangeland between August and October. Likewise, 80% of the herders migrated from winter to summer rangeland between April and May. In the eastern region, the start date of migration between rangelands has not changed from that in the past, whereas in the western (14%) and central (75%) regions, migration started earlier from winter to summer rangelands because of cordyceps collection. Herders indicated that yaks must compete with horses on the rangelands where cordyceps is collected. Similarly, herders of the western (9%) and central (20%) regions said that they migrated to winter rangeland earlier than they did in the past because of forage shortage (western and central region) and unpredictable weather (central region).

3.5. Labour situation

Difference in gender involvement with yak herding was observed in different regions. (i) In the eastern region, equal proportions of herders were male (48%) or partnerships between female and male (48%), and the rest were herded by more than two persons (4%). (ii) In the central region, about half of the herders were female (55%) or partnerships between female and male (40%), and the rest were herded by more than two persons (5%). (iii) In the western region, a high proportion of herders was female (77%), followed by partnerships between female and male (23%). Although most of the herders (west, 77%; central, 70%) said that two people were involved during herd migration, less than half of the herders mentioned that two people were involved in yak herding (west, 23%; central, 40%). When two people were involved with yak herding, they usually had defined roles and responsibilities. One person looked after the yak calves, performed milking, processed the milk to butter and cheese, and took care of shearing and household chores. The other person herded the yaks (drive and gather) and collected forage and firewood. When one person was herding yaks, a part-time herder also contributed to yak herding. A part-time herder returned to the village to attend meetings, looked after children and elderly people, brought food items to yak herds and collected the yak products.

There was no significant association between the profile characteristics of herders and the experienced labour shortage to herd yaks ($P > 0.05$). The herders (west, 77%; central, 55%; east, 76%) had the opinion that family labour was currently sufficient to maintain yak herding. In contrast, most livestock professionals (89%) believed that the yak farming families experience labour shortage to herd yaks ($P < 0.05$).

Herders who experienced labour shortage ($n = 20$) and livestock professionals ($n = 25$) agreed that the access to modern education accounted for labour shortage in yak herding to a large extent. Nowadays, most children of yak-based family were attending school, and the literate youth (even if unemployed) were often not willing to herd yaks. Seven herders and 23 livestock professionals expressed the view that young people leave and move to towns. Currently, six herders thought that they were relatively old (>65 years) which caused the labour shortage for herding yaks. Seven herders believed that the involvement of family members in cordyceps collection, tourism activities (west, 2) and diversification of livestock farming (east, 2) contributed to family labour shortages, which was in contrast with the view of livestock professionals (cordyceps collection, 16; tourism activities 15; diversification of livestock farming, 21). Moreover, some herders (west, 3; central, 4; east, 3) thought that the increased size of their own herd size caused labour shortage.

Herders who experienced labour shortage solved this problem by selling yaks, seeking assistance from relatives, or collaborating with neighbouring yak herders to combine their yaks (Figure 1). Some herders (west, 4; central, 1; east, 1) did not do anything in response to their labour shortage.

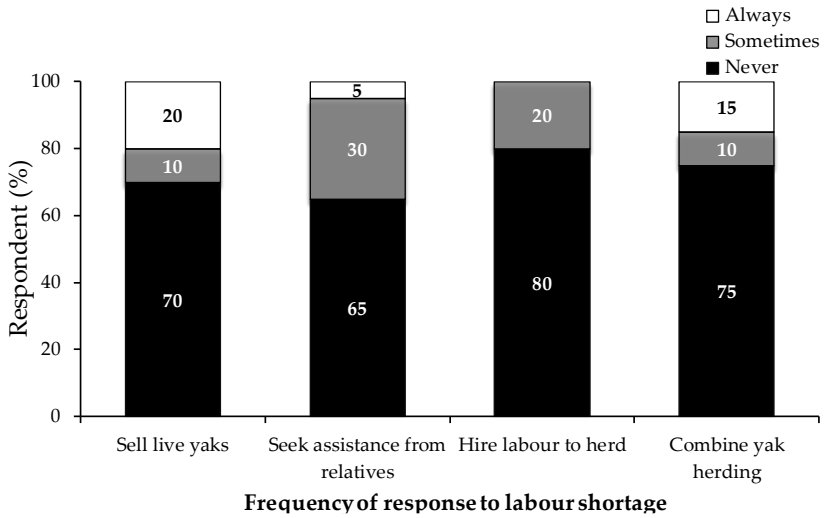

Figure 1. Response to labour shortage by yak herders who experience labour shortage (%).

3.6. Forage

Herders responded that they used to own rangeland (49%), and they used governmental and communal rangelands (24%), and rangelands owned by monastic bodies, cattle-yak hybrids farmers, or other yak farmers (27%). Those herders who used rangeland owned by others paid a fee either in cash or with yak products. Depending on the size and quality of the rangeland, herders of the western and central region paid-in-kind 15–60 kg butter per rangeland per year (representing a value of US$ 4.5–7.5 per kg butter; 1 US$ = Bhutanese Ngultrum 67) and in the eastern region they paid-in-kind 2–20 kg butter per rangeland per year to rangeland owners. The *Land Act* 2007 dissolved this system of rangeland arrangement as the rangeland was to be nationalised. However, the *Land Act* 2007 had not been implemented yet when the study areas were visited.

There was no significant association between herder characteristics and the experienced forage shortage, except for age ($\beta = -0.15$, $P = 0.03$, odd ratio = 0.86, 95% CI = 0.72–0.96). Currently, most herders (west, 91%; central, 100%; east, 88%) experienced forage shortage, which was confirmed by the view of 96% of the livestock professionals ($P > 0.05$). In general, both herders and livestock professionals believed that the prohibition of the traditional method of rejuvenating rangelands was the main cause for forage shortage (Table 5). Herders were aware that burning bushes and shrubs in the rangeland was prohibited. More than half of the respondents (herders and livestock professionals) believed that the increase in yak population in the community, and competition with cattle, cattle–yak hybrids and horses were contributors to the forage shortage in yak farming regions (Table 5).

Herders and livestock professionals disagreed on some aspects causing forage shortage (Table 5). Only a small part of the herders believed that an increase in family yak herd size, rangeland division among family members, less snow coverage on the rangeland and lease of rangeland attributed to forage shortage. In contrast, more than half of the livestock professionals thought that those factors (increased family yak herd size, less snow coverage on the rangeland, lease of rangeland) resulted in forage shortage. However, livestock professionals agreed with herders of a specific region (Appendix 1) that the rangeland division among the family members (east herders, 76%; livestock professionals, 63%) and less rain (west herder, 64%; livestock professionals, 63%) caused forage shortage. However, this traditional method of subdividing rangeland among the family members will be dissolved when the *Land Act* 2007 is implemented. In the western region, ~91% of the herders stated that the increasing horse population related to cordyceps collection and tourism had caused forage shortage. Also, some herders (west, 55%; central, 60%) considered that cordyceps collection contributed to areas of bare soil susceptible to erosion. In addition, ~40% (west) and

65% (central) of the herders believed that the increased wild herbivores (takin, *Budorcas taxicolor*; blue sheep, *Pseudois nayaur*) caused forage shortage. Equal proportions of the herders in the western region believed that less snow coverage (32%) and more snow coverage (32%) on the rangelands caused forage shortage. Those herders who viewed that less snow coverage on the rangeland caused forage shortage mentioned that grasses and forbes required melt water to grow.

Table 5. Yak herders' (n = 62) experience and livestock professionals' (n = 27) view on aspects affecting forage availability (see for details per region Appendix 1).

Respondent group	Level of effect on forage availability (%)					*P*-value
	Not at all	Small extent	Moderate extent	Large extent	Don't know	
Increase family yak herd size						
Yak herders	69	12	13	5	1	0.016
Livestock professionals	37	30	11	18	4	
Increase community yak herd size						
Yak herders	42	10	28	18	2	0.261
Livestock professionals	44	30	7	15	4	
Increase competition with cattle						
Yak herders	42	7	24	22	4	0.980
Livestock professionals	19	30	29	15	7	
Increase competition with horse						
Yak herders	42	22	12	24	0	0.219
Livestock professionals	22	19	32	22	4	
Rangeland division among family members						
Yak herders	60	6	3	30	1	0.378
Livestock professionals	22	26	26	11	15	
Cordyceps collection sites						
Yak herders	64	9	12	14	0	0.697
Livestock professionals	48	15	12	11	15	
Prohibited burning of the rangeland						
Yak herders	36	7	21	34	2	0.651
Livestock professionals	19	23	4	39	15	
Land Act 2007 (lease rangeland)						
Yak herders	64	1	3	13	18	0.022
Livestock professionals	37	26	19	7	11	
Less rainfall						
Yak herders [A]	48	22	16	1	9	0.001
Livestock professionals	30	33	8	22	7	
Soil erosion						
Yak herders	60	17	16	7	0	0.204
Livestock professionals	33	19	7	15	26	
Less snow coverage on the mountains [B]						
Yak herders	51	9	11	4	13	0.010
Livestock professionals	26	41	14	15	4	

[A]4% of the herders believed that heavy rainfall in summer caused forage shortage. [B]12% of the herders thought that more snow cover on the rangeland caused forage shortage. *P*-values are given (Mann–Whitney U test).

However, the largest contrasts across the regions were found in feeding cattle feed concentrate, supplementary forage, selling yaks, and constructing fences around the rangeland to keep other ruminants away (Figure 2). During forage shortage, more than half of the herders (west, 86%; central, 75%) provided cattle concentrate purchased from the towns, to their yaks. Herders of the western (55%) and central (45%) regions supplemented their yaks with improved mixed forage (mixture of cocksfoot, rye, and others), and herders also provided supplementary forage such as turnips, radish and others crops (west, 14%; central, 85%). In contrast, herders of the eastern region did not provide any supplementary feed and forage, but sold live yaks (56%) and made or maintained fences around the rangeland to keep other animals away (76%) as a response to forage shortage.

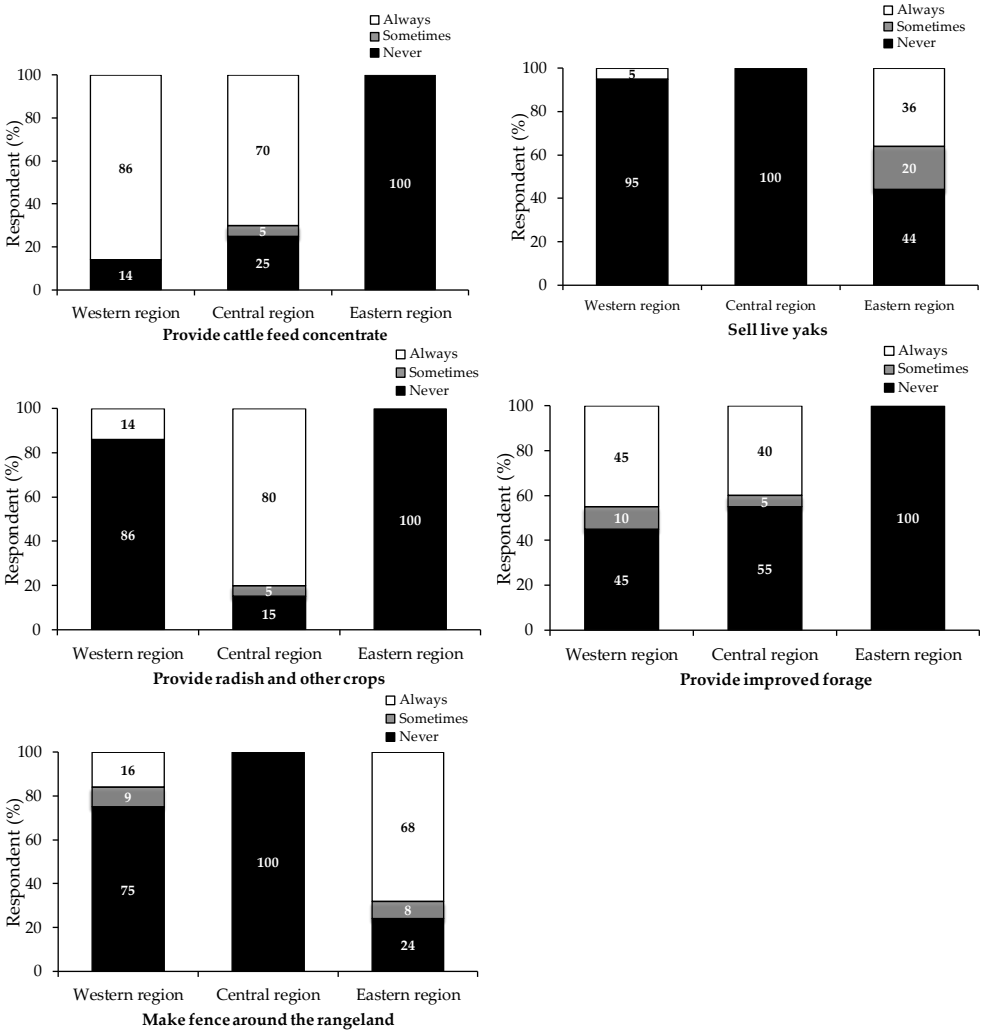

Figure 2. Measures against forage shortage by yak herders in different regions (%).

3.7. Yak mortality

Most of the herders (west, 96%; central, 95%; east, 84%) observed yak mortality from September 2016 to October 2017. Herders of the western region observed a higher average number of yak mortalities (15 ± 2 animals) than did herders of the central (11.6 ± 1.7 animals) and the eastern (5.1 ± 0.7 animals) regions ($P < 0.05$).

There was no association between characteristics of herders and the experienced yak mortality, except for herd size ($\beta = 0.15$, $P = 0.03$, odd ratio = 1.16, 95% CI = 1.05–1.39). For a unit increase in yak herd size, the probability of the yak herder to mention yak mortality as a problem increased by 1.16 times.

Table 6 presents the causes of yak mortality indicated by herders and livestock professionals. Herders (96%) and livestock professionals (96%) believed that wildlife predators attributed substantially to yak mortality ($P > 0.05$). In addition, both herders (67%) and livestock professionals (88%) mentioned accidents to be a cause of death among yaks. A high number of yak accidents seemed to occur during forage shortage when animals were walking towards high-risk areas to obtain forage. Only few herders believed that poisonous plants, contaminated drinking water, unavailability of veterinary care, absence of sheds for yaks, and cold and bad weather conditions were causes of yak mortality. In contrast, more than half of the livestock professionals thought that these factors did contribute to yak mortality. Regional differences on the yak mortality were found for gid (*Coenurus multiceps multiceps*) infestation (western region) and outbreak of diseases (eastern region).

Herders had limited strategies to cure sick yaks and to prevent them from getting sick (Figure 3). Most of the herders visited or contacted livestock extensionist to treat sick yaks in occasional or in the majority of cases. Furthermore, many herders sought advice from neighbouring yak herders to treat sick yaks. Herders in the western (91%) and central (70%) regions spent extra time to look after the sick yaks, whereas, in the eastern region, this was often not undertaken. In the western region, local practitioners (healers) also treated yaks that had, for example, fractured limbs and bones. In the western and central regions, local rituals for divine support were conducted, which, in most situations, was a scent offering. Vaccinations and annual local rituals were performed to prevent yaks from getting sick by at least 64% of the herders in all regions.

Table 6. Yak herders' (n = 62) experience and livestock professionals' (n = 25) view on aspects affecting yak mortality (see for details per region Appendix 2).

Respondent group	Level of effect on yak mortality (%)					*P*-value
	Not at all	Small extent	Moderate extent	Large extent	Don't know	
Lack of forage in rangelands						
Yak herders	50	18	17	14	1	0.023
Livestock professionals	28	16	24	32	0	
Water shortage						
Yak herders	79	11	6	3	1	0.093
Livestock professionals	56	4	20	12	8	
Outbreak of diseases						
Yak herders	53	20	11	12	4	0.238
Livestock professionals	32	24	16	12	16	
Gid infestation						
Yak herders	45	20	11	17	7	0.004
Livestock professionals	20	12	24	44	0	
Plant poisoning						
Yak herders	58	36	3	3	0	0.000
Livestock professionals	12	28	32	16	12	
Drinking contaminated water						
Yak herders	73	18	6	3	0	0.000
Livestock professionals	24	24	28	25	0	
Unavailability of veterinary care						
Yak herders	70	15	9	5	1	0.005
Livestock professionals	32	36	16	12	4	
Wildlife predators						
Yak herders	4	26	35	35	0	0.200
Livestock professionals	4	20	20	56	0	
Poor shed quality or absence of shed						
Yak herders	74	15	8	2	1	0.001
Livestock professionals	36	32	16	8	8	
Cold and bad weather conditions						
Yak herders	65	23	8	4	0	0.001
Livestock professionals	28	24	28	16	4	
Accidents with yaks						
Yak herders	32	46	15	6	1	0.508
Livestock professionals	12	76	4	8	0	
Heat stress						
Yak herders	100	0	0	0	0	0.000
Livestock professionals	52	20	20	0	8	

P-values are given (Mann–Whitney U test).

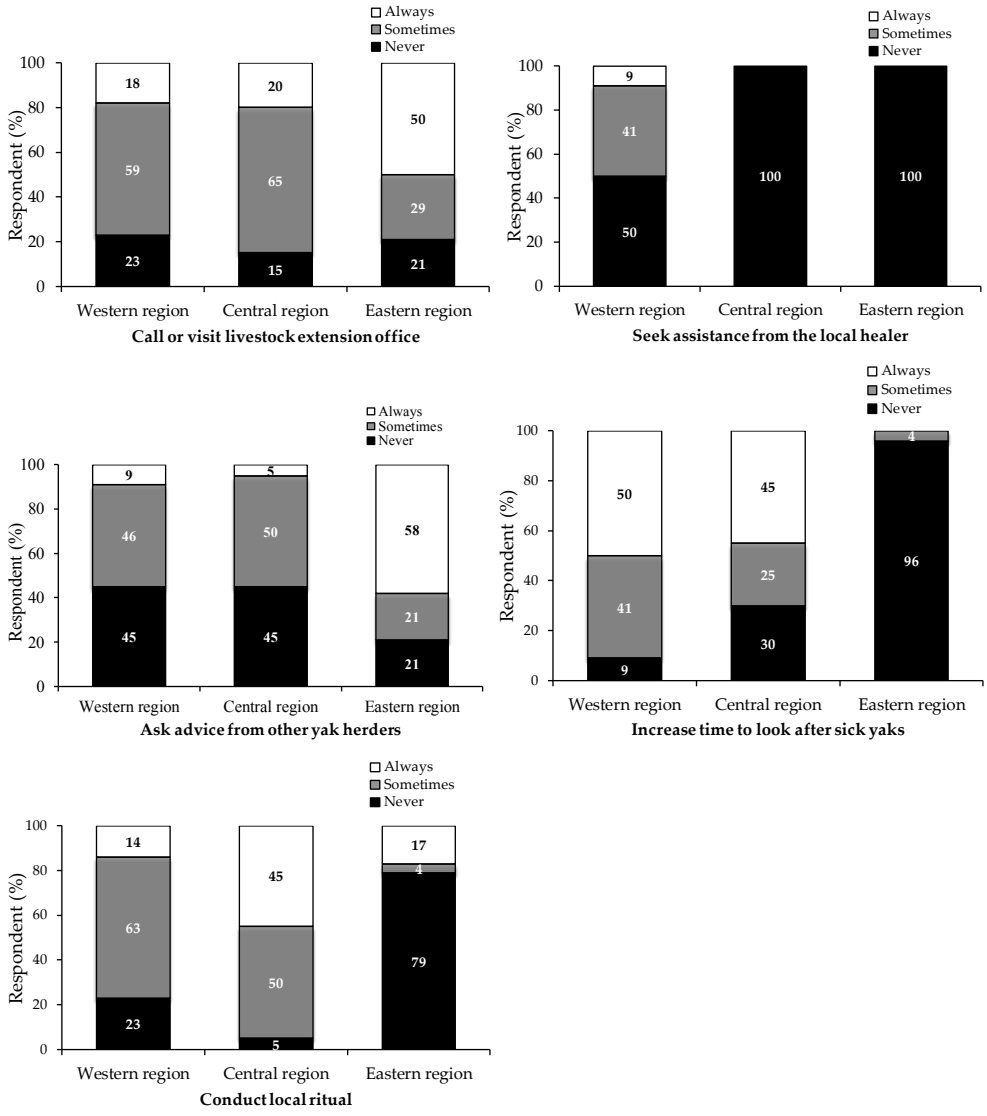

Figure 3. Yak herders' response to what they do when yaks have a health issue in three yak farming regions (%).

3.8. Perceived level of changes in yak farming

Table 7 shows the herders' and livestock professionals' perceived level of changes on aspects related to yak farming. Both herders (59%) and livestock professionals (36%) believed that the market for selling yak products has improved over the years. Still, ~33% of the herders of the western region thought that the market for selling yak products had somewhat deteriorated. About half of the herders mentioned that the number of family members available to herd yaks had

remained the same, while 66% of the livestock professionals thought this had decreased over the years. However, both herders (74%) and livestock professionals (71%) believed that the number of young people (potential successors) in the community had decreased compared with the past. For the number of yak farming households and the yak population in the communities, large regional differences were found. In the western region, 76% of the herders stated that the yak population in the community had decreased over the years. However, in the eastern region, 60% of the herders thought that both the yak population and the number of yak farming households had increased over the years. The yak herds were divided among family members when they settled with the new family, and this probably explained why the yak farming households and yak population in the eastern region had increased over the years.

Most herders and livestock professionals expressed that the forage availability had decreased in summer and winter compared with the past years. About half of the respondents (herders, 53%; livestock professionals, 49%) believed that wild carnivore predation on yaks had increased over the years. Equal proportions of the herders believed that the level of disease and parasites had remained the same (26%), increased (30%) or decreased (30%) over the years. About 50% of livestock professionals thought that the level of diseases and parasites had decreased over the years. A majority of herders and livestock professionals indicated a better access to extension and health services in recent times.

4. Discussion

Herding yaks in Bhutan is often a family business, and herder perceptions on the change in yak farming practices are often based on experiences acquired over multiple years or even over generations (Stuiver et al., 2004). Although perceptions are subjective by nature, and only 3 of 25 yak farming blocks were visited, we believe the collected information from three regions is relevant for the future of yak farming. Moreover, data were collected from different livestock professionals who worked with yak-based communities, to supplement the information. The approach provided new insights and a better understanding of the current situation and developments in yak farming from different perspectives, both from those of the yak herders and livestock professionals.

Table 7. Yak herders' (n = 67) and livestock professionals' (n = 28) perceived level of change compared with the past years (for details per region, see Appendix 3).

Respondent group	Level of perceived changes (%)						*P*-value
	Much decreased	Somewhat decreased	About same	Somewhat increased	Much increased	Don't know	
Market for selling yak products							
Yak herders	0	14	26	38	21	1	0.048
Livestock professionals	11	14	29	25	11	11	
Labour availability to herd yaks							
Yak herders	14	24	53	9	0	0	0.007
Livestock professionals	33	33	19	0	7	7	
Successor (youth) to yak farming							
Yak herders	23	51	17	6	0	3	0.078
Livestock professionals.	18	36	35	0	0	11	
Yak farming household number							
Yak herders	20	24	24	23	9	0	0.076
Livestock professionals	21	47	7	14	4	7	
Size of yak population in the community							
Yak herders	4	32	26	27	11	0	0.152
Livestock professionals	14	18	36	25	0	7	
Forage availability in winter rangeland							
Yak herders	35	41	23	1	0	0	0.030
Livestock professionals.	11	57	18	11	3	0	
Forage availability in summer rangeland							
Yak herders	21	62	17	0	0	0	0.005
Livestock professionals.	4	57	29	7	3	0	
Wild-carnivore predation on yaks							
Yak herders	0	14	26	20	33	7	0.474
Livestock professionals	11	11	22	19	30	7	
Prevalence of diseases and parasites							
Yak herders	6	24	26	27	3	14	0.049
Livestock professionals	14	36	36	11	4	0	
Access to veterinary and health services							
Yak herders	2	3	21	64	11	0	0.239
Livestock professionals	11	11	25	32	21	0	

P-values are given (Mann–Whitney U test).

The herders of different regions emphasised that they wanted to produce yak products for sale on the basis of customer preferences. Currently, herders and middlemen bring the yak products to local shops or urban areas to sell the products. Some herders sell their yak products along the motorway or barter yak products for cereals and grains with farmers in the lowland valley. In the past, most herders took yak products to the lowland valley and products were sold door-to-door. In this process, the host family of the herders played a crucial role in selling yak products. The host

families provided a place for herders to stay when they reached the lowlands, and they also assisted in selling the yak products. Now, most herders said that they did not need assistance from their host family because selling yak products had improved over the years with the connection to motorways between these yak farming villages. However, most yak farming regions in Bhutan are not connected with roads, and road constructions are incomplete, or roads are poorly maintained. This probably explains why most livestock professionals formed the view that poor road transport and the distance between producers and urban areas were the main factors that affect selling of yak products. A proper marketing channel should be in place whereby herders can bring their yak products to the nearest market areas or form a yak herder association to collect yak products and market them. Moreover, establishing a niche-marketing strategy for yak products by branding and standard package design (adding value) could be of great value to stimulate the sales of yak products in Bhutan.

Herders of the western and central yak farming region mentioned that the males were involved with tourism, cordyceps collection, and other high-revenue economic activities. Consequently, females performed the entire task of yak herding. On the one hand, the increased involvement of women in yak herding may be viewed as a promotion of gender equality because women have equal access to and control over the resources (Wangdi, 2016). On the other hand, it may be argued that women have increased responsibilities beside the daily household chores they are expected to conduct, as males are involved in off-farm work. Because of the increased involvement of women in yak herding, managing a yak herd will become more difficult. Consequently, the yak farming family will experience labour shortages.

Modernisation (e.g. education, better roads) has certainly improved the living standards of yak-based families in Bhutan, but it has had repercussions on the availability of family labour to herd yaks. In the past, children assisted their parents in yak herding. Nowadays, most yak-based families send their children to school to improve their living standard. Most respondents said that the literate youth often seemed to view yak farming as an old-fashioned way of supporting their livelihood. Respondents also said that the literate young family members often left their village for towns because there were modern technologies available, better job opportunities, education and health care. Literate young family members who remained in the village were also not interested in yak farming because this practice had lower economic returns than did other livelihoods. Access to modern education for the children of yak-based families, therefore, seemed to be a major underlying cause of labour shortage to herd yaks.

The decreased number of young family members (successors) to take over yak farming compared with the past was expressed in many discussions with yak herders. The number of yak farming

households may, therefore, decrease. For example, six advanced-age herders felt that yak herding had become more difficult for them because of the large distances to walk with the yaks. These six herders would certainly leave yak farming soon, but they had no successor. In interviews with non-yak farmers of the same village (data not shown in Results section), seven of eight respondents stated that they left yak farming ~4–5 years ago because of the labour shortage. This was also found in the district of Haa (western Bhutan), where 90 households have left yak farming in the past 20 years due to labour shortage (Norbu, 2010). It illustrates that the labour availability to herd yaks is a key factor for the future of yak farming in Bhutan.

Following the example of collaborative reindeer herding in Norway (Thomas et al., 2018), a stronger social cohesion involving active collaboration could partly reduce labour shortages in yak herding. Another strategy is to explore novel sustainable sources of income based on yak farming, to ensure the viability of yak farming. For example, most herders mentioned that the use of horses is the only benefit they have from tourism. Community-based tourism could be promoted, where local people obtain a bigger role in tourism, such as, for example, in planning and administration (Suntikul and Dorji, 2016). Community-based tourism is likely to encourage young and adult family members to remain in yak farming.

Similar to yak-based transhumant families in Nepal (Aryal et al., 2014), and to cattle-based transhumant families in Switzerland (Jurt et al., 2015) and Bhutan (Namgay et al., 2014), engagement in high-revenue economic activities is perceived as a cause of labour shortages in yak-based transhumant families in Bhutan. In Bhutan, cordyceps collection, legalised in 2004, is such an activity. Cordyceps collection improved enormously the lives of yak-based families of the western and central region. Herders said that they were able to send their children to school, purchase yaks, horses, or a house or land in the lowland valleys. The cordyceps collection generated high revenues in the short term, but the current way of collection might not be sustainable in the long term. In the interview, many herders mentioned that the cordyceps harvest had decreased over the years due to increased number of cordyceps collectors, which is in agreement with the results of other studies (Negi et al., 2006, Shrestha and Bawa, 2014). So, if the situation does not change, the communities may need to rely less on cordyceps in the future. Moreover, herders mentioned that the cordyceps collection in the summer rangelands caused increased forage shortage due to the many horses that transport food items and other basic necessities for the collectors that graze on these rangelands. The summer rangeland carrying capacity is ~0.05 livestock units per hectare (Wangchuk et al., 2013b). In Bhutan, one livestock unit is defined as an adult yak weighing 300 kg with a daily dry-matter requirement of 2% of live bodyweight . Therefore, the extra horses grazing on these rangelands contributed to over-grazing (Wangdi, 2016). In the

western region, tourism also increased the presence of horses, placing greater pressure on forage availability. Herders stated that they needed ~50 horses for 15 tourists during trekking and camping to Lunana (T. Phuntsho, pers. comm.). The increased equine population over the years as indicated by yak herders corresponded with the increased equine population by 100% in the western region between 2008 and 2018 (DoL, 2008, 2018).

Although herders did not mention the increased presence of stray dogs in the community, livestock extensionist of the neighbour block stated that because of tourists, food wastes were produced, which attracted stray dogs to yak farming regions. These stray dogs freely roam nearby yak farming villages, and during food scarcity they sometimes attacked young yaks, which has been estimated to cause the death of 15–20 young yaks annually over the past 5 years in Lunana block (J. Rizin, pers. comm.). These stray dogs not only cause yak mortality, they are also the host of gid. Gid is a parasitic disease that infects young yaks below 3 years of age. Young yaks are infected when they graze on pasture contaminated with dog faeces infested with eggs of the tapeworm. The eggs of the tapeworm hatch to become larvae in the small intestine of yaks, and then the larvae travel from the intestine to the brain, where they develop into cysts. In the western yak farming region, gid infestation in young yaks has been the major important cause of calf mortality, and herders believed that this gid infestation has increased over the years, even though they dewormed their yak calves.

In the regions under study, yak predation by wild, often endangered, predators (e.g. tiger, snow leopard, bear, Asiatic wild dog) was said to be the main source of tension between herders and wildlife. Yaks freely graze on the rangelands during the day, where they mostly remain unattended by the herders (they return to the campsite), and, therefore, become more vulnerable to predator attacks. Although herders did not mention it, Bhutan's strong conservation policy to protect wild endangered predators could contribute to yak mortality, because most respondents mentioned that the yak predation by wild predators had increased over the years. However, a decline in wild prey or livestock outnumbering wild prey populations (Suryawanshi et al., 2017), and predators' habitat loss could contribute to increased yak predation. Because yaks were the mainstay economy of yak-based families in Bhutan, the increased number of wild-predator attacks on yak is an important issue that requires appropriate mitigation measures to minimise this human–wildlife conflict. An alternative solution to human–wildlife conflicts may focus on compensating farmers for the loss of livestock through predation (Ikeda, 2004, Namgail et al., 2007). Other measures that could be effective are training and education of yak herders on wild predators, corralling young and weak yaks, and improving yak management practices (Treves and Karanth, 2003). Preventing forage shortage could also reduce the number of yak predations because yaks stray away from the main herd when they experience forage shortage, making them more prone to predator attacks.

Herders of the central and eastern regions mentioned that the ban on burning of rangelands and prohibition of clearing bushes in the rangelands (e.g. *Forest and Nature Conservation Act* 1995) have increased forage shortage due to receding rangelands. Fire is an effective tool to control spread of these shrubs in the rangeland (Sharma et al., 2014). Recently, (Wangchuk et al., 2013b) showed that prescribed burning could increase the carrying capacity of rangeland from 0.05 to 0.23 livestock unit per ha in Bhutan; they further recommended to perform one prescribed burning every 6 years to maintain the quality of rangeland. To have control and safe burning of areas a local herder association could be established, such as, for example, similarly to the Prescribed Burn Associations established in United States. Such associations should train herders and stimulate them to assist each other in executing prescribed fires on the rangelands (Weir et al., 2016). In contrast, it may be argued that the shrub proliferation increases biodiversity and carbon sequestration capacity and improves soil fertility (Maestre et al., 2016).

The response of herders to cope with labour shortage, forage shortage and yak mortality is mostly based on herders' traditional knowledge and skills. For example, during forage shortage, herders of western and central regions provide supplementary feed and forages that they generally purchased from lowland farmers. In the eastern region, most herders have taken preventive measures to combat forage shortage by constructing and maintaining fences around the rangeland, to keep away other animals. However, the *Land Act* 2007 does not allow herders to build or renovate fences, and yaks and other animals owned by other family members trespass the rangeland, which results in conflicts among rangeland users (Wangdi and Norbu, 2018). So far, the *Land Act* 2007 of Bhutan has not been implemented, yet herders mentioned that the rangeland conflicts have increased because rangeland users (other yak herders, horse and cattle–yak hybrid owners) do not follow agreed norms and rules of communities on the use of rangelands. In agreement with the current study, conflicts as consequences of leasing rangeland also were observed in Nepal after the nationalisation of rangeland in 1957 (Dong et al., 2016).

Our results showed that most livestock professionals were aware of herders' experience and perception on labour shortage, forage shortage and yak mortality. However, some underlying causes to forage shortage, labour shortage and yak mortality as perceived by the livestock professionals were different from those perceived by the herders. Most livestock professionals strongly viewed that the young and adult family members of yak-based communities were increasingly engaged with high-revenue economic activities. This possibly explains why most of the livestock professionals think that the yak-based communities face a labour shortage. However, herders in the western region mentioned that only their horses are hired by tourist operators and middle persons, while the herders are not involved in tourism. Herders in the western and central

regions collected cordyceps only for 2 months in a year, facing a potential labour shortage only in that period. Similarly, more than half of the livestock professionals thought that increased herd sizes caused forage shortages, which contradicts the herders' view. But herders tended to blame each other for the forage shortage.

Despite herders' professionalism on yak farming, they may be unaware of the impact of harsh weather conditions and absence of protective sheds to assist in the maintenance of the health and welfare of yaks. The livestock professionals have a high level of education and might be better informed by using data records, which could be a reason for a different opinion, whereas herders mostly do not keep records, and their view is based on their experience.

Livestock professionals should encourage the herders to be more vigilant and to supervise their yaks regularly to prevent predation and yaks from drinking contaminated water and eating poisonous plants. For example, when yak feed on senecio and crotalaria plants, which are the first plants to appear in the early spring, they consume pyrrolizidine alkaloids, which might cause skin lesions and liver damage (Winter et al., 1992).

5. Conclusions

Yak-based transhumant pastoralism in Bhutan is affected by socioeconomic developments and regulation. Forage shortage and yak mortality were the main challenges experienced by herders. The market to sell yak products, livestock extension and health services for yaks have improved over the years due to better connection to passable roads. However, forage shortage and yak predation have increased over the years because of strong environmental policies and competition for available rangelands. Labour availability has reduced slightly, and the number of family successors staying in the industry has decreased over the years due to education and other sources of income. Without change of policy, the number of yak-based farming households will decline further in the future.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix 1. Yak herders' (western, n = 20; central, n = 20; eastern, n = 22) view on aspects with the level of effect on forage availability in different yak farming regions (%).

Region	Level of effect on forage availability					*P*-value
	Not at all	Small extent	Moderate extent	Large extent	Don't know	
Increased in family yak herd size						
Western region	59	14	23	4	0	0.382
Central region	75	10	5	10	0	
Eastern region	72	12	12	0	4	
Increase community yak herd size						
Western region	59	9	23	9	0	0.315
Central region	50	15	25	10	0	
Eastern region	20	8	36	32	4	
Increase competition with cattle–yak hybrids						
Western region [A]	77	0	14	5	5	0.002
Central region	25	10	40	20	5	
Eastern region	24	12	20	40	4	
Increase competition with horse						
Western region	9	18	27	46	0	0.005
Central region	70	5	10	15	0	
Eastern region	48	40	0	12	0	
Rangeland division among family members						
Western region	68	9	5	14	0	0.000
Central region	95	5	0	0	0	
Eastern region	24	4	4	68	0	
Cordyceps collection site						
Western region	45	18	18	19	0	0.000
Central region	40	10	20	30	0	
Eastern region	100	0	0	0	0	
Prohibited burn the rangeland						
Western region	68	5	18	10	0	0.017
Central region	15	10	40	30	5	
Eastern region	24	8	8	60	0	
Rangeland lease (*Land Act* 2007)						
Western region	68	0	9	18	5	0.077
Central region	85	0	0	5	10	
Eastern region	44	4	0	16	36	
Less rainfall amount						
Western region	36	32	27	5	0	0.049
Central region	65	20	5	0	10	
Eastern region [B]	44	16	16	0	16	
Soil erosion						
Western region	55	9	28	8	0	0.491
Central region	75	20	5	0	0	
Eastern region	52	20	14	13	0	
Less snow cover on rangeland						
Western region [C]	32	14	18	0	4	0.004
Central region	75	5	5	0	15	
Eastern region [C]	48	8	8	12	20	
Declare rangeland as protected areas						
Western region	73	9	18	0	0	0.001
Central region	100	0	0	0	0	
Eastern region	100	0	0	0	0	
Protect community forest						
Western region	68	18	5	0	9	0.237
Central region	100	0	0	0	0	
Eastern region	100	0	0	0	0	

[A]In the western region, cattle was reared but not cattle-yak hybrids. [B]Heavy rainfall in summer cause forage shortage. [C]The rest viewed that more snow coverage on the rangeland cause forage shortage.

Appendix 1. Yak herders' (western, *n* = 20; central, *n* = 20; eastern, *n* = 22) view on aspects with the level of effect on forage availability in different yak farming regions (%) cont...

Region	Level of effect on forage availability					*P*-value
	Not at all	Small extent	Moderate extent	Large extent	Don't know	
Increase competition with wild animals						
Western region	55	18	18	5	5	0.000
Central region	35	25	35	5	0	
Eastern region	100	0	0	0	0	

Appendix 2. Yak herders' (western, *n* = 22; eastern, *n* = 21; central, *n* = 19) experience on aspects with level of effect on yak mortality in different regions (%).

Region	Level of effect on yak mortality					*P*-value
	Not at all	Small extent	Moderate extent	Large extent	Don't know	
Lack of forage in rangelands						
Western region	41	23	18	18	0	0.189
Central region	75	20	5	0	0	
Eastern region	38	13	25	21	4	
Water shortage						
Western region	82	5	9	4	0	0.972
Central region	70	10	10	5	5	
Eastern region	83	17	0	0	0	
Outbreak of diseases						
Western region	64	18	14	4	0	0.000
Central region	75	10	0	0	15	
Eastern region	25	29	17	29	0	
Gid infestation						
Western region	0	27	23	50	0	0.000
Central region	70	25	5	0	0	
Eastern region	67	8	4	0	21	
Plant poisoning						
Western region	41	55	0	4	0	0.003
Central region	45	45	10	0	0	
Eastern region	83	13	0	4	0	
Drinking contaminated water						
Western region	73	18	4	5	0	0.010
Central region	50	30	15	5	0	
Eastern region	92	8	0	0	0	
Unavailability of veterinary care						
Western region	50	32	14	4	0	0.011
Central region	80	5	5	5	5	
Eastern region	79	9	8	4	0	
Wild-carnivore predation on yaks						
Western region	0	23	27	50	0	0.583
Central region	0	20	40	40	0	
Eastern region	13	33	38	17	0	
Poor shed quality or absence of shed						
Western region	64	27	9	0	0	0.169
Central region	80	5	10	5	0	
Eastern region	79	13	4	0	4	
Cold and bad weather conditions						
Western region	59	27	9	5	0	0.035
Central region	50	35	10	5	0	
Eastern region	84	8	4	4	0	
Accidents with yaks						
Western region	27	45	14	14	0	0.758
Central region	30	55	10	0	5	
Eastern region	38	38	21	4	0	

Appendix 3. Yak herders' (western, *n* = 22; central, *n* = 20; eastern, *n* = 25) perceived level of change on aspects compared with past years in different regions (%).

Region	Level of perceived changes						*P*-value
	Much decreased	Somewhat decrease	About same	Somewhat increased	Much increased	Don't know	
Market for selling yak products							
Western region	0	33	38	19	10	0	0.233
Central region	0	10	15	35	35	5	
Eastern region	0	0	24	56	20	0	
Labour availability to herd yaks							
Western region	14	29	52	5	0	0	0.653
Central region	15	15	60	10	0	0	
Eastern region	12	28	48	12	0	0	
Having successor to yak farming							
Western region	14	62	24	0	0	0	0.206
Central region	45	40	10	0	0	5	
Eastern region	12	52	16	16	0	4	
Size of yak population in your community							
Western region	5	71	10	14	0	0	0.018
Central region	5	10	50	20	15	0	
Eastern region	4	16	20	44	16	0	
Yak farming household number							
Western region	33	48	14	5	0	0	0.777
Central region	25	25	25	20	5	0	
Eastern region	4	4	32	40	20	0	
Forage availability in summer rangelands							
Western region	14	57	29	0	0	0	0.616
Central region	25	65	10	0	0	0	
Eastern region	24	64	12	0	0	0	
Forage availability in winter rangelands							
Western region	33	57	10	0	0	0	0.111
Central region	35	30	35	0	0	0	
Eastern region	36	36	24	4	0	0	
Wild-carnivore predation on yaks							
Western region	0	5	10	19	67	0	0.353
Eastern region [A]	0	24	36	12	12	8	
Central region	0	10	30	30	25	5	
Access to veterinary health services							
Western region [B]	0	5	19	62	9	0	0.266
Central region	5	5	20	50	20	0	
Eastern region [B]	0	0	16	76	4	0	
Prevalence of diseases and endoparasite							
Western region	0	10	19	48	10	14	0.778
Central region	10	40	15	20	0	15	
Eastern region	8	24	40	16	0	12	

[A]Rest respondents did not have conflicts with wildlife animals. [B]Rest respondents did not have access to veterinary services or yaks were not sick.

Chapter 3

Welfare and management practices of free-ranging yaks in Bhutan

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Abstract

Highland pastoralists in Bhutan highly depend on their yaks. Currently, these communities experience labour shortage, forage shortage, and poor livestock extension and veterinary services, which may pose threats to yak welfare. The aim of this study was to assess the welfare and management practices of free ranging yaks in Bhutan. To this end behaviour and health status of the animals was observed and herders were interviewed in three yak farming regions (east, central and west) of Bhutan in autumn and early winter. In total 567 cows and 549 calves were scored for integument condition, body cleanliness, ocular and nasal discharge, diarrhoea and damage signs, hip bone visibility, mutilation damages, and gait. We assessed 324 cows for avoidance distance and subclinical mastitis. Moreover, 272 calves were assessed for avoidance distance. Behaviour of the herds was observed in six consecutive blocks of 20 min. Each block was divided into two: first 5 min of counting the number of animals eating, lying, standing idle and walking, followed by 15 min of counting the number of events of behaviour. Interviews with herders were conducted to supplement the welfare assessment. The avoidance distance was different between the regions for calves, but not for lactating cows. Integument lesions, dirty body areas, nasal discharge, ocular discharge, diarrhoea signs, subclinical mastitis, and lameness were virtually absent. A few instances of agonistic behaviour and flehming behaviour were observed. Yaks in the central and western region performed more scratching and rubbing than in the eastern region. Herders mentioned that yak bulls are castrated without analgesia. Although there are several potential risk factors for yak welfare, welfare status of yaks living in Bhutan was assessed to be good during the time of visit.

Keywords: animal welfare; behaviour; castration; health; livelihood; yak

1. Introduction

Highland pastoralists in Bhutan depend mainly on yak farming for their livelihoods. These yak-based transhumant communities migrate with their herds in the Himalayas between summer (5000 m above sea level) and winter rangeland (2500 m above sea level) in response to forage availability and extreme climatic conditions. Yaks are kept for example for milk and hair, and are in some areas also used as pack animals for transportation and traction. In transhumant yak farming systems, forage shortage in winter, labour shortage, and inaccessibility to veterinary and extension services are the main constraints (Derville and Bonnemaire, 2010, Wangchuk and Wangdi, 2015).

Yak herders do not keep records of morbidity and mortality rates of their herd. Although yaks are well adapted to their environment anatomically (e.g. large chest capacity, big heart, large lung surface area relative to animal's body size; Weiner et al., 2003) and physiologically (e.g. low haemoglobin counts but high affinity for the presence of low atmospheric oxygen at higher altitude; Weiner et al., 2003), harsh conditions in the mountains with feed shortage in winter and spring affect the performance of these animals (Gyamtsho, 2000). Herders try to provide supplements such as maize and wheat flour, and cattle concentrates during feed shortage (Wangchuk and Wangdi, 2015), but generally they have limited financial resources for this. Furthermore, yak herders have poor access to veterinary services because the herds are generally about 1–3 days (winter) up to 10 days (summer) walking from the nearest livestock extension centre (Derville and Bonnemaire, 2010). Hence, yak herders try to treat diseases and injuries by use of indigenous knowledge and ethno-veterinary medicines (Dhendup, 2015). A typical disease in the central and western Bhutan, for example, is gid (*Coenurus multiceps multiceps*), an endoparasite that forms cysts in the animal's brain, and is a major health issue increasing the risk of mortality among young yaks (Gyamtsho, 2000).

Besides food shortage and health issues, herders' skills and knowledge on handling and restraining the animals are essential factors that may affect the welfare of animals (Waiblinger et al., 2006). Because yaks are kept on rangelands without fences and have a large freedom to move, they may experience stress in the process of gathering, restraining and handling for milking, vaccinating, or shearing them. Furthermore, the development philosophy of Bhutan is based on the quality of life of Bhutanese people rather than the economy and is expressed in the Gross National Happiness. Animals, as sentient beings, are enclosed in this philosophy. So far, however, assessing their welfare is not operationalised in practice. That means no animal welfare guidelines are effectuated and animal protection regulation is at a pioneer stage. Although yak welfare might not be the first thing

yak herders worry about, knowing the status and underlying issues that impair yak welfare will give benefit to the yak-based communities. For example, improving animal welfare can contribute to reduce mortality and morbidity, and improve product quality, which brings financial benefits to farmers (Appleby and Mitchell, 2018).

Therefore, the aim of this study was to assess the welfare and management practices of free ranging yaks in Bhutan. To this end behaviour and health status of the animals was observed and herders were interviewed in three yak farming regions. Our hypothesis was that yaks might be under poor health and welfare condition because of feed shortage, inaccessibility to veterinary and extension services, and traditional management practices. Since the perceptions, opinions, traditions and beliefs of herders how to manage yaks may vary, we also hypothesised that welfare indicators may give different outcomes between yak farming regions.

2. Material and methods

2.1. Ethics approval and consent

The study (application id. 5069623915B73E79DE0037) was approved by the research ethic committee of UWICER-DoFPS, Bhutan. Approval was needed for the interviews and visiting the protected areas where yak herders are located. During the field visit, a verbal consent was obtained from the yak herders to participate in the study. The observer maintained a minimal distance (around 3–6 m) from the animals to not cause distress, except during the avoidance distance measurements. All data collection was done by the same person (first author).

2.2. Herd selection and visits

Bhutan has 10 districts with a total of 25 blocks where yak farming is operated (DoL, 2018) and the yak farming districts can be stratified into three regions. These three regions are characterised by differences in culture and tradition, yak products, breeding practices, and livelihood sources (Derville and Bonnemaire, 2010). Within each of these regions one block (the local administrative unit) comprising several villages was selected to have as good as possible representation of yak farming in Bhutan: Merag (east), Saephu (central) and Laya (west) (Figure 1). Visiting more blocks per region was not feasible due to time consuming traveling in these very remote areas. These visited blocks were about 1 day walking distance from the nearest road also had a substantial number of accessible yak farming communities. Within these blocks 59 yak herds (east, 19; central, 20; west, 20) from 13 villages (east, 3; central, 6; west, 4) were visited while staying on the winter rangeland, located at around 3000 m above sea level. The purposeful sampling technique was used

to identify and select the yaks herds based on the number of herds in the areas and distance from the yak farming villages (the investigator considered to visit herds that were maximal 1 day walking distance from the village) using local livestock extensionists' and the local health workers' information. Herds were visited between October 2018 and January 2019. This season was selected because the herds stay at one location for a longer time and the winter rangelands are easier to access than the summer rangelands, which are at a higher altitude and even more remote areas. The herd assessments and face-to-face interviews with yak herders were first all carried out in the eastern region (October), followed by the western region (November/December) and finished in the central region (December/January). The resulting time effect in the data collection was unavoidable considering the long travel time between regions.

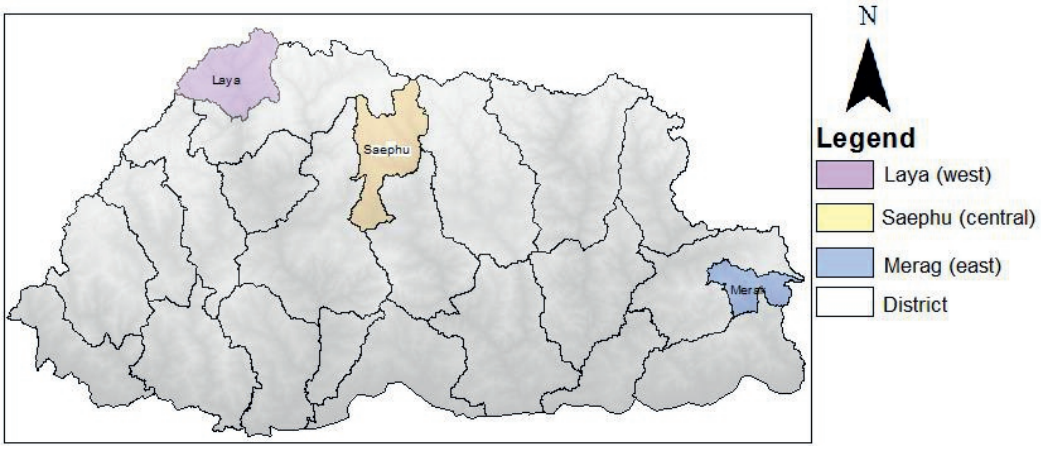

Figure 1. Locations of the three study areas in Bhutan.

2.3. Welfare assessment

The welfare protocol and assessment procedure applied was based on elements of the Welfare Quality protocol for cattle (Welfare Quality®, 2009). The protocol was adapted to include specific features of yaks using literature (Liu et al., 2019) and expert knowledge on yak biology and behaviour, and to allow assessment in the open field under mountainous conditions. The yak welfare assessment protocol involved 3 h of animal-based measurements and a 30 min interview with the yak herder using a semi-structured questionnaire. The protocol and questionnaire were pretested with one yak herd and were revised accordingly.

Yaks were observed at two different moments of the day: lactating cows with their calves when being restrained during milking, and the whole herd when free ranging on the rangeland. After the observations, herders were interviewed in the Bhutanese national language (western and central

region) and the local dialect called *sharchopkha* (eastern region). The questionnaire was translated from English to the national language, which was verified by a qualified translator. Being a native speaker of the local dialect in the eastern region the interviewer (the first author) was able to directly translate the questions during the interview.

2.4. Assessment during milking procedure

During the milking procedure, cows and their calves were assessed for their response to an unfamiliar human, integument condition, body cleanliness, ocular and nasal discharge, and signs of diarrhoea and damages (e.g. ear tag, nose ring). In addition, subclinical mastitis and gait was scored. For each of these measures the used procedures are described below.

Avoidance distance

Of 50 herds (east, 14; central, 17; west, 19) in total 324 lactating cows (east, 115; central, 62; west, 147) and 272 calves (east, 92; central, 80; west, 100) were assessed for avoidance distance. The avoidance distance test was performed without disturbing the daily milking routine. The test was performed on calves before milking, and on lactating cows after milking. The unfamiliar observer approached the animal from a distance of 3 m. After the animal was aware of the presence of the observer, the observer lifted one arm with an inclination of approximately 45° from the body and walked towards the animal at a rate of one step per second. When the animal responded by moving away (moves back, moves or shakes head, or moves forward), the distance (in cm) between the observer's hand and the animal at the moment of withdrawal was estimated visually. When the observer could touch the animal, the distance was assigned 0 cm. The avoidance distance test could not be done in some herds because the cows were not milked (east, 1 herd; central, 1 herd) or the herder did not give permission (east, 4 herds; central, 2 herds; west, 1 herd).

Health examination

Of 57 herds (east, 18; central, 19; west, 20) in total 567 lactating cows (east, 267; central, 124; west,176) and 549 calves (east, 257; central, 117; west, 175) were inspected to assess integument condition, body cleanliness, ocular and nasal discharge, signs of diarrhoea and hip bone visibility (Table 1). Observations were done from a distance between 3 and 6 m. Each of these health indicators were scored as present or absent. An equal proportion body side of an animal (left or right) was scored for the integument condition and body cleanliness. If the right side of the first animal was selected to inspect, then left side of the next animal was considered, and so on. Observations around milking could sometimes not be done because the cows were not milked

(east, 1 herd; central, 1 herd). Because of the long hair yaks have, hip bone observations replaced the Body Condition Score (Welfare Quality® 2009). The hipbone was scored as clearly visible (protruding hip bone) or not clearly visible (covered in fat). It was not possible to inspect and score animals from a near distance, not even during the milking process, for safety reasons because the animals can easily become agitated.

Table 1. Summary of the yak health indicators adapted from Welfare Quality® (2009).

Variable	Description
Integument condition	Animals were inspected for swellings, fresh wounds, or lesions in the body region (between neck and rump region), front limb (including knee), and hind limb (including the hock). These were recorded separately. Lesions and wounds were counted if the lesion or wound was at least ~2.5 cm in diameter.
Body cleanliness	Animals were examined for cleanliness in the body area and hind limb. The animal was scored as clean (less than 25% of the area in question covered with plaques, or less than 50% of the area covered with liquid dirt) or dirty (25% of the area in question or more covered with plaques, or more than 50% of the area covered with liquid dirt).
Ocular discharge	Presence of any visible flow (wet or dry) from the eyes of at least 3 cm long.
Nasal discharge	Presence of any visible flow (transparent, coloured) from the nostril.
Diarrhoea sign	Animals were considered to suffer from diarrhoea if the tail was soiled with loose watery manure, with the size of at least a hand palm.
Hip bone	Depression between the hip bones was defined as a visible hip bone (Edmonson et al., 1989).

Invasive procedures

Of 57 herds (east, 18; central, 19; west, 20) in total 567 lactating cows (east, 267; central, 124; west,176) and 549 calves (east, 257; central, 117; west, 175) were inspected for damages inflicted by the herders (such as nose ring and ear tag). Information about the number of animals with a nose-ring and on the castration practices were obtained through the interviews with the herders.

Subclinical mastitis

Fifty-six herds (east, 17; central, 19; west, 20) were tested for subclinical mastitis by using the California Mastitis Test (Sargeant et al., 2001). About 50% of the lactating yak cows in a herd (east, 131; central, 71; west, 106) were selected and tested. The herder was provided with a test paddle and asked to fill it with two to three squirts of milk from each quarter in a designated cup. An equal amount of reagent was added in each separate cup containing milk. The mixture was swirled gently for 5 sec, and the reaction was scored either negative (no thickening of the mixture) or positive (gel-like appearance of the mixture) for subclinical mastitis. The paddle was rinsed with disinfectant after each test.

Gait score

Of 57 herds (east, 18; central, 19; west, 20) in total 567 lactating cows (east, 267; central, 124; west,176), 549 calves (east, 257; central, 117; west, 175), and 6 bulls (west) were scored for gait condition. The animals were scored for gait condition at two occasions: i) when the animals were gathered for milking in the morning, and ii) when the herder drove the herd to the rangeland after milking. The observer maintained around 10 m distance from the animals and observed the animals while they were gathered for milking and or driven to rangeland. A two-point scale (not lame, lame) was used to classify the gait of the yaks. A yak was considered lame when it was clearly limping while walking, which is comparable to a score of 3.0 based on the protocol of Flower and Weary (2006).

2.5. Animal observations when on rangeland

Behavioural observations when the animals were on the rangeland included all animals (cows, bulls, heifers, calves) that were present. At some locations, herds used a common rangeland (east, 4; central, 12; west, 10) for grazing. In these cases, herds were observed and assessed together. In total therefore 35 herds (east, 15; central, 8; west, 12) were assessed for behaviour. A binocular was used for observations.

The observations consisted of two parts: 5 min focused on behavioural states followed by 15 min focused on behavioural events. Both observations were repeated 6 times in a row (6 × 20 min) in a 120 min recording session and finished with an additional, 7th 5 min period of behavioural states observation. Behavioural observations were either done in the morning or afternoon depending on the local situation. The behavioural states were assessed by counting the number of animals eating, lying down, standing idle, and walking once within 5 min (Table 2). The behavioural events assessed were agonistic behaviour (head butts, chasing, fighting), allogrooming (adult-adult licking, adult-young licking), sexual behaviour, self-licking, rubbing and scratching, and play behaviour (Table 2). For the behavioural events the observation of animals was done continuously for 15 min.

2.6. Water source inspection

Total number of drinking water sources where yaks could make use of was recorded. A sample of each water source was taken in a transparent plastic cup and held up to the light to assess the cleanliness of water. Water was classified as clean (water clear and no evidence of crusts of dirt or decay), partly dirty (water clear but contains particles), or dirty (water coloured, such as brown, green, red).

Table 2. The ethogram describing the yak behaviour adapted from Welfare Quality® (2009).

Variable	Description
Behavioural state	
Eating	Taking grass or forbs, woody twigs and leaves from trees and shrubs into the mouth.
Lying down	Lying on the chest on the ground.
Standing idle	Standing posture without performing any other activity.
Walking	Is walking without eating.
Others	All other behaviours not included in the lists (e.g. suckling, licking)
Behavioural event [1]	
Head butt	Interaction with physical contact (butting, hitting, thrusting, striking or pushing). One yak butting or pushing another yak by the forehead or horns; the receiver may or may not give up its present position (but does not flee).
Chasing	One yak makes another yak flee (with or without physical contact).
Fighting	Two yaks push their foreheads, horn bases, or, horns against each other while planting their feet on the ground with both exerting force against each other.
Allogrooming	Touch body parts of group mate with the tongue, but not licking around the anal region or prepuce.
Self-licking	Touch own body parts with tongue.
Rubbing and scratching	Use of horn or legs to scratch any own body part or rub any part of the body against any object (e.g. soil, rock, pole).
Flehming behaviour	Bull rests chin on yak cow, and exhibits flehming behaviour (sniffing female genital area, followed by raising the nose into the air with mouth slightly opened).
Play behaviour	Fast galloping with the tail lifted up, interrupted by sudden change of direction, hind leg kicking, body rotations and twists.

[1]A new bout starts if the same animals restart the specific type of behaviour after more than 10 sec.

2.7. Interview

A face-to-face interview with yak herders was conducted using a semi-structured questionnaire with both open-ended and close-ended questions. The questionnaire had three sections:

- Basic respondent information that included age, sex, level of education, and years of yak herding.
- Current yak management and husbandry practices related to assistance during calving, mortality and cause, access to livestock extension and animal health care services, painful practices (disbudding, dehorning, nose ringing, male castrating) and use of anaesthesia or analgesia.
- Opinion of herders on naming of yak, and whether herders think that yaks have feelings (sentient beings). The complete questionnaire is available on request.

2.8. Data processing and analyses

Data collected was entered in an Excel spreadsheet for each yak herd and exported to R (version 3.5.0) for the analysis (R Team Core, 2018). Data were tested for normality using the Shapiro-Wilk

test, and accordingly parametric and non-parametric tests were performed. The percentages of calves per herd and cows per herd with integument alterations, body cleanliness, ocular and nasal discharge and signs of diarrhoea, lameness, visible hipbones, and ear tags were calculated. Left and right-side scores of an animal body for integument alterations and body cleanliness were summarised as one variable because integument alterations and dirty bodies were virtually absent. It was scored as present if either an integument alteration or dirty body was observed. In addition, the percentage of cows that presented at least one quarter positive by the clinical mastitis test was also calculated. A Kruskal-Wallis test was used to test the differences between the regions at *P*-values < 0.05 for the abovementioned health indicators.

The avoidance distance and behavioural data were analysed using the R packages car (Fox and Weisberg, 2019), MASS (Ripley et al., 2013), lme4, glmer (Bates et al., 2015) and lsmeans (Lenth, 2016). For all the models, region was treated as a fixed effect and herd as a random effect. In the preliminary analyses, differences in avoidance distance of calves and cows to an unknown person was fitted using a linear mixed model (LMM). The residuals versus fitted value and residuals quantile-quantile plot of the model showed deviations from normality (Bolker et al., 2009). Furthermore, residuals of the model did not meet the assumption of normality using the Shapiro-Wilk test. Therefore, a constant value of 1 was added to the original data of the avoidance distance, and thereafter the data were log-transformed and used in a linear mixed model. In addition, whether animals could be touched or not in the avoidance distance test was predicted with a generalized linear mixed models (GLMM) using a binominal logit link. When the fixed effect was significant ($P < 0.05$), the Corrected Bonferroni method of Dunn's test was used for post-hoc pairwise comparisons (Dinno, 2017). The model results are given in the supplementary material (Appendix 1 and 2).

Starting and end time of observations on the rangeland differed due to weather, herder's activity (e.g. salt feeding, duration of milking procedure), and visibility of the animals in the landscape. Therefore, behavioural data were segregated as morning (all observations between 625–1200 h) and afternoon (all observations between 1500–1750 h) observations, which were analysed separately. In the afternoon observation, only one herd from the central region was observed for the behaviour, and it was excluded from further analysis. For every 5 min of behavioural observation the proportion of each behaviour was calculated as the number of individuals performing a behaviour divided by the number of animals observed. The mean for each behavioural state was calculated from the seven observation periods. The percentage of yaks eating, lying, standing idle and walking were transformed using arcsine square root transformation to

achieve normality and homogeneity of error variance. A linear mixed model was used to analyse regional differences in behavioural states of yaks, and herd was used as the random effect. The response variables were back-transformed to plot graphs, and the model estimates are given in supplementary material (Appendix 3). Similarly, the number of behavioural events per animal per herd was calculated as the count of each event happening divided by the total number of animals. The mean for each behavioural event was calculated from the six observation periods. The mean behavioural counts for the different events were subjected to generalized linear mixed effect model using the glmmTMB package (Magnusson et al., 2017). The number of events per animal per 15 min is reported because behaviour of yaks was observed for 15 min and the number of yaks per 15 min could vary. The Corrected Bonferroni method of Dunn's test (Dinno, 2017) was used for post-hoc pairwise comparisons when the fixed effect was significant ($P < 0.05$). The model results are given in the supplementary material (Appendix 4 and 5).

Regional differences (east for Merag, central for Saephu and west for Laya) for age of respondents, herding experience and yak herd size were compared based on the median and using the Kruskal–Wallis test. The median was used rather than the mean because variables were skewed (e.g. respondent age). Multiple responses for the cause of yak mortality were recoded to a yes or no response. The percentages for the causes of yak mortality, frequency of livestock services received, frequency of deworming and ectoparasite treatment, and painful practices (disbudding, dehorning, nose ringing, castrating) were calculated. The Fisher's exact test was used to test if there were differences between the regions for health evaluation variables and painful practices. Furthermore, the effect size was also estimated by epsilon-squared (ε^2) method to assess the strength of relationships between variables.

3. Results

3.1. Avoidance distance

Avoidance distance of calves and lactating cows to an unknown person is shown in Figure 2. The avoidance distance for calves differed significantly between the regions (LMM, $F = 35.684$, $df = 2$, $P < 0.001$). The avoidance distance for calves in the central and western region was shorter than for calves in the eastern region ($P < 0.001$). However, no differences in avoidance distance for lactating cows was found between the regions (LMM, $F = 2.276$, $df = 2$, $P = 0.104$).

The mean percentage of calves that could be touched by an unfamiliar observer was higher for the western region (41%, range 0–71%) than in the eastern (6%, range 0–14%) and central region (12%, range 0–50%) (GLMM, $F = 17.136$, $df = 2$, $P < 0.001$). The mean percentage of lactating cows

that could be touched by an unfamiliar observer was higher for the western (16%, range 0–55%) and eastern region (11%, range 0–75%) than in the central region (5%, range 0–50%) (GLMM, F = 3.242, df = 2, $P = 0.016$).

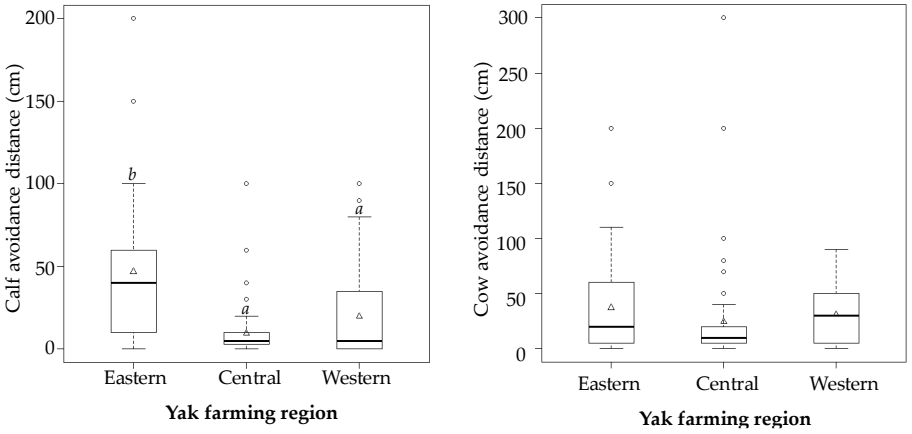

Figure 2. The avoidance distance (cm) for calves and lactating cows to an unknown person in three yak farming regions. The boxplot shows the median (horizontal line), mean (triangle), and 25th and 75th percentile. The whiskers extend to the 10th and 90th percentile. Means of bars with different letters within each region are significantly different ($P < 0.05$).

3.2. Herd health

Seven health parameters were assessed for lactating cows and calves during the milking procedure. Out of 567 cows and 549 calves, six cows (east, 0.9%; central, 3.2%; west, 1.4%) and five calves (east, 1.1%; central, 1.3%; west, 3.3%) were found to have lesions. Four cows (east, 1.1%; central, 0.0%; west, 2.0%) and four calves (east, 0.9%; central, 0.0%; west, 3.0%) had a visible hip bone, and three cows (east, 0.9%; central, 0.0%; west, 1.3%) and three calves (east, 0.0%; central, 1.3%; west, 2.0%) were lame. In all visited herds, there was no sign of nasal discharge, while four cows (east, 1.7%; central, 3.2%; west, 3.3%) and three calves (east, 3.3%; central, 0.0%; west, 0.0%) were observed to have ocular discharge. No signs of diarrhoea were observed in any of the visited herds. Eleven calves were scored dirty at one of the body sides and/or hind limb (east, 1.1%; central, 10.0%; west, 2.0%). Furthermore, nine cows were scored dirty at one of the body sides and/or hind limb (east, 5.2%; central, 3.2%; west, 0.7%) (Appendix 6).

No differences were observed between the regions regarding animals being scored for lesions, dirty body, nasal discharge, ocular discharge, diarrhoea, subclinical mastitis, and lameness ($P > 0.05$). However, the percentage of cows with a dirty hind limb (east, 4 herds; central, 1 herd; west, 0 herd), ocular discharge (east, 2 herds; central, 1 herd; west, 0 herd) and visible hipbone (east, 0 herd;

central, 0 herd; west, 4 herds) differed between regions ($P < 0.05$). All yak cows were tested negative for subclinical mastitis. Occasionally a calf or cow with a lesion was observed within a herd (east, 1; central, 1; west, 2). In addition, one to two calves per herd (east, 0; central, 0; west, 4) and one to two cows per herd (east, 1; central, 0; west, 2) were observed with a visible hip bone. Likewise, a single calf (east, 0; central, 1; west, 2) and one to two lactating cows (east, 1; central, 0; west, 1) were lame within a herd. Moreover, two lame bulls in one herd of the western region were observed. In all visited herds, one to two animals per herd were observed to have ocular discharge (east, 2; central, 1; west, 0).

One to two calves per herd were scored dirty at one of the body sides (east, 1; central, 1; west, 3) and hind limb (east, 1; central, 4; west, 2). Similarly, one to two cows per herd were scored dirty at one of the body sides (east, 2; central, 1; west, 2) and hind limb (east, 1; central, 4; west, 2).

3.3. General herd behaviour

The percentage of animals eating, lying down, standing idle, walking, and exhibiting other activities (suckling, licking) is shown in Figure 3. In the morning, there were no differences for number of yaks eating (LMM, F = 1.039, df = 2, $P = 0.354$), lying down (LMM, F = 2.403, df = 2, $P = 0.090$), standing idle (LMM, F = 0.240, df = 2, $P = 0.787$) and exhibiting other activities (LMM, F = 0.041, df = 2, $P = 0.960$) between the regions. However, a difference was found in walking behaviour between the regions (LMM, F = 5.512, df = 2, $P = 0.004$). Similarly, in the afternoon, there was no difference in the percentage of yaks eating (LMM, F = 2.844, df = 1, $P = 0.190$), lying down (LMM, F = 2.557, df = 1, $P = 0.200$), standing idle (LMM, F = 5.430, df = 1, $P = 0.083$), walking (LMM, F = 2.071, df = 1, $P = 0.257$) and exhibiting other activities (LMM, F = 0.248, df = 1, $P = 0.665$).

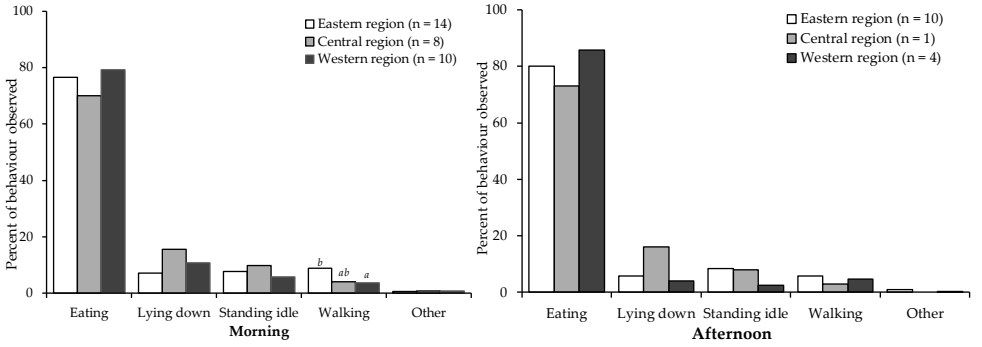

Figure 3. Yak behaviour (least squares means) observed in the morning (625–1200 h) and afternoon (1500–1750 h) when on rangeland in three yak farming regions. Means of bars with different letters within each behaviour are significantly different ($P < 0.05$).

Table 3. Number of events (per animal per 15 min least square means and minmax) per type of behaviour for three yak farming regions in Bhutan.

Activity	East	Central	West	*P*-value (ε^2)
Head butts				
Morning (*n* = 32)	0.016 (0 - 0.050)	0.004 (0 - 0.010)	0.007 (0 - 0.030)	0.092 (0.087)
Evening (*n* = 16)	0.017 (0 - 0.065)	0	0.004 (0 - 0.018)	0.193 (0.153)
Chasing				
Morning (*n* = 32)	0.041 (0 - 0.130)	0.021 (0 - 0.040)	0.017 (0 - 0.060)	0.080 (0.099)
Evening (*n* = 16)	0.039 (0 - 0.134)	0	0.025 (0 - 0.046)	0.434 (0.039)
Fighting				
Morning (*n* = 32)	0.009 (0 - 0.060)	0.014 (0 - 0.050)	0.008 (0 - 0.040)	0.749 (0.031)
Evening (*n* = 16)	0.017 (0 - 0.099)	0	0.003 (0 - 0.016)	0.356 (0.055)
Adult-young licking				
Morning (*n* = 32)	0.036 (0 - 0.180)[a]	0.148 (0 - 0.460)[b]	0.095 (0 - 0.270)[ab]	0.011 (0.248)
Evening (*n* = 16)	0.059 (0 - 0.217)	0.106	0.182 (0.042 - 0.541)	0.058 (0.077)
Adult-adult licking				
Morning (*n* = 32)	0.004 (0 - 0.030)[a]	0.018 (0 - 0.050)[ab]	0.025 (0 - 0.100)[b]	0.026 (0.212)
Evening (*n* = 16)	0.003 (0 - 0.017)	0	0	0.995 (0.155)
Self-licking				
Morning (*n* = 32)	0.294 (0.100 - 0.590)[a]	0.816 (0.570 - 1.540)[b]	0.419 (0.110 - 0.930)[a]	0.000 (0.596)
Evening (*n* = 16)	0.273 (0.106 - 0.513)	0.228	0.417 (0.160 - 0.976)	0.203 (0.069)
Scratching and rubbing				
Morning (*n* = 32)	0.106 (0.040 - 0.230)[a]	0.199 (0.100 - 0.340)[b]	0.203 (0.020 - 0.340)[b]	0.001 (0.384)
Evening (*n* = 16)	0.123 (0.014 - 0.326)	0.083	0.179 (0.073 - 0.290)	0.349 (0.107)
Flehming behaviour				
Morning (*n* = 32)	0.080 (0 - 0.400)	0.029 (0 - 0.090)	0.050 (0 - 0.120)	0.143 (0.152)
Evening (*n* = 16)	0.070 (0.012 - 0.178)	0.032	0.084 (0.014 - 0.159)	0.689 (0.001)
Play behaviour				
Morning (*n* = 32)	0.016 (0 - 0.040)	0.005 (0 - 0.030)	0.011 (0 - 0.020)	0.131 (0.152)
Evening (*n* = 16)	0.039 (0 - 0.158)	0.011	0.010 (0 - 0.032)	0.227 (0.111)

[a,b] least square means in the columns with different superscripts differ significantly ($P < 0.05$). ε^2, epsilon-squared.

3.4. Self-grooming and social behaviour

A total of 3549 behavioural event counts were recorded, and the majority of behavioural events were self-grooming bouts (self-licking, 62%; self-scratching and rubbing, 22%), followed by agonistic behaviour (6%), flehming behaviour (5%), allogrooming (2%), and play behaviour and others (3%). In the morning, yaks of the central region (0.816 times per animal in 15 min) performed more self-licking than those of the western (0.419 times per animal in 15 min) and eastern region (0.294 times per animal per 15 min). Furthermore, yaks in the central and western region tended to perform more scratching and rubbing than in the eastern region ($P < 0.05$). In the morning, the number of self-licking, scratching and rubbing, adult-adult licking, and adult-young licking was different between the regions ($P < 0.05$), whereas chasing, fighting, flehming behaviour, and play were not (Table 3). In the morning observations yaks in the eastern region tended to show a slightly higher number of head butts and chasing than in the other two regions ($P > 0.05$). In the afternoon, no differences were observed for self-licking, self-scratching and rubbing, adult-adult

licking, adult-young licking, head-butts, chasing, fighting, and play between the eastern and western region (NB: for the central region only one afternoon observation was present and therefore not included in the analysis) (Table 3).

3.5. Respondent characteristics

Of the 59 yak herders approached, 52 (88%) agreed to participate in the interview. The others responded not to have time. The respondents were mainly male (81%) in the eastern and female in the central (73%) and in the western (82%) region. Most respondents were illiterate (east, 94%; central, 84%; west, 82%) and the rest had attended primary education. The median age of the respondents differed among regions (east, 55 years; central, 38 years; west, 41 years) ($P < 0.05$; $\varepsilon^2 = 0.13$) whereas herding experience (east, 31.5 years; central, 20.0 years; west, 23.0 years) did not ($P > 0.05$; $\varepsilon^2 = 0.04$). Although the median yak herd size did not differ among the regions (east, 52; central, 49; west, 50) ($P > 0.05$; $\varepsilon^2 = 0.07$), the median number of calves (east, 12; central, 4; west, 8) ($P < 0.05$; $\varepsilon^2 = 0.26$) and lactating cows was significant (east, 15; central, 6; west, 8) ($P < 0.05$; $\varepsilon^2 = 0.27$).

3.6. General management practices

All herds were reared using a free-range grazing system, and herders did not drive animals to water sources. In all herds, supplements (for example, maize flour mixed with common salt) were provided to calves, weak and lactating animals around milking provided in winter and spring. Young stock, cows and bulls had access to rangeland 24 h a day. The median number of natural running drinking sources was two. The majority of herds (east, 88%; west, 75%) had access to optical clean running drinking water sources, while the rest of the herds had at least one natural running water source qualified as partly dirty (east, 1–3 number per herd; west, 1–2 number per herd). In the central region, most herds (89%) had at least one running drinking water source qualified as dirty. In addition, in the central region, one-third of the visited yak herds also had a man-made water pond (stagnant) for their animals, all these were qualified as partly dirty or dirty.

In the central and western region, a small and simple night shelter close to the campsite was provided only for calves in winter and spring. No night shelter was provided in the eastern region. Calves were tethered and kept in the overnight shelter until morning for milking the yak cows.

In general, cows were collected from rangeland to the campsite for milking in the morning. The calves were allowed to suckle for a short time to stimulate the milk let down and then were tethered next to the cow. Cows were generally either tied to the horns or limbs with a short rope during

milking procedure. During the time of the visit, lactating yak cows were milked once a day, between 530–830 h. Except for one herd in the eastern region, no fixed milking order was followed.

3.7. Health

The majority of the respondents (east, 81%; central, 100%; west, 100%) mentioned that they experienced yak mortality over the last year (October 2017 to November 2018). Most respondents of the central and western regions stated that wild predators caused the highest mortality rate in all animal age groups (Table 4). Moreover, most respondents of the western region mentioned that the gid infestations contributed to high mortality among young animals of less than 3 years old, even though most of these herders deworm these young animals (Table 4). Some herders (east, 1; central, 16; west, 2) also expressed that they did not deworm the yaks because the animals did not show signs of sickness and diarrhoea. In addition, the majority of the respondents (central and western) said that they did not treat their animals against ectoparasites (Table 4).

Over half of the respondents stated that they sought livestock extension services whenever they were required (Table 4). The distance between the yak herds and the extension service centre probably explains why only few respondents vaccinate their yaks (east, 1 herd; central, 1 herd; west, 0 herd). Moreover, most respondents in the central (84%) and western (100%) region did also not use indigenous medicines to treat sick animals. In the eastern region about 75% respondents said that they fed aconite (*Aconitum* spp.) root extract to sick animals in general.

3.8. Painful management practices

All respondents mentioned that the herder themselves or the neighbour herders perform the painful procedures. A few young female animals received an ear tag to make their herd attractive and to make it easier to identify animals. For this, the ear of an animal is pierced by a stitching pin and the ear tag is inserted. The ear tag is made of a short bunch of yak coloured hair tail (not to be confused with a common ear tag used in cattle and pigs). In the visited herds, one to three calves per herd were ear tagged in the eastern (4 herds) and central (2 herds) region. Likewise, 1–4 cows per herd in 3 herds (east) and 1–12 cows per herd in 8 herds (central) were ear tagged. Although herders said that they weaned older calves, no animals were observed with a nose-ring or a stick inserted through the nose in the visited herds probably it was not the period to wean calves. A few respondents of the eastern region said that they weaned older calves (about 2 years old) by inserting a temporary nose ring, when the dam has calved again in the following year, and the older calf still attempted to suckle. In these cases, the calf's nasal septum is pierced by a piece of bamboo,

sharpened at the end, and then a piece of leather is stitched to the bamboo that serves as a nose-flap. In the west, most respondents said that they pierced the bull's nasal septum by a stitching pin and/or sharp knife, and then inserted a wooden stick (about the diameter of a small finger), sharpened at both ends. A nose ring is inserted into the bull's nasal septum when they are used for ploughing fields and transportation.

Table 4. Percentage of herders per answer for four health variables and painful practices for three yak farming regions.

Variables	Eastern (n = 16)	Central (n = 19)	Western (n = 17)	P-value (ε^2)
Cause of mortality [1]				
Predator	18.7	84.2	88.2	0.000 (0.430)
Disease (includes diarrhoea)	43.7	31.7	5.9	0.032 (0.120)
Gid infestation	0	0	64.0	0.000 (0.552)
Accident	0	15.8	47.1	0.002 (0.220)
Others (unknown, plant and water poison)	31.3	42.1	0	0.006 (0.61)
Frequency of livestock extension services received [2]				
Never	18.7	36.8	41.2	0.460 (0.036)
Whenever required	75	63.2	52.9	
Sometimes	6.2	0	5.9	
Frequency of deworming [2]				
Not at all	6.3	84.2	11.8	0.000 (0.706)
Once a month	0	5.3	35.3	
Once every 2–3 months	0	0	35.3	
Whenever received anthelmintic drug	0	5.3	11.7	
When animals are less active, loss appetite, diarrhoea	93.7	5.3	5.9	
Frequency of ectoparasite treatment [2]				
Not at all	43.7	94.7	88.2	0.000 (0.323)
Once every six month	0	0	5.9	
Animal rubs, or herder observe lice and ticks on yak hair	56.3	5.3	5.9	
Painful practices in a herd [1]				
Nose ringing	18.7	0	88.2	0.000 (0.643)
Ear tagging	12.5	68.4	0	0.000 (0.451)
Dehorning	0	0	6.30	0.308 (0.044)
Bull castration	93.7	100	94.1	0.527 (0.023)
Bull castration age (years) [2]				
No	6.3	0	5.9	0.000 (0.424)
2 –≤ 3	68.7	15.8	0	
3 –≤ 4	18.7	63.2	11.8	
4 –≤ 5	6.2	5.3	64.7	
5 –≤ 6	0	10.5	17.6	
Don't know	0	5.3	0	

[1]Fisher exact test. [2]Kruskal-Wallis test. NB. Multiple answers for yak mortality cause, so the total do not equal to 100%. ε^2, epsilon-squared.

In the visited herds, most respondents castrate the male yaks not used for breeding between the age of 2 and 6 years. Most herders incised the scrotum at the lower part. The testicles are then

pulled, and spermatic cords are either cut with a knife or pulled until they break. In one herd in the central region a Burdizzo device was used. Only five herders (east, 0; central, 4; west, 1) used iodine as an antiseptic after castration. Although all respondents believed that the animals have feelings and the potential to feel stress, anaesthesia and analgesics were not used during painful procedures.

All respondents named animals to identify them (east, 31.8%; central, 19.1%; west, 40.0%), gather them (east, 63.6%; central, 76.2%; west, 56.0%) and because of the traditional practice of giving name (east, 4.6%; central, 4.7%; west, 4.0%).

4. Discussion

In this study the welfare of free-ranging yaks, mainly lactating cows and suckling calves, was assessed. The main findings are that the yaks seem to be in good welfare conditions after returning from the summer rangelands and that differences in yak welfare between regions are marginal.

The yaks of the central region showed smaller avoidance distances to an unknown human than those in the other two regions. In general, avoidance distance of animals reflects on the quality and frequency of interactions between a herdsperson and the animals (Waiblinger et al., 2006, Battini et al., 2011). Unlike in the eastern and western region, the winter rangeland in the central region is connected with a main road. It could be that the yaks in the central region are more accustomed to new stimuli such as unfamiliar humans and approaching vehicles. Another reason that may affect the response of the yaks to an unfamiliar human could be the amount and type of interactions the herders have with their animals. In general, females are found to be empathetic than males, in other words, females believe in giving more care and have more positive interaction with their animals (Herzog et al., 1991, Lensink et al., 2000, Kılıç and Bozkurt, 2013). In the visited herds, more than half of the herders were female, especially in the central (73%) and western (82%) region. This probably explains why yaks in these two regions have a smaller avoidance distance to an unfamiliar human than in the eastern region. The survey also found that herders of all yak farming regions were 18 years or older because most children are send to school. In the past, children used to accompany their parents and assist in herding yaks, simultaneously obtaining all kinds of skills to take good care of the yaks. Furthermore, literate young pastoralists are less interested to take up yak farming because they view yak farming as an age-old tradition to support their livelihoods (Wangchuk and Wangdi, 2015) and they prefer to be involved in other activities such as collecting the cordyceps (*Cordyceps sinensis*) and tourism. As a consequence of access to education and access to alternative sources of income, the workload will increase for herders (parents), which may reduce

the time herders can spend on their animals and therefore bring about a less intimate human-animal relationship (Lensink et al., 2000).

Other factors that might have had an effect on the avoidance distance measurements where the feedings before milking and the way animals were collected for milking. All herders hand-fed maize flour mixed with common salt (east) or wheat flour mixed with forage such as turnips (central and west) to calves and lactating cows to achieve quick cooperation. Although the avoidance distance test for the yak cows was performed after milking, our results may be affected by this feeding (Windschnurer et al., 2008, Ebinghaus et al., 2016). In addition, all herders in the survey said that the yak cows have names and they are called by their names when gathered for milking. Studies have shown that calling cows by name and talking softly with cows during milking neutralises negative emotions of animals, such as fear of humans (Bertenshaw and Rowlinson, 2009, Lürzel et al., 2018). These all affect the animal reactions towards human.

Most yaks were clean, indicating that clean and dry areas for lying are available although no bedding was provided in the rangeland. Integument alterations were virtually absent. Observations, however, were done from a distance (3–6 m between the observer and animal) to not stress the animals, and most parts of the animal's body were covered with long hair, which impaired visual detection. Therefore, this number might be an underestimation. The low prevalence of lame yaks implicates that the management system and living conditions are of low risk for leg and claw problems. Our findings further support the benefits of yaks having free access to rangeland with respect to cleanliness, integument injuries and locomotion (Popescu et al., 2013, Zuliani et al., 2018).

A few cases of ocular discharge and absence of nasal discharge indicate low to no infections of eyes and respiratory system in the visited herds. A few visited herds (calf, 2 herds; cow, 3 herds had animals with ocular discharge above the warning threshold of 3% (Welfare Quality®, 2009). No yaks were observed with diarrhoea though some herders responded that there were a few cases of diarrhoea. These animals could have been missed by the current method of scoring or animals might have been out of sight during observations. Herders of the eastern and central region further acknowledged that diarrhoea among yaks is common in spring and summer, which may cause mortality. This is probably caused by the change of roughage intake from dry roughage with a poor nutritive value to green fresh roughages with high nutritive value (Zuliani et al., 2018). On top of that, ascaris infestation can cause diarrhoea. Most herders indicated that they do not deworm their animals or deworm only when they show signs of diarrhoea. Some yak herds (central) were grazing together with cattle in the winter rangeland, and these yaks may be at higher risk of disease

transmission, such as foot and mouth disease, bovine viral diarrhoea virus (Mishra et al., 2008) and *Cryptosporidium* spp (Qin et al., 2014). In general, bovine diseases could be a serious threat to yak health and cause economic loss to transhumant families due to morbidity and mortality.

Predators such as tiger (*Panthera tigris*), bear (*Ursus thibetanus*), snow leopard (*Panthera uncia*) and Asiatic wild dog (*Cuon alpinus*) are being mentioned by herders as the major contributor to yak mortality, and also as a cause of lesions and lameness. Herders mentioned that they only gathered the lactating cows and their calves near the campsite in the evening during the lactation period and survey the rest of the animals every 3–7 days. This lack of supervision could explain why wild predators are the most common cause of yak mortality.

Yaks exhibited a high level of synchronicity of eating during the time of our visit. An advantage of a high degree of synchronicity in a herd is that it probably allows low-ranking animals to meet the basic feeding requirement, when the majority of animals are resting (Napolitano et al., 2009). In the present study, the range of yaks eating (34% to 98%) was close to the reported 34% to 80% in free-ranging Chinese yaks (Wiener et al., 2003), but wider than the 42% to 64% in wild yaks (Buzzard et al., 2014). In our study, the difference in time spent on eating between herds could have been affected by time of a day, weather condition, forage quality and availability in the rangeland, season, and age and sex of the animals. For instance, in the central region, forage quality and quantity in the rangeland seem to be lower compared to other two regions probably because the rangelands were used by cattle as well. The poor forage quality and quantity in the rangeland might explain why the yaks in the central region spent slightly less time eating (more idling or ruminating) than in the eastern and western region (Arave and Albright, 1981, Luming et al., 2008). In winter and spring when forage is scarce, yaks have to cover large distances in search for forage to meet the daily energy requirement. When the weather conditions are worse, they reduce time spent in searching for forage to reduce energy expenditure (Liu et al., 2019). This implies how yaks adapt their grazing strategy to availability of forage and weather conditions.

The visits of the yak herds in the eastern region in October coincided with the breeding season of yaks, which is from June–November (Wiener et al., 2003). The presence of a few yak cows in oestrus during the time of our visit in the eastern region may account for the slightly higher counts of agonistic and flehming behaviour compared to the central and the western region. Still, the low percentage of observed agonistic behaviour and the presence of only few lesions in yak integuments suggests social stability in the herds or that they are able to avoid conflicts due to the large space they have. In addition, animals also perform social licking to reduce tension, besides maintaining cleanliness of their body (Sato et al., 1991).

In the visited yak herds, we found a relatively high percentage of self-grooming. Since we did not observe (very) dirty yaks it could indicate a high ectoparasite load (Mooring and Samuel, 1998). The observations on scratching and rubbing support this suggestion, because ectoparasites cause skin irritation, and thus these animals often scratch and rub body parts. Unfortunately, no observations on ectoparasites were conducted to support this observation. Herders of the central and western region, however, said that the yaks are rarely treated against ectoparasites which might explain these observations.

The traditional way of castration is an important welfare concern because the castration is carried out without administration of an analgesic. In Bhutan, herders castrate mature instead of young bulls because the herder can more easily palpate the scrotum to conduct the castration procedure. However, wounds due to castration heal slower in a mature bull, and this may prolong the pain (Norring et al., 2017). Moreover, herders daily interact with lactating yak cows and calves during milking, while the rest of the yaks are gathered and restrained only to feed salt and shear. Bulls are rarely handled by herders. When being castrated at the age of about 3 years the stress level is expected to be high as they are restrained, grounded and the castration procedure is then performed. A higher awareness among herders on the welfare impact of castration and improving surgical procedures could reduce this issue. Training provided by livestock professionals or local livestock extensionists and better access to health services can help to reduce this welfare issue.

In this study, the decision was made to evaluate the welfare of yaks once during autumn and early winter because the herds stay at one location for a longer time and the winter rangelands are easier to access than the summer rangelands, which are at a higher altitude and at very remote areas. Given that the animals are probably at the height of their welfare status in this period, because they return from the summer rangelands where good quality feed is sufficient available, the findings of this study can serve as a baseline for further studies such as how behaviours are driven by the herd hierarchy. The authors emphasis, however, that yaks should actually also be assessed for welfare in early summer after a challenging winter period with poor forage and weather conditions (Hernandez et al 2018). Potentially, herders or livestock extensionists could be trained to perform the protocol in future studies to be able to collect data year-round.

5. Conclusions

This study is the first that gives an impression of the welfare of free-ranging yaks kept in an open field under mountainous conditions. Generally, it can be concluded that yaks in Bhutan experience relatively high levels of welfare under existing management systems during autumn and early winter.

For instance, the avoidance distance to an unknown person of yak cows and calves was similar to that of farmed buffalos and extensively kept dairy cows. A relatively high amount of self-grooming, scratching and rubbing observed in some herds demonstrates the importance of treating against ectoparasites in yaks. In addition, this study identified several potential risk factors for poor welfare such as limited accessibility to veterinary services, not providing any additional winter forage, and painful procedures. We identified the traditional bull castration and piercing the nasal septum without the use of analgesia was one prominent identified welfare issue that needs attention. This study would also motivate and influence policy makers in Bhutan to explore and include welfare guidelines in the livestock development policy, which has been lacking so far.

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Appendix 1. The fixed effects results from the linear mixed model (LMM) for avoidance distance. The eastern region is the "intercept", used as the reference.

Fixed effects	Estimate	Standard error	Dendf	*t*-value	Model *P*-value
Calf					
(Intercept)	3.377	0.173	268.940	19.499	0.000
Central region	–1.538	0.215		–7.170	
Western region	–1.515	0.205		–7.401	
Lactating cow					
(Intercept)	2.944	0.184	321.430	15.979	0.104
Central region	–0.474	0.228		–2.077	
Western region	–0.250	0.183		–1.369	

Appendix 2. The fixed effects results from the generalized linear mixed model (GLMM) for touched or not touched in the avoidance distance. The eastern region is the "intercept", used as the reference.

Fixed effects	Estimate	Standard error	z value	Model *P*-value
Calf				
(Intercept)	–2.708	0.453	–5.972	0.000
Central region	0.748	0.553	1.354	
Western region	2.374	0.484	4.901	
Lactating cow				
(Intercept)	–2.082	0.371	–5.608	0.032
Central region	–1.071	0.661	–1.620	
Western region	0.493	0.363	1.360	

Appendix 3. The fixed effects results of general linear mixed model (LMM) for behavioural states in the morning (625–1200 h) and afternoon (1500–1750 h). The eastern region is the "intercept", used as the reference.

Time	Variable	Fixed effects	Value	Standard error	*t*-value	Model *P*-value
Morning	Eating	(Intercept)	1.080	0.047	23.029	0.354
		Central region	–0.076	0.076	–0.998	
		Western region	0.040	0.071	0.564	
	Lying	(Intercept)	0.228	0.463	4.922	0.090
		Central region	0.167	0.077	2.177	
		Western region	0.044	0.072	0.607	
	Standing idle	(Intercept)	0.243	0.041	5.994	0.787
		Central region	0.026	0.067	0.380	
		Western region	–0.024	0.063	–0.385	
	Walking	(Intercept)	0.279	0.029	9.591	0.004
		Central region	–0.109	0.040	–2.724	
		Western region	–0.107	0.037	–2.876	
	Other	(Intercept)	0.043	0.021	2.037	0.960
		Central region	0.003	0.034	0.082	
		Western region	0.009	0.032	0.286	
Afternoon	Eating	(Intercept)	1.115	0.048	23.113	0.190
		Western region	0.130	0.077	1.687	
	Lying	(Intercept)	0.232	0.036	6.465	0.200
		Western region	–0.107	0.067	–1.599	
	Standing idle	(Intercept)	0.278	0.034	8.093	0.083
		Western region	–0.145	0.062	–2.330	
	Walking	(Intercept)	0.234	0.031	7.526	0.257
		Western region	–0.075	0.051	–1.489	
	Other	(Intercept)	0.062	0.027	2.280	0.665
		Western region	0.015	0.024	0.629	

Appendix 4. The fixed effects results of glmmTMB model for behavioural events in morning (625–1200 h). The eastern region is the "intercept", used as the reference.

Variable	Estimate	Standard error	z value	Model *P*-value
Head butt				
(Intercept)	0.016	0.003	4.551	0.092
Central region	–0.012	0.006	–2.026	
Western region	–0.009	0.006	–1.604	
Chasing				
(Intercept)	0.041	0.008	5.452	0.080
Central region	–0.020	0.013	–1.601	
Western region	–0.024	0.012	–2.075	
Fighting				
(Intercept)	0.009	0.004	2.090	0.749
Central region	0.005	0.007	0.606	
Western region	–0.001	0.007	-0.187	
Adult-young licking				
(Intercept)	0.036	0.023	1.545	0.011
Central region	0.112	0.038	2.960	
Western region	0.059	0.035	1.662	
Adult-adult licking				
(Intercept)	0.004	0.006	0.776	0.026
Central region	0.014	0.008	1.657	
Western region	0.020	0.007	2.627	
Self-licking				
(Intercept)	0.294	0.055	5.298	0.000
Central region	0.523	0.079	6.627	
Western region	0.126	0.073	1.725	
Scratching and rubbing				
(Intercept)	0.106	0.017	6.291	0.0002
Central region	0.092	0.028	3.291	
Western region	0.097	0.026	3.685	
Flehming behaviour				
(Intercept)	0.080	0.017	4.638	0.143
Central region	–0.052	0.027	–1.915	
Western region	–0.030	0.0245	–1.209	
Play behaviour				
(Intercept)	0.016	0.003	4.887	0.131
Central region	–0.011	0.005	–2.009	
Western region	–0.005	0.005	–0.946	

Appendix 5. The fixed effects results of glmmTMB model for behavioural events in evening (1500–1750 h). The eastern region is the "intercept", used as the reference.

Variable	Estimate	Standard error	z value	Model *P*-value
Head butt				
(Intercept)	0.017	0.005	3.248	0.193
Western region	–0.013	0.009	–1.571	
Chasing				
(Intercept)	0.039	0.010	3.954	0.434
Western region	–0.014	0.017	–0.814	
Fighting				
(Intercept)	0.017	0.008	2.120	0.356
Western region	–0.014	0.014	–0.988	
Self-licking				
(Intercept)	0.273	0.064	4.290	0.356
Western region	0.144	0.110	1.308	
Adult-young licking				
(Intercept)	0.059	0.038	1.578	0.058
Western region	0.123	0.062	1.999	
Adult-adult licking				
(Intercept)	0.003	0.002	1.902	0.995
Western region	–0.003	0.002	–1.401	
Scratching and rubbing				
(Intercept)	0.123	0.031	4.000	0.349
Western region	0.056	0.053	1.041	
Flehming behaviour				
(Intercept)	0.070	0.017	4.024	0.689
Western region	0.013	0.030	0.431	
Play behaviour				
(Intercept)	0.039	0.012	3.299	0.131
Western region	–0.028	0.020	–1.417	

Appendix 6. The percentage of health variables per herd assessed in three yak farming regions (median and min–max).

Variables	Eastern (*n* = 17)	Central (*n* = 19)	Western (*n* = 20)	Model *P*-value
Lesions				
Calf body area	0 (0 - 8)	0 (0 - 7)	0 (0 - 12)	0.79
Calf hind limb	0 (0 - 0)	0 (0 - 0)	0 (0 - 10)	0.41
Calf fore limb	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.00
Lactating cow body area	0 (0 - 8)	0 (0 - 17)	0 (0 - 8)	0.86
Lactating cow hind limb	0 (0 - 4)	0 (0 - 50)	0 (0 - 0)	0.57
Lactating cow fore limb	0 (0 - 4)	0 (0 - 0)	0 (0 - 0)	0.32
Dirty				
Calf body area	0 (0 - 5)	0 (0 - 50)	0 (0 - 8)	0.28
Calf hind limb	0 (0 - 5)	0 (0 - 50)	0 (0 - 5)	0.16
Lactating cow body area	0 (0 - 20)	0 (0 - 17)	0 (0 - 13)	0.13
Lactating cow hind limb	0 (0 - 10)	0 (0 - 17)	0 (0 - 0)	0.29
Ocular discharge				
Calf	0 (0 - 4)	0 (0 - 0)	0 (0 - 0)	0.10
Lactating cow	0 (0 - 4)	0 (0 - 25)	0 (0 - 0)	0.31
Nasal discharge				
Calf	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.00
Lactating cow	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.00
Diarrhoea				
Calf	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.00
Lactating cow	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.00
Hip bone visible				
Calf	0 (0 - 0)	0 (0 - 0)	0 (0 - 25)	0.05
Lactating cow	0 (0 - 6)	0 (0 - 0)	0 (0 - 18)	0.38
Lame				
Calf	0 (0 - 0)	0 (0 - 20)	0 (0 - 25)	0.41
Lactating cow	0 (0 - 17)	0 (0 - 0)	0 (0 - 7)	0.58

Chapter 4

The future of yak farming from the perspective of yak herders and livestock professionals

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Abstract

The declining number of yak farming families is perceived as a socio-political and economic concern in Bhutan. However, there is limited understanding of what influences herders' plans and decisions on yak farming. We studied factors determining future perspectives of yak farming by interviewing yak herders and livestock professionals. We analysed relationships between herders' characteristics and level of concerns, and future plans related to yak farming. Furthermore, relationships between level of concern and future plans were analysed. Most of the herder characteristics did not influence their future plans with yak farming. Age and level of perceived concern of the herders was associated with their wish for their children to continue yak farming in the future. Nevertheless, they expect that the number of yak farming families will decline in the next ten years. Additionally, most of the livestock professionals believe that the number of yak farming families will decline in the future. No differences were observed between the aggregated score of concern of herders and livestock professionals. The most important factors threatening the future of yak farming in Bhutan according to herders and livestock professionals are forage shortage, predation and no successor to take up yak farming.

Keywords: yak farming; future; opinions, perceived concern; sustainability

1. Introduction

Yak is the main source of livelihood for transhumant pastoralists residing 2500 m above sea level in 10 northern districts of Bhutan. In transhumance systems, herders migrate with their yak herds between summer and winter rangelands to maximize forage availability, while their families remain in permanent villages (Allen et al., 2011). Yaks are kept mainly for milk and meat purposes, and in some areas yak bulls are used as a draft animal to plough agricultural fields. Besides, the transhumance pastoralism system maintains socio-cultural landscapes, which often have spiritual importance to the wellbeing of the community and is assumed to preserve biodiversity in the mountains (Gyamtsho, 2000). Furthermore, the unique cultural identity of yak-based communities supports tourism, which generates high revenues to Bhutan (Suntikul and Dorji, 2016). However, there are numerous challenges that yak herders face, such as declining labour availability, low forage availability in the rangeland, yak mortality, and limited access to the market to sell yak products (Derville and Bonnemaire, 2010, Wangchuk and Wangdi, 2015, Joshi et al., 2020). The numerous challenges to yak farming have continued to increase over the years due to socioeconomic developments, changing policies (Wangchuk and Wangdi, 2015, Dorji et al., 2019a, Joshi et al., 2020) and climate change (Wangchuk and Wangdi, 2018).

Socioeconomic developments have impacted yak-based transhumant pastoralists at family level. While acknowledging that modern education for younger pastoralists is important to develop skills and knowledge to improve living standards, a lack of awareness and incentives for them to stay in their village to take over yak farming means they will migrate from villages to urban areas where they can find better services and facilities (Wangchuk and Wangdi, 2015, Wangdi, 2016). In addition, both young and adult family members prefer to be engaged in other activities than yak farming, such as collecting the mushroom cordyceps (*Cordyceps sinensis*) and medicinal plants, which gives them a relatively high economic return (Wangchuk and Wangdi, 2015, Wangdi, 2016, Dorji et al., 2019a). In addition, the policy to increase food safety in Bhutan has led to the import of cheap dairy products and to non-yak dairy development. Both are mentioned as threats to the sale of yak products (Phuntsho and Dorji, 2016).

Policy developments and climate change affect forage availability. For example, regulations that prohibit herders from burning and removing shrubs on rangelands (*Forest and Nature Conservation Act* of 1995), a method that was effective to control shrubs and maintain forage production on the rangelands in the past (Phuntsho and Dorji, 2016), were instated. This has become more urgent due to climate change which causes shrub proliferation due to warming and lengthening of the

growing season (Wangchuk and Wangdi, 2018). Other regulations related to nature conservation affect yak farming by an increase of human-wildlife conflicts (Dorji et al., 2019a).

Hence there are many reasons to expect yak farming to decline in the near future. Policy makers perceive the decline in yak farming as a socio-political and economic concern to Bhutan. In order to find a solution within the context of these socioeconomic developments and regulations to maintain yak farming in Bhutan, interventions to support these communities may be needed. In order to understand where to target the new policies, the perceived level of concern regarding these factors affecting the yak farming practices from yak herders' and livestock professionals' perspective need to be known. Since there are regional differences in yak farming, constraints and level of concern on factors might be different. Moreover, demographic factors including age, gender, education, herd size, source of income are used to assess management practices of farmers and decisions in farming (Corner-Thomas et al., 2015, Cornish et al., 2016, Myeni et al., 2019). We hypothesised that the perceived level of concerns of factors that affect yak farming practices is likely to be associated with herders' demographics and regional differences. We also hypothesised that herders who are more concerned about factors that affect yak farming are more likely to quit yak farming in the future. Therefore, this study builds on the previous efforts of Dorji et al. (2019a), and assesses the factors that determine the future of yak farming from the perspective of yak herders and livestock professionals.

2. Materials and methods

2.1. Study area

Bhutan has 10 districts with in total 25 *geogs* (blocks) where yak farming is operated (DoL, 2007). Yak-based communities in Bhutan can be classified into three regions based on specific types of yak cheese produced, cattle–yak hybridisation practice, and source of income (Derville and Bonnemaire, 2010). Three yak farming blocks matching the different yak farming regions were visited: Merag (eastern region), Saephu (central region), and Laya (western region) as shown in Table 1. In Bhutan, blocks are the local administrative unit. One block consists of several villages. These three blocks were maximal one day walk from the nearest road and they were located over 3000 m above sea level (masl). Hereafter, we will use the name of the regions (east, central, west) instead of the name of the blocks for the sake of convenience. Detailed information required about villages and yak herders to be visited in each block was gathered either from local livestock extensionists or obtained from Livestock Statistic (DoL, 2007).

Table 1. Descriptions of yak farming regions.

Region	Block	Altitude (masl)	Coordinates	Source of income	Yak dairy products
East	Merag	3215	27°17'49.20" N 91°50'6.00" E	Yak, cattle and cattle–yak hybrids, sheep, medicinal plants	Butter, cheese (fermented and fresh)
Central	Saephu	3500	27°29'10.14" N 89°53'56.94" E	Yak, cattle and cattle–yak hybrids, cordyceps, medicinal plants, vegetables (potatoes, cabbages)	Butter, cheese (dried and fresh)
West	Laya	3800	28°04'00.00" N 89°41'00.00" E	Yak, horse, tourism, cordyceps, medicinal plants, agriculture (buckwheat, mustard)	Butter, cheese (dried and fresh)

2.2. Data collection

During the field visit, a verbal consent was obtained from the yak herders taking part in the study. Sixty-seven herders (east, $n = 25$; central, $n = 20$; west, $n = 22$) were interviewed face to face using a semi-structured questionnaire. In the western and central region, the Bhutanese national language was used to interview the herders, which was translated from English by a qualified local translator. In the eastern region the local dialect called *sharchopkha* was used, which was translated by the interviewer, who is a native speaker of this dialect. The semi-structured questionnaire consisted of two sections (Table 2):

- Respondent's perceived level of concern about factors related to yak farming challenges.
- Respondent's future plans with developing yak herd size in the next 10 years, their wish for their children to continue yak farming, and their opinion on the number of yak farming families in the next 10 years.

Besides yak herders, 2 yak researchers and 26 local livestock extensionists working with yak-based communities were interviewed face to face ($n = 2$) or using email ($n = 26$). The questions included the respondents' perceived level of concern of factors and opinions on the number of yak farming families in the next 10 years (Table 2). Details about the data collection procedure can be found in non-published material (Dorji et al., unpublished).

The questionnaire for the yak herders was tested with three yak herders of the Tsento yak farming block (which were not included in the analysis), while the questionnaire for livestock professionals was tested with two BSc students of College of Natural Resources who worked with yak-based communities to check for problems in the questionnaire design, such as unclear wording, sensitive

questions, and misinterpretation of questions. The revised version of the questionnaire was used to interview yak herders and livestock professionals.

Table 2. Variables and descriptions used to determine the factors affecting the herders' future plans and decisions on yak farming.

Variables	Description of topics addressed
Independent	
Yak farming region	East, central, west.
Respondent's sex	Male, female.
Respondent's age	Years
Respondent's education	Illiterate (cannot read and write), literate
Number of yak herders	One, more than one person involved in yak farming
Size of yak herd owned	Total number of yaks owned by the herder.
Preferred source of income	Yak farming, other (cordyceps collection, tourism, cattle and cattle–yak hybrid farming, small business)
Dependent	
Concern factors related to yak farming [1]	Are you concerned about [a concern factor] in relation to yak farming practices? 4-point Likert-scale: 1 = not at all concerned, 2 = to a small extent concerned, 3 = to a moderate extent concerned, 4 = to a large extent concerned, 0 = I don't know. Concern factors questioned are: yak population size in the community, summer forage availability, winter forage availability, water availability, access to a high-quality breeding bull, conception rate of yak cows, yak body size, milk yield, prevalence of diseases and parasites, access to veterinary and extension services, predation, market situation, labour availability, successor to continue yak farming, number of yak farming families, and training availability to improve yak farming.
Future plan with herd size	What is your plan with respect to the yak herd size in the next 10 years? Binary variable: 0 = definitely decrease, probably decrease, or maintain the same, 1 = probably increase, or definitely increase.
Wish for their children to continue yak farming	Do you wish your children to continue yak farming? Binary variable: 0 = definitely no, probably no, or unsure, 1 = probably yes or definitely yes.
Future trend of yak farming families	How do you see the number of yak farming families developing in the next 10 years? Binary variable: 0 = definitely decrease or probably decrease, 1 = or remain same, probably increase, or definitely increase.

[1]Also used as independent variable for yak herders' future plans and decisions on yak farming.

2.3. Characteristics of the herders

The proportion of male/female respondents was 76%/24% (east), 40%/60% (central), and 34%/56% (west). The age of respondents (mean ± s.e.m) was 49.1 ± 3.1 (east), 41.9 ± 2.8 (central) and 39.7 ± 3.1 (west) years. The majority of the herders were illiterate (east, 73%; central, 80%; west, 88%) Dorji et al. (unpublished). The average yak herd size was 54.6 ± 5.8 (east), 47.4 ± 4.7

(central) and 49.8 ± 8.6 (west). More than half of the respondents preferred choice of livelihood was yak farming (east, 54%; central, 71%; west, 65%) (Dorji et al., unpublished).

2.4. Data processing and analyses

All statistical analyses were performed in R-Studio (version 3.5.0). The characteristics, perceived concerns on factors affecting yak farming practices (called concern factors hereafter), and future plans and decisions on yak farming of the yak herders used in the analyses are shown in Table 2. The internal consistency of the 16 concern factors affecting yak farming was checked using Cronbach's alpha. The Cronbach's alpha coefficient ($\alpha = 0.81$) showed that the question items had an acceptable internal consistency (Gliem and Gliem, 2003).

Descriptive statistics were computed for all variables. Medians were determined for the 16 factors of concern related to yak farming. Next, deviations from the medians were calculated by subtracting the median from the individual rates of each respondent. The aggregated score was computed by summing the deviations from the median of 16 concern factors. A 'zero' value was used when the original response was 'don't know', to prevent an effect of this answer on the aggregated score. The aggregated score of concern was calculated because we expect that some respondents have more concerns than others, which may be explained by personality traits and attitudes and perceived risk of the respondents (Adler et al., 2019). For example, herders with a neurotic profile tend to be nervous, easily depressed, fearful, highly sensitive, and insecure (Willock et al., 1999) and therefore they might potentially be more concerned. The aggregated score of concern was tested for normality and homogeneity of variance. The quantile-quantile plot and Shapiro–Wilk's test showed that the aggregated score of concern was normally distributed ($P > 0.05$). Additionally, the Levene's test indicated that the aggregated score of concern met the assumption of homogeneity of variance ($P > 0.05$). Multiple linear regression was used to examine whether the characteristics of the respondents or region influenced the aggregated score of concern. The residual plots did not indicate evidence of poor fit of the model. In regression modelling, correlation among explanatory variables is undesirable because the standard errors of coefficients can be overestimated, which may affect the regression results (Daoud, 2017). Thus, variance inflation factors (VIFs) were used to detect multicollinearity between explanatory factors (O'brien, 2007) using the package "vif" in R. VIFs more than 5 were considered unfavourable (Daoud, 2017), and were removed from the final model.

The Likert-type items used to get insight into the herders' future plans and decisions on yak farming were converted to a binary variable (Table 2) because there were only a few respondents who

selected a specific answer option. For example, only 4 of 67 herders planned to decrease their herd size in the next 10 years (detail in Appendix 1). The response 'don't know' was excluded from the analysis. Binary logistic regression was used to test the relationships between the respondent's characteristics and their future plans and decisions on yak farming (plans with developing yak herd size in the next 10 years, their wish for their children to continue yak farming, and their opinion on the number of yak farming families in the next 10 years). The Hosmer–Lemeshow goodness of test was used to assess the model using the package generalhoslem (Jay, 2019) and a confusion matrix was used to check the model accuracy using the package caTools in R (Tuszynski, 2020). Furthermore, model fitness was assessed by calculating McFadden's pseudo R^2 (Hu et al., 2006). Further, the point-biserial correlation (Cureton, 1956) was used to test whether the aggregated score of concern was associated with the herders' future plans and decisions on yak farming. The Fisher exact test was used to evaluate the association between herder's plans with developing yak herd size in the next 10 years and their wish for children to continue yak farming, and the opinion on the number of yak farming families in the next 10 years.

The Wilcoxon–Mann–Whitney test was used to examine the differences between yak herders' and livestock professionals' aggregated score of concern, while the Fisher exact test was used to check if the opinion of herders on the number of yak farming families differed from the opinion of livestock professionals.

3. Results

3.1. Concern factors related to yak farming

The majority of the herders expressed that the forage availability in rangelands (86.6%), predation on yaks (88.0%), and presence of a successor (72.6%) are concern factors to yak farming. Regional differences were found for availability of high-quality breeding bulls (central, 75%), smaller body size of adult yaks over generations (east, 80.0%; central, 75.0%), prevalence of diseases and parasites (east, 76.0%; west, 68.0%), and access to veterinary services (east, 84.0%). Similarly, livestock professionals perceived forage shortage (83.0%), availability of high-quality breeding bulls (89.3%), predation on yaks (92.9%), labour availability to herd yaks (92.8%), and lack of training to improve yak farming (89.3%) as concern factors to yak farming. The yak herder's and livestock professionals' perceived level of concerns of factors related to yak farming is included in Appendix 2. Although no difference was observed between the aggregated score of concerns of herders and livestock professionals ($\chi = 1.86$, $P = 0.06$) (Figure 1), the concern level for individual factors to yak farming practices is different.

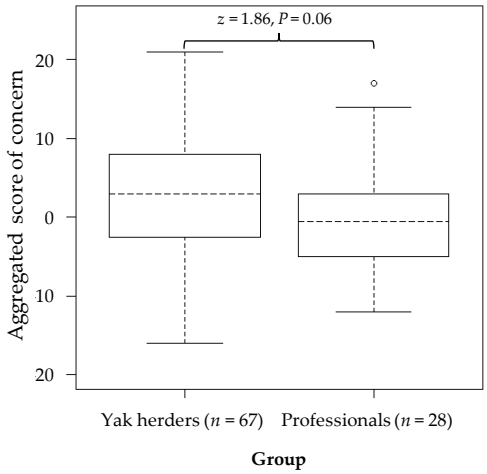

Figure 1. Respondents' aggregated score of concern factors to yak farming.

The herders' sex, education, age, and the region did not influence their aggregated score of concern ($P > 0.05$), but size of the herd owned was positively related with the aggregated score of concern ($P = 0.04$). The herders' aggregated score of concern to yak farming is likely to increase (odds ratio = 1.07) with a unit increase in current yak herd size (Table 3).

Table 3. Multiple linear regression results for variables influencing the aggregated score of concerns related to yak farming.

Variable	Coef.	SE	*t* value	$P > \|t\|$	Odds Ratio	VIF
Region east (intercept)	2.34	5.51	0.42	0.67	10.39	
Region central	−2.29	2.46	−0.93	0.35	0.10	1.36
Region west	−2.97	2.63	−1.13	0.26	0.05	
Sex female	−0.07	2.35	−0.03	0.97	0.93	1.47
Age	−0.04	0.09	−0.49	0.62	0.96	1.69
Education literate	−1.56	2.94	−0.53	0.60	0.21	1.46
Size of the herd owned	0.07	0.03	2.13	0.04*	1.07	1.13
More than one herder involved in herding	0.61	2.15	9.28	0.78	1.84	1.20
Prefer source of income (others)	−0.11	2.10	−0.05	0.96	0.89	1.10

Number of observations = 67; $R^2 = 0.12$; * significance at $P < 0.05$. Coef. = coefficient; SE, standard error; VIF, variance inflation factor.

3.2. Herders' future plan with herd size

Half of the herders planned to increase the current yak herd size in the next 10 years. The reasons they mentioned were earning more income through sales of yak products (e.g. cheese, meat, sell live animals, hair products) and that it is a reliable source of income while other activities such as cordyceps collection are not (Table 4). Some herders plan to maintain the current herd size because

it is able to meet the family daily household requirements, family labour is sufficiently present, and there is no successor to take over yak farming. A few herders responded to decrease the current yak herd size because of experiencing forage and labour shortage (Table 4).

Table 4. Yak herders' (n = 67) plans on the development of their herd size in the next 10 years.

Plan	Reasons	Respondents (n)
Increase herd size (n = 39) [1]	Yak has multiple functions and generates therefore more income	27
	Yak farming is a traditional way of life	6
	Other (measure to cope with high mortality due to predation, if more rangeland is available, social status)	8
Maintain same herd size (n = 21) [1]	Selling yak products meet the daily household requirements	12
	Family labour is sufficient present	10
	Rangeland owned by family is sufficient for current herd size	7
	No successor but yak farming is the main livelihood	5
	Yak farming is a traditional way of life	1
Decrease herd size (n = 4)	No successor	3
	Forage shortage	1
Not sure (n = 3)		3

[1] Respondents could give multiple reasons.

The characteristics of the herders had no effect on their future plans with regard to herd size (Table 5), but the association between region and herders' plans on the development of their herd size was stronger in the western region than the eastern and central regions (average marginal effect, AME = 0.43). Moreover, the herders' plans on the development of their herd size in the next 10 years was not associated with the aggregated score of concern (t = −0.28, r_{pb} = −0.04, P = 0.78).

Table 5. Binary logit model results for variables influencing the herders' plans on the development of their herd size in the next 10 years.

Variable	Coef.	SE	z value	$P > \|z\|$	Marginal Effects		VIF
					Average	SE	
Region east (intercept)	1.40	1.45	0.97	0.33			
Region central	0.33	0.65	0.48	0.63	0.08	0.16	1.44
Region west	2.27	0.87	2.61	0.01*	0.43	0.13	
Sex female	−0.80	0.72	−1.11	0.27	−0.15	0.13	1.53
Age	−0.03	0.02	−1.20	0.23	−0.01	0	1.44
Education literate	−0.29	0.77	−0.37	0.71	−0.05	0.15	1.21
Size of the herd owned	0	0.01	0.32	0.75	0	0.32	1.11
More than one herder involved in herding	0.05	0.62	0.08	0.93	0.01	0.12	1.18
Prefer source of income (others)	−0.45	0.62	−0.71	0.48	−0.09	0.13	1.10

Number of observations = 64; Hosmer and Lemeshow test $\chi^2(8) = 4.31$ (P = 0.83); Correct prediction = 70.31%; McFadden Pseudo R^2 = 0.15; * significance at $P < 0.05$. Coef. = coefficient; SE, standard error; VIF, variance inflation factor.

3.3. Herders' wish for their children to continue yak farming

The majority of the herders (82%) wish their children to continue yak farming in the future because they consider yak farming a reliable source of income and give importance to the traditional way of life (Table 6). Some herders also mentioned that the children have to make their own choice or should not continue yak farming in the future, with the argument that yak farming is a tough way of living and the herders usually have to endure a lonely life when at the summer rangelands. A few herders were unsure whether they wish their children to continue yak farming in the future.

Table 6. Yak herders' (n = 67) wish for the children to continue yak farming in future (yes/no) and their opinion on number of yak farming families in the next 10 years.

Opinions	Reasons	Respondents (n)
Wish for the children to continue yak farming in the future		
Yes (n = 55) [1]	Yak farming is a reliable source of income	38
	Yak farming is a traditional way of life	17
	Children are interested to continue yak farming	1
	Depends on children as it is a challenging occupation	3
Not sure (n = 8)	Depends on children as it is a challenging occupation	8
No (n = 4)	Forage shortage	1
	Yak farming is a challenging occupation	3
Number of yak farming families		
Increase (n = 13) [1]	Yak herd division among family members	7
	Yak farming is a reliable source of income	4
	Government support to yak farming	3
	Children are interest to continue yak farming	1
Remain same (n = 8)	Yak farming is a traditional life style	4
	Rangeland owned by a family is sufficient	3
	Yak farming is a reliable source of income	1
Decrease (n = 39) [1]	Easy lifestyles at towns (challenging occupation)	37
	Others (forage shortage, yak mortality, alternate income)	7
Don't know (n = 7)		7

[1] Respondents could give multiple reasons.

The age of the herder had a significant positive effect on the wish for their children to continue yak farming in the future (P = 0.03), but sex, education, size of the herd owned, and region did not (Table 7). This relation indicates that when the herder's age increases their wish for children to continue yak farming is likely to increase (AME = 0.01). Moreover, the association between region and herders' wish for their children to continue yak farming was stronger in the western region than in the eastern and central region (AME = 0.25). Additionally, the herders' wish for their children to continue yak farming was positively associated with their aggregated score of concern (t = 2.89, r_{pb} = 0.34, P = 0.01).

Table 7. Binary logit model results for variables influencing the herder's wish for their children to continue yak farming.

Variable	Coef.	SE	z Value	$P > \|z\|$	Marginal Effects		VIF
					Average	SE	
Region east (intercept)	−3.54	2.21	−1.60	0.11			
Region central	0.02	0.81	0.03	0.98	0	0.13	1.60
Region west	2.44	1.19	2.04	0.04 *	0.25	0.11	
Sex female	−0.42	0.84	−0.50	0.62	−0.05	0.11	1.45
Age	0.08	0.04	2.13	0.03*	0.01	0	1.53
Education literate	−0.17	0.90	−0.19	0.85	−0.02	0.12	1.31
Size of the herd owned	0.03	0.02	1.34	0.18	0	0	1.22
More than one herder involved in herding	0.67	0.80	0.83	0.40	0.08	0.09	1.22
Prefer source of income (others)	0.03	0.82	0.04	0.97	0	0.10	1.28

Number of observations = 67; Hosmer and Lemeshow test $\chi^2(8) = 7.20$ ($P = 0.51$); Correct prediction = 82.09%; McFadden Pseudo $R^2 = 0.22$; AIC = 69.44; * significance at $P < 0.05$. Coef. = coefficient; SE, standard error; VIF, variance inflation factor.

3.4. Number of yak farming families in 10 years

Of the herders 58% of the herders believed that the number of yak farming families will decline in the next 10 years, because young and adult family members will continue to migrate to towns looking for better economic opportunities and easy lifestyles (Table 6). Another reason mentioned by herders was a decreasing forage availability and an increasing predation on yaks, which might discourage yak farming families to continue in the future. In contrast, youth outmigration from their villages ($P = 0.00$) is believed by most livestock professionals (96%) to negatively affect the number of yak farming families in the next 10 years. A few herders also think that the number of yak farming families will remain the same in the future because current yak farming families are those who own adequate rangeland. Some herders (east, $n = 7$) think that the number of yak farming families will increase in the future because of traditional practices of dividing the yak herd among the family members in these communities (Table 6). In addition, a few herders of the central ($n = 1$) and western ($n = 2$) regions think that governmental support might encourage yak farming and increase the number of yak farming families in the future.

Table 8 shows that the herders' characteristics and the region did not influence their opinion on the number of yak farming families in the next 10 years ($P > 0.05$). Moreover, the herders' aggregated score of concern was not associated with their view on the number of yak farming families in the next 10 years ($t = -0.38$, $r_{pb} = -0.05$, $P = 0.70$). In contrast, a negative association was observed for the livestock professionals' aggregated score of concern and their opinion on the number of yak farming families in the next 10 years ($t = -2.15$, $r_{pb} = -0.39$, $P = 0.04$). The result

indicates that when the livestock professionals' aggregated score of concern increases, the odds of thinking that the number of yak farming families will decline in the next 10 years increases. The herders' opinion on the number of yak farming families in the next 10 years differed from livestock professionals ($P = 0.00$).

Table 8. Binary logit model results for variables influencing the herders' opinion on the number of yak farming families in the next 10 years.

Variable	Coef.	SE	z Value	$P > \|z\|$	Marginal Effects		VIF
					Average	SE	
Region east (intercept)	−0.50	1.33	−0.38	0.71			
Region central	−1.07	0.71	−1.49	0.13	−0.24	0.15	1.54
Region west	−1.03	0.81	−1.27	0.20	−0.23	0.17	
Sex female	0.32	0.68	0.47	0.64	0.07	0.14	1.44
Age	0	0.02	−0.09	0.92	0	0	1.48
Education literate	0.96	0.80	1.20	0.23	0.21	0.18	1.41
Size of the herd owned	0.01	0.01	0.88	0.38	0	0	1.23
More than one herder involved in herding	0	0.62	0	1	0	0	1.20
Prefer source of income (others)	−0.39	0.63	−0.06	0.53	−0.08	0.13	1.11

Number of observations = 60; Hosmer and Lemeshow test $\chi^2(8) = 3.76$ ($P = 0.88$); Correct prediction = 66.67%; McFadden Pseudo $R^2 = 0.06$; AIC = 91.92. Coef. = coefficient; SE, standard error; VIF, variance inflation factor.

3.5. Association between the herders' plans and decisions on yak farming

Herders' plans on the development of their herd size was not associated with their wish for their children to continue yak farming and their opinion on the number of yak farming families in the next 10 years ($P > 0.05$). Additionally, no association between the herders' wish for their children to continue yak farming and their view on the number of yak farming families in the next 10 years was observed ($P > 0.05$).

4. Discussion

This study aimed to deepen our understanding of the relationship between (perceived) level of concern, future plans and herders' characteristics for yak farming in Bhutan.

Herders' characteristics, the region, and the herders' aggregated score had no relation with herders' opinion on the number of yak farming families in the next 10 years, which contradicts with our expectation. Our hypothesis on the decreasing number of yak farming families comes from Wangchuk and Wangdi (2015). Wangdi (2016) further reports that the age of herders affects the opinion on future of yak farming. The fact that no relation between the age of herders and their

opinions was found in this study may be explained partly by the differences in analysis approach. The age of the herders was treated as a continuous variable in the logistic regression, while Wangdi (2016) probably used age as categorial variable (young and elderly) to investigate whether age and their opinion on future of yak farming was related. In addition, we took into account more than one factor that may be associated with the opinion of the herders on the number of yak farming families in the future, so logistic regression is an appropriate approach (Peng et al., 2002, Cassidy, 2005). If the aggregated score of concerns and characteristics of the herders do not appear to affect the opinion on the number of yak farming families in the future, then possibly the motivation of a person (Ryan and Deci, 2000, Kollmuss and Agyeman, 2002, Edwards-Jones, 2006, Warren et al., 2016, Bukchin and Kerret, 2018), risks perceived by a person (Warren et al., 2016, Adler et al., 2019), and/or current situation and constraints (Kollmuss and Agyeman, 2002) do. Therefore, further analysis is required to examine relationships between aforementioned variables to deepen our understanding on future trends of yak farming. Furthermore, the R^2 and pseudo R^2 of the models are low but significant (Tables 3 and 5). They indicate that even if the dependent variable was associated with the predictor when other predictors in the model are held constant (Frost), there are other potential important factors affecting the herders' plan and decision on yak farming that were excluded in the model such as personality traits. The pseudo R^2 of 0.22 (in Table 7) indicates a good model fit (McFadden, 1979).

A substantial number of yak herders (east, 48%; central, 70%; west, 55%) said that the number of yak farming families will decrease in the next 10 years. Except for one, livestock professionals agreed that outmigration of the villages to towns and cities is the main reason. We single out the youth outmigration from the villages as the main potential threat to yak farming in the future due to access to education for children of yak-based communities and economic opportunities. In other studies by Dorji et al. (2019a) and Phuntsho and Dorji (2016), it was shown that the younger generation of the yak-based families indeed had less interest to take up yak farming and prefer to migrate to towns and cities, which offer better amenities. Another study reported that the number of yak farming families has declined by ~31% from 1400 in 1996 to 968 in 2013 in Bhutan (Wangdi, 2016). They indicate that this is probably due to outmigration leading to no successor and labour shortage. A similar decline in the number of the transhumance families by 35 to 50% was reported in Nepal (Tiwari et al., 2020). The increasing youth outmigration from the villages was also reported in other parts of Bhutan (Walcott, 2009, Lorway et al., 2011) and other transhumant communities in other countries (Oteros-Rozas et al., 2013b, Aryal et al., 2014, Jurt et al., 2015, Joshi et al., 2020, Tiwari et al., 2020), affecting rural development and also leading to the loss of unique cultural traditions of the yak-based communities. Thus, a decreasing number of successors to take over yak

farming is a policy issue, which requires governmental interventions when one wants to stop this process. One strategy is to provide good facilities (e.g. communication services, health services, upgrade schools) that should encourage younger literate pastoralists to stay in the yak farming business. However, some interventions by the government would also have to identify priorities of different stakeholders in addition to yak herders. For instance, yak farming communities request to revise the *Forest Act* by allowing them to conduct prescribed burning of rangelands to control shrub proliferation (Wangdi, 2016), while the Department of Forest and Park Services aims to strengthen conservation of biodiversity in protected areas and does not want to allow burning of rangelands.

Although more than half of the herders think yak farming will decline, most herders wish their children to continue yak farming in the future. The reason given by herders was that they view yak farming more like a traditional way of life than a profession, which was also the feeling expressed by transhumant herders in other countries (Bhasin, 2011, Oteros-Rozas et al., 2013a). Herders said that yak farming is their culture and tradition and so it is their and their children's responsibility to keep yak farming alive. Younger generations, however, were not interviewed to ascertain that they are not interested in yak farming. Bernués et al. (2011) indicated that having children in the farming family and successors willing to take over farming should be the core focus when assuring the sustainability of transhumant pastoralism systems. Moreover, the positive association between herders' aggregated score of concern and their wish for children to continue yak farming in the future perhaps explains the confidence herders have in yak farming as a reliable source of income and the perceived responsibilities to maintain their unique culture and tradition.

We also found that herders of the western region had a stronger wish for their children to continue yak farming and planned changes in herd size in the next 10 years than in the other two regions. This observation is interesting because cordyceps collection (western and central region) and horses used in tourism and transportation (western region) are a very lucrative occupation compared to yak farming (Wangdi, 2016), which has less economic return and is a challenging occupation. Two reasons probably explain why most herders in the western region wish their children to continue yak farming. First, the Bhutanese government has legalised cordyceps collection in 2004 to encourage yak-based communities to stay active in the mountains and maintain keeping yaks, which might be a successful strategy in this region. Second, herders of the central and western region expressed that cordyceps yield and quality has declined compared to the past and they view yak farming as a reliable source of income, which was consistent with previous studies in Bhutan (Wangchuk and Wangdi, 2015, Wangdi, 2016). The decreased cordyceps quality and quantity was also reported in other Himalayan countries because of over exploitation of the resources (Winkler,

2013, Hopping et al., 2018), so the perception of the herders could be accurate. This implies that the government should explore novel alternative livelihoods for yak-based communities and assure better prices for their yak products to encourage pastoralists to stay in yak farming business, but it does not necessarily guarantee sustainable yak farming. For future research, we suggest studying the willingness of the younger generation of yak-based communities to take up yak farming in the future, and the related requirements.

The present study observed a very weak association between the herders' wish for their children to continue yak farming in the future and their plan on the development of herd size in the next 10 years. This could be because the herders' plans on the development of herd size greatly depend on other important factors, such as forage availability (Nawaz et al., 2016), the social purpose of keeping yaks (e.g. social symbol of the family), or for the future generation (Mulder et al., 2010) than the herder's characteristics in our study. From our survey, some herders mentioned that they would expand their yak herd size to cope with losses due to predation which they mentioned has increased over the years. A similar increase of wild predation on yaks was reported in the Ghunsa valley in Nepal (Sherchan and Bhandari, 2017). A few herders (n = 3) also stated that whether they keep a small or large herd size, they should look after them anyway, so they plan to expand their herd size in the next 10 years. Elsewhere, the expansion of herd size is a strategy to reduce risk under the challenging living environment and climate change, such as in the Saami reindeer herders in Norway (Næss and Bårdsen, 2010) and pastoral herders in northern Kenya (McPeak, 2005). Nevertheless, probabilities of yak herders to remain with yak farming are higher when they plan to expand their herd size, based on the assumption that they do not experience resource and management constraints, such as labour and forage shortage. Ondersteijn et al. (2003) reported that the age is negatively related to growth of dairy herd size. The young farmers who have just taken over the farms are in effort to meet their financial needs, while the experienced farmers have a stable herd size that maintains a stable income.

Our cross-sectional analysis indicated that the herders' aggregated score of concern was positively associated to the size of herd owned. A possible explanation is that herders become more concerned to meet forage and labour requirements and other management with increasing herd size (Gray, 2009, Gargiulo et al., 2018). In this context, it is important to get insight into which factors require immediate attention or even an intervention. For example, our survey results showed that the forage availability in rangelands (east, 86%; central, 87%; west, 91%), predation on yaks (east, 84%; central, 85%; west, 95%), and presence of a successor (east, 72%; central, 80%; west, 68%) were a concern in all visited regions.

Although herders' aggregated score of concern did not differ from livestock professionals', their opinions on the number of yak farming families in the next 10 years differed. It could be that many herders will continue yak farming for another 10 years as their average age was 41 years. Whereas livestock professionals might have learnt and/or heard during meetings that the younger pastoralists have no interest in yak farming and they think that number of yak farming families will decline in the future because of no successors. Nonetheless, more than half of the respondents (herders and livestock professionals) view that the number of yak farming families will decline in the future.

5. Conclusions

To our knowledge, this is the first kind of study unravelling the factors that affect the future for yak farming in Bhutan from the perspective of herders and livestock extensionists. We conclude that not many herders' characteristics were associated with perceived concerns and the future plans and decisions on yak farming as was hypothesised, but probably there are other factors such as the motivation of a person in farming and risks perceived by a person. Nevertheless, our work underscores that policy makers should consider and incorporate factors that associate with perceived concerns such as forage shortage, predation, and decreasing successor to take up yak farming. This would contribute to the chances for sustaining yak farming in Bhutan. In addition, development policies should aim for financial security by helping yak farmers selling their products for a good price and by looking for novel alternate livelihoods. Besides, they should also provide better local infrastructures, communication services, health services, and upgrading the existing schools to give opportunities for young people to stay in the local communities having a good future perspective.

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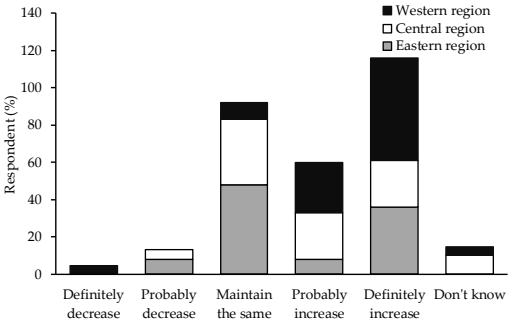
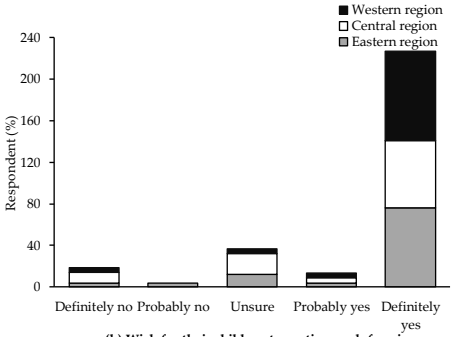
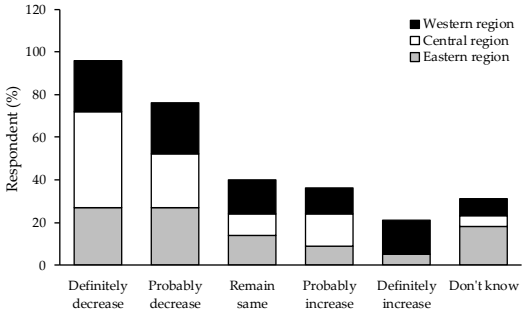
Appendix 1. Herders' future plans and decisions on yak farming.



(a) Plan with yak herd size in the next 10 years



(b) Wish for their children to continue yak farming



(c) Number of yak farming families in the next 10 years

Appendix 2. Yak herder's (n = 67) and livestock professionals' (n = 28) perceive level of concerns of factors related to yak farming.

Aspects	Level of perceived concern (%)				
	Not at All	To Small Extent	To Moderate Extent	To Large Extent	Don't Know
Forage availability in winter rangeland					
Yak herders	11.9	13.4	25.4	47.8	1.5
Livestock professionals	10.7	25	28.6	28.6	7.1
Forage availability in summer rangeland					
Yak herders	10.5	17.9	23.9	47.8	0
Livestock professionals	0	25	28.6	64.4	0
Water availability					
Yak herders	53.7	10.4	19.4	14.9	1.5
Livestock professionals	14.3	3.6	46.4	21.4	14.3
Quality breeding bull availability					
Yak herders	59.7	13.4	17.9	9	0
Livestock professionals	7.1	25	25	11	3.6
Conception rate of yak cow					
Yak herders	61.2	11.9	17.9	1.5	7.5
Livestock professionals	17.9	28.6	28.6	14.3	10.7
Milk yield of yak cow					
Yak herders	34.3	11.9	26.9	25.4	1.5
Livestock professionals	21.4	28.6	32.1	14.3	3.6
Body size of adult yak					
Yak herders	38.8	23.9	25.4	10.4	1.5
Livestock professionals	21.4	35.7	21.4	3.6	17.9
Prevalence of diseases and parasites					
Yak herders	32.8	23.9	14.9	23.9	4.5
Livestock professionals	7.1	39.3	32.1	21.4	0
Access to veterinary and extension services					
Yak herders	46.3	29.9	13.4	9	1.5
Livestock professionals	17.9	14.3	25	42.9	0
Predation on yaks					
Yak herders	9	10.5	19.4	58.2	3.0
Livestock professionals	0	14.3	7.1	71.4	7.1
Market for selling yak products					
Yak herders	79.1	13.4	6	0	1.5
Livestock professionals	17.9	14.3	32.1	28.6	7.1
Labour availability to herd yaks					
Yak herders	49.3	22.4	17.9	9	1.5
Livestock professionals	3.6	28.6	25	39.3	3.6
Successor (youth) to yak farming					
Yak herders	22.9	17.9	26.9	28.4	4.5
Livestock professionals	10.7	14.3	21.4	39.3	14.3
Yak population in the community					
Yak herders	44.8	19.4	20.9	14.9	0
Livestock professionals	17.9	42.9	17.9	21.4	0
Number of yak farming families					
Yak herders	49.3	17.9	13.4	19.4	0
Livestock professionals	21.4	17.9	35.7	21.4	3.6
Training to improve yak management practices					
Yak herders	52.2	29.9	6	7.5	4.5
Livestock professionals	7.1	14.3	46.4	28.6	3.6

Chapter 5

Transition towards sustainable yak farming in Bhutan: stakeholders' viewpoints and recommendations for future steps

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Submitted

Abstract

The Bhutanese government has initiated a highland development programme in the year 2016 to promote yak farming because the number of yak farming families is declining. However, there are several cross-cutting policies and issues that affect successful implementation of interventions to support yak farming in transition. We studied the challenges and opportunities to sustain yak farming and related trade-offs around problems and solutions through individual and focus group interviews with six stakeholder groups (i.e. yak herders from two regions, livestock extensionists, park rangers, livestock officials, and forest officials). Overall the yak herders rated forage availability and yak mortality as the main threats to yak farming, while government officials rated labour availability (park rangers, livestock officials, forest officials) and rural-urban migration (extensionists, park rangers) as the main threats. In addition, livestock officials also view forage availability as a main threat to yak farming. Despite differences in the opinions of government officials and herders on labour availability, all stakeholder groups perceived that the number of successors to take up yak farming is decreasing. Most problems and solutions that were identified in the focus group interviews had diverging views among the stakeholder groups. There is clearly a need for a multi-stakeholder dialogue aiming to discuss problems and solutions together. This should take away misleading and disputed claims, and provide understanding about the approach to cope with risks and uncertainty around transhumance yak based communities. This will also ensure that any future policy intervention to promote and facilitate sustainable yak farming tries to align with different stakeholders' interests. A strong collaboration should lead to appropriate policy and legislation, which would reduce challenges and barriers, and simultaneously give opportunities to yak herders and their children to stay in yak farming in future.

Key words: transhumance; sustainability; stakeholder group; Bhutan; convergence/divergence framework; policy

1. Introduction

Yaks (*Poephagus grunniens* or *Bos grunniens*; Linnaeus, 1766) is the main animal in farming systems for highland pastoralists who reside above 2500 m above sea level in Bhutan. In the ten districts of Bhutan where this is the case, about 41000 yaks were recorded in 2018 (DoL, 2018). These transhumance communities largely depend on yaks for food (meat, milk and its products), clothes, and source of income through sale of excess yak products. Castrated yak bulls are used as pack animals for transportation and traction. The transhumance yak farming system is a cyclic process and follows a vertical migration. The yak herders with their herds migrate between summer (high altitude) and winter rangelands (low altitude) depending on forage availability and weather conditions.

In transhumant yak production systems, forage shortage, inaccessibility to veterinary and health services, mortality and labour shortage to herd are the main constraints (Wangchuk and Wangdi, 2015, Wangdi, 2016, Dorji et al., 2020). The current resource constraints in yak farming have further escalated due to increasing pressure from external factors, such as the socioeconomic development, policy dynamics (Dorji et al., 2020), and climate change (Wangchuk and Wangdi, 2018). For example, in the past when herds reached the winter rangelands, all family members were involved in yak farming, including herding, feeding supplements, processing milk to butter and cheese, and marketing of yak products. At present, however, most men in the central and western yak farming regions are predominately involved in off-farm activities, while women take responsibility to look after the yaks (Wangchuk and Wangdi, 2015). In addition, most young literate pastoralists are said to be unwilling to venture into yak farming because it is a tough way of life. They are increasingly engaged in off-farm opportunities, such as collecting of medicinal plants and mushrooms (cordyceps), or they migrate to towns, which offer better facilities (Wangchuk and Wangdi, 2015).These activities have increased the horse population in the rangelands as these animals are used for transportation. This has led to increased feed competition and consequently degradation of rangelands. Besides, increasing temperature in the mountains due to climate change affects the type of vegetation. It seems that more shrubs are growing at areas where previously grass was predominant (Wangchuk and Wangdi, 2018).

The number of yak farming families is declining rapidly (1400 families in 1996 and 968 in 2013 (Wangdi, 2016). This decline is a socio-political and economic concern to the Bhutanese government, as the transhumance pastoralists play an essential role in environmental stewardship while preventing resource exploitation in the alpine regions (Wangdi, 2016). Although yak farming

is of less interest among the youth of transhumant families, in the current 12th five year plan of the Bhutanese government it was stated that the government aims to promote sustainable livelihoods of yak farming families (Twelfth Five Year Plan, 2018-2023).

In the past, a handful of strategies were initiated in response to resource constraints. Artificial insemination (yak semen imported from China) was initiated in order to improve yak breed and performance. However, only a few yak herders could access artificial insemination facilities because most herds are located in very remote areas and yak cows are scattered during breeding season (Phuntsho and Dorji, 2016). This indicates that the solution to the constraint has not really been thought through properly and problems should be evaluated from different perspectives prior to implementation of an improvement strategy. Moreover, it is very difficult to achieve desirable outcomes for different stakeholders because there are several crosscutting policies, regulations, and acts that may hinder the successful implementation of interventions. For instance, the *Forest and Nature Conservation Act* 1995 that prohibits burning and clearing of shrubs around rangelands seems to conflict with communities' traditional practice of rangeland management and with the pasture development programme of the livestock department. So, any future policy interventions to support yak farming should align with requirements and wishes of different stakeholders (governmental agencies, yak-based communities) as much as possible. Yak farming is in transition, but it is unclear how different stakeholders perceive the challenges and opportunities related to this transition. Therefore, this study aims to identify the perceived challenges and opportunities to sustain yak farming and related trade-offs around problems and solutions through (individual and focus group) interviews with different stakeholders. The outcome of this study can help policy makers which direction they could take in order to support and maintain yak farming in the future.

2. Materials and method

2.1. Stakeholder analysis and recruitment

We listed eight potential stakeholder groups who are believed to have an interest in yak-based transhumant communities: yak herders, local livestock extensionists (referred hereafter as extensionists), park rangers of national parks and nature reserves, policy makers of the Department of Livestock (referred as livestock officials), policy makers of the Department of Forest and Park Services (referred as forest officials), tourism industry, NGOs (e.g. Royal Society for the Protection of Nature), and citizens in towns. Five key stakeholders were identified on the basis of Eden and Ackermann's power versus interest matrix (Schmeer, 1999, Bryson, 2004, Rosso et al., 2014) (Table 1). Tourism industry, NGOs and citizens in towns were excluded because these stakeholder groups

have low interest and low power to influence the issues or earlier identified themes (Dorji et al., 2020) and may not be familiar with the current situation in yak farming. The remaining stakeholder groups have two different backgrounds: yak herders and government officials (extensionists, park rangers, livestock officials, forest officials).

Two stakeholder groups of yak herders were recruited, one group (n = 10) in the eastern region (Merag block), and one group (n = 10) in the central region (Saephu block). These two yak farming regions were selected based on differences in the alternate source of income for these communities and on the different yak dairy products they produce (fermented cheese in the eastern region and dry cheese in the central region). Participants were recruited from the same villages or nearby villages within the region. Extensionists (n = 3) and park rangers (n = 4) were recruited based on information of a previous field study in 2017. During the time of visit in the central yak farming region, four park rangers of Wangchuck Centennial Parks in the central Bhutan were available. Recruitment of extensionists was challenging because yak farming blocks are distantly located from one another. We contacted extensionists who were working (n = 1) or worked (n = 2) in yak-based communities in the eastern region to take part in the study. Although the recruitment for extensionists (eastern region) and park rangers (central region) could be a source of bias, we opted to proceed with this recruitment in an effort to get a bird's view on whether their views differ from herders that we recruited for focus group meetings. Livestock officials (n = 6) were recruited from the Department of Livestock, Ministry of Agriculture and Forests (MoAF) in consultation with the Director General of the department. Forest officials (n = 4) were recruited from the Department of Forest and Park Services (DoFPS), MoAF based on their expertise and availability. Individual participants were contacted and invited to take part in the focus group meetings. In total 37 participants took part in the different focus group meetings. Meetings were organised between participants with a similar background and/or experience per stakeholder group to enable them to freely share their opinions and views (Krueger, 2002, Ochieng et al., 2018).

Before data collection started, a verbal consent was obtained from the participants that they agreed to take part in the study and for audio-recording of the interviews. Participants were also assured that their identity would remain confidential. Both individual interviews and focus group interviews were conducted on the same day.

Table 1. Stakeholders relationship with yak-based transhumant communities.

Group	Relation and information they may provide	Importance / interest	Influence / power	Role to yak farming
Yak herders	Experience on current situation on yak farming practices	High	Little	Support
Local livestock extensionists	Extensionist deals with herders on a regular basis (e.g. train, support and provide advice to herders on production and health of livestock), and implement livestock policy at the grass-root level	High	Medium	Support
Park rangers of protected areas	Yak farming regions are located within protected areas (parks and sanctuaries) and rangers often deal with yak herders, and implement forest policy at the grass-root level	Medium	Medium	Support and hinder /oppose
Policy maker: Department of Livestock	Develops policy based on recent information and priorities of the organization to maintain and support yak farming	High	High	Support
Forest official: Department of Forest and Park services	Update information on the policies and priorities of the organization for conservation, protection, and sustainable utilisation of natural resources	Medium	High	Support and hinder /oppose
Tourism industry	Hire horse from yak-based communities for tourist trekking, and visit yak farming village	Low	Little	Support and hinder /oppose
NGOs	Preserve natural environment	Low	Little	Hinder /oppose
Citizens in towns	Yak product consumers	Low	Little	Support

2.2. Individual interviews

Prior to the focus group interview (FGI), herders were interviewed face-to-face because most were illiterate, while the government officials were asked to fill out a question list themselves. Both were conducted to gather information about their opinion, perception and knowledge about yak farming. The following topics were addressed:

- Participants' perceived level of familiarity with four main themes related to yak farming in Bhutan identified from the previous study (Dorji et al., 2020): the market situation to sell yak products, labour availability to herd yaks, yak mortality, and forage availability on rangelands.

A 4-point Likert-scale was used: 1, not at all aware; 2, to a small extent aware; 3, to a moderate extent aware; 4, to a large extent aware. This question was excluded for yak herders.

- Participants had to rank the three most important threats to sustaining yak farming from the four themes and the reasons why they rank it like this (open-ended question).
- Participants' opinion on trends on the number of farming families over the years. A 5-point Likert item was used: 1, definitely decrease; 2, probably decrease; 3, remain the same; 4, probably increase; 5, definitely increase.

2.3. Focus group interviews

Perceptions of the different key stakeholders in yak farming practices were used to identify challenges and opportunities for implementation of interventions to sustain yak farming. In total six FGIs for six different stakeholder groups with 3–10 participants per FGI were conducted from November to December 2019. FGIs were organised close to where participants were working. The facilitator conducted an informal introduction to gain the trust of the participants and the group agreed on the house rules during the meeting (Krueger, 2002, Ochieng et al., 2018). The facilitator briefed the participants on the aims and expectations for the FGI. All FGIs were facilitated by the first author and a research assistant took notes on the contents of discussion and organised the audio-recordings. Since we were depending on availability and voluntarily willingness to participate in FGI, the desired number of six participants per group was not completely met (Krueger and Casey, 2000).

In the FGI, the four themes around yak farming in Bhutan were used as input and served as basis for the discussion. The FGI was conducted using a list of pre-defined questions prepared by the research team, and a probing technique (e.g. what, which) was used to specific individuals, whenever required. The procedure for the FGI was: firstly, individual participants gave their opinion on the current situation with respect to each theme (forage availability, market situation, yak mortality, labour availability and rural-urban migration); secondly, the group listed potential factors that affected each theme as indicated above; and finally from a list of factors (the facilitator also provided potential factors to ensure the same list of factors in all FGIs) the group had to discuss and assign the first three most important factors (one shared group opinion), the reasons why they ranked it like this, and suggest solutions in what way these issues can be dealt with. The facilitator actively intervened to stimulate quiet and shy individuals participating in the FGIs to also speak up during the process of reaching consensus.

A FGI lasted on average 110 min ranging from 80 min (forest officials) to 150 min (livestock officials). FGIs were both conducted in English and the Bhutanese national language (Dzongkha) for extensionists, park rangers, livestock officials and forest officials. The Bhutanese national language for the herders of the central region and local dialect (*sharchopkha*) for the herders of the eastern region was used to conduct the FGIs. The protocol and questions for the FGIs were tested with three Bachelor of Science students studying Animal Science at the College of Natural Resources, Royal University of Bhutan.

2.4. Data processing

Individual interviews and FGIs are analysed using the constant comparison analysis (Onwuegbuzie et al., 2009). For the threats to yak farming, 3 = first; 2 = second; and 1 = third most important threats to yak farming were assigned. The values assigned by individual participants on each threat were summed per group, and the total score was divided by total number of participants in a group to correct for the differences in sample size to obtain the threat score. The threat score of each theme indicates the perceived level of threat to yak farming, with a higher threat score indicating a greater threat to yak farming.

3. Results

3.1. Characteristics of respondents

Herders of the eastern region were mainly illiterate (n = 8) and 3 were female. Their median age and herding experience was 42 years and 17.5 years (range 9–50 years). Herders of the central region were also mostly illiterate (n = 8) and female (n = 7). Their median age and herding experience was 40 years and 25 years (range 15–30 years). All extensionists were male with a diploma (2-years programme) in animal husbandry, and a median age and working experience was 31 years and 3 years (range 3–7 years). All park rangers were male with a one-year certificate (n = 2), diploma (n = 1) and bachelor's degree (n = 1) in forestry, and a median age and working experience was 33 years and 3.5 years (range 2–8 years). Five of six livestock officials were male with education level ranging from a diploma in animal husbandry to a PhD in epidemiology. Their median age and working experience was 44.5 years and 5 years (range 2–25 years). Likewise, three out of four forest officials were male with education level ranging from a bachelor's degree in forestry to a PhD in sustainable forest management. Their median age and working experience was 33 years and 3.5 years (range 3–30 years).

3.2. Individual opinions

Level of familiarity

Most government officials stated that they were familiar with the mortality, forage, labour and market situation in relation to yak farming (Figure 1). The forest officials mentioned additionally (*n* = 3) that they were aware of the current situation of yak-based communities from different sources, including media, government website and blogs, and during meetings and seminars.

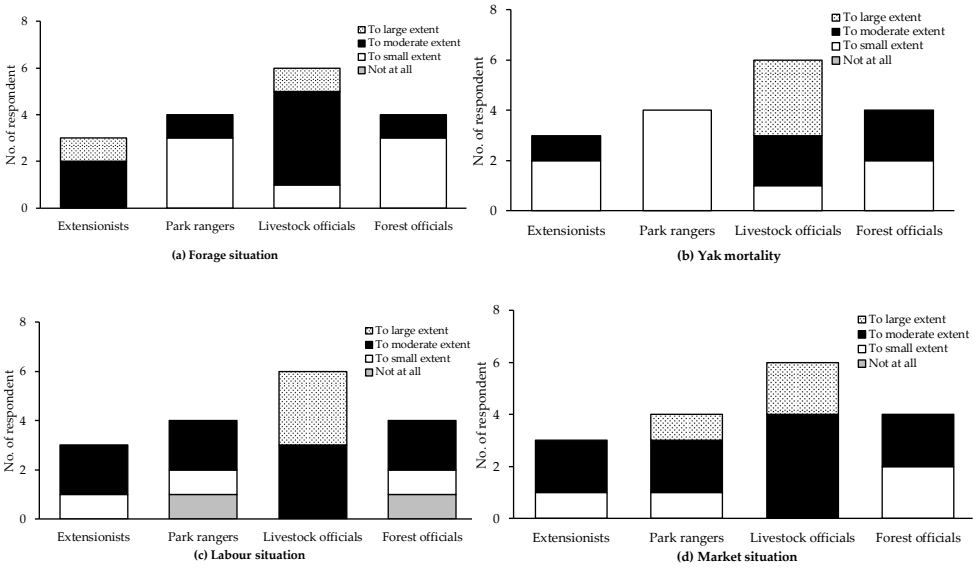

Figure 1. Number of participants per FGI and their level of familiarity on the themes related to yak farming.

Threats to yak farming

Herders perceived forage availability on rangelands (eastern herders, central herders), and herders of the central region also rated yak mortality as the principal threats to yak farming (Table 2). In contrast, government officials considered labour availability (park rangers, livestock officials, forest officials) and rural-urban migration (extensionists, park rangers) as the main threats to yak farming. In addition, livestock officials perceived forage availability as the most important threat to yak farming. We decided to consider the first most important threat to yak farming in order to compare the most important threat perceived by different stakeholder groups, however, when the second most important threat value was approximately equal to the first threat (≥ 0.6 rounded up to 1) we also considered it as an important threat.

Table 2. Average of the participant's score on the threats to sustain yak farming.

Group	Forage availability	Yak mortality	Labour availability	Rural-urban migration	Market situation
Eastern herders	**2.7**	1.7	0.2	0.4	0.4
Central herders	**1.9**	**1.9**	1.5	0.6	0
Extensionists	1.3	0	2.0	**2.7**	0
Park rangers	0	0.7	**2.3**	**2.0**	0
Livestock officails	**1.8**	0.8	**1.7**	1.5	0.2
Forest officials	1.5	0.8	**2.5**	1.5	0.5

Notes: Higher numbers indicate higher threats to yak farming (in bold is the most important threat(s) to yak farming per focus group).

Participants who rated forage availability as the main threat mentioned that rangeland division among family members, increased livestock population, and climate change as reasons (Table 3). With regard to labour availability and rural-urban migration, access to education for children, modernisation and alternative sources of income were mentioned (Table 3). Overall, most participants considered the market situation to sell yak products as the lowest threat to yak farming.

Table 3. Participants' reasons for ranking the first three most important threats to yak farming.

Aspect	Reasons (source, *n*)
Forage availability	Increased cattle, cattle-yak hybrids, and yak population (EH, 1; CH, 4; EA, 1; LO, 3; FO, 1)
	Rangeland division among family members (EH, 9; LO, 1)
	Climate change (FO, 2)
	Shrub proliferation in rangelands (EA, 1)
	Competition with wild herbivores (FO, 2)
Yak mortality	Wild predation on yaks (EH, 1; CH, 10; PR, 2; LO, 2; FO, 1)
	Disease outbreak (EH, 1; LO, 2; FO, 1)
	Plant poisoning (EH, 6)
Labour availability	Alternative source of income (EH, 2; CH, 8; EA, 1; PR, 3; LO, 3; FO, 2)
	Access to modern education (CH, 2, EA, 1: LO, 1; FO, 1)
Rural-urban migration	Alternative source of income and easy lifestyle in towns (EH, 4; CH, 3; EA, 2; PR, 2; LO, 2; FO, 3)

EH, eastern herders; CH, central herders; EA, extensionists; PR, park rangers; LO, livestock officials; FO, forest officials.

Trends on the number of yak farming families

All participants of four stakeholder groups (central herders, extensionists, park rangers, livestock officials) mentioned that the number of yak farming families has decreased over the last 10 years,

while a few participants (eastern herders, forest officials) were unsure about the past trends (Figure 2). All participants of three stakeholder groups (central herders, extensionists, park rangers) expected that the number of yak farming families will further decline in the next 10 years (Figure 2). The reasons stated by participants were that most young pastoralists are not interested in yak farming because of an alternative source of income.

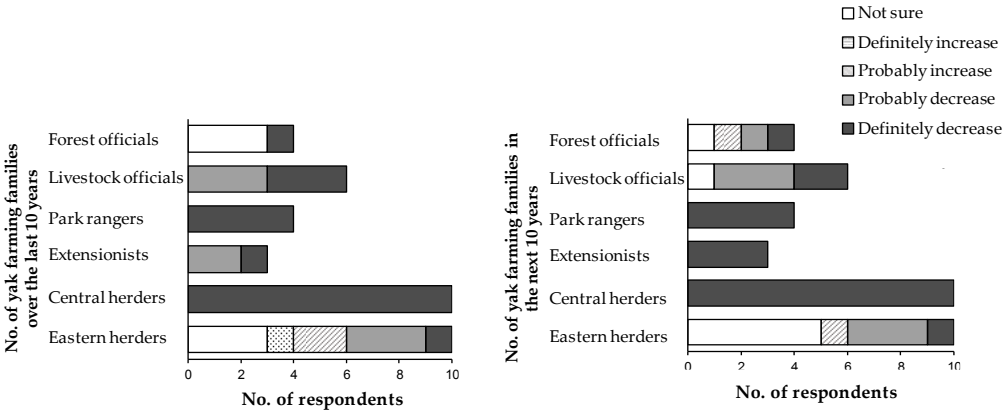

Figure 2. Participants' opinion on the trends of the number of yak farming families over the years.

3.3. Group opinions

The findings are presented in three subsections: i) current situation and the factors affecting a theme; ii) solutions to the most important issues; and iii) convergence/divergence views on problems and solutions.

Current situation

Forage availability

Herders expressed that they experience forage shortage, which they think has increased over the years. Except from the park rangers, all stakeholder groups supported this. The argument given by park rangers was that the herders constantly migrate with their herd from one rangeland to another in search for forage, which is an adaptive strategy. Nonetheless, park rangers also acknowledge various factors that affect forage availability on rangelands (Figure 3).

The traditional practice of dividing rangeland among family members caused forage shortage according to eastern herders, extensionists, and livestock officials. Three stakeholder groups ranked the increased cattle and cattle-yak hybrids as the most important factor affecting the forage

availability on rangelands. Some stakeholder groups also thought that increased horse population is a cause of forage shortage.

Three stakeholder groups criticised the *Forest and Nature Conservation Act* 1995 of Bhutan (used as the *Forest Act* 1995) for causing shrub to proliferate on rangelands which in turn has led to forage shortage. Forest officials emphasised the significant impact of climate change (less precipitation) on forage production on the rangeland.

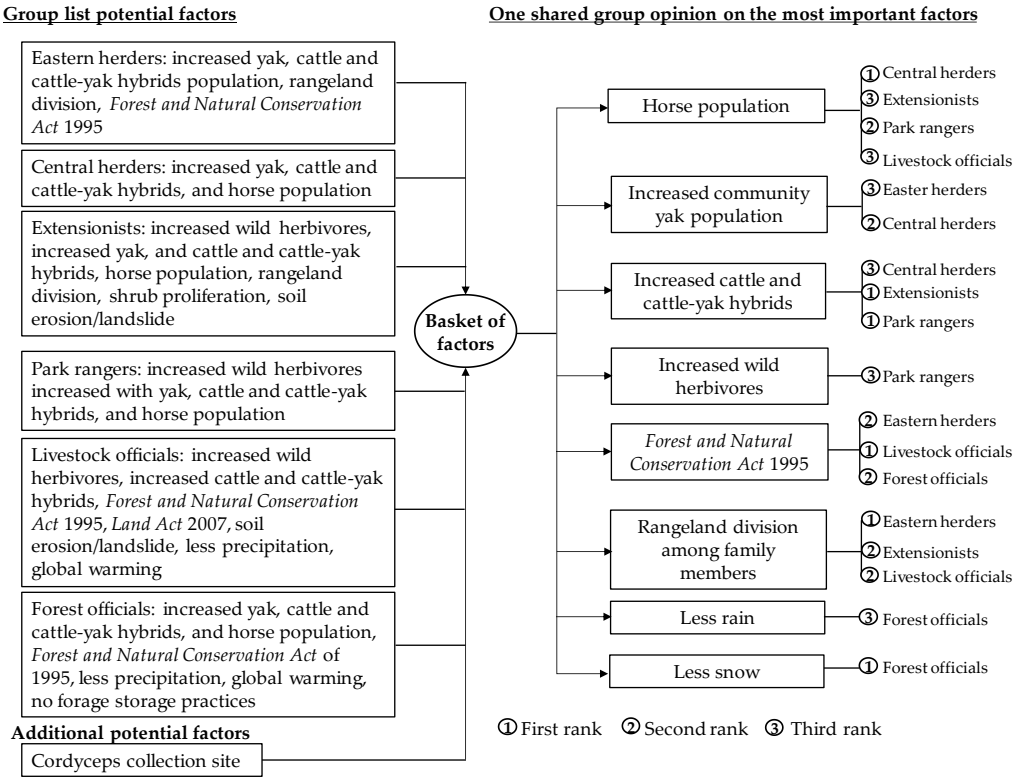

Figure 3. Process involved during group consensus ranking the first three most important factors affecting forage availability on rangelands. Participants listed factors (left side) and facilitator provided potential factors (bottom-left side) to form a basket of factors (central). From the basket of factors the different stakeholder groups ranked the first three most important factors (right side).

Yak mortality

Herders mentioned that they experience yak mortality, which was also recognised by other stakeholder groups. Several potential factors that caused yak mortality listed by stakeholder groups

were predators, forage shortage, intake of poisonous plant and poisonous water, diseases, accidents with yaks, and bad weather conditions (Figure 4).

All stakeholder groups mentioned that endangered wild predators, such as snow leopard (*Panthera uncia*) and Asiatic wild dog (*Cuon alpinus*) were the leading cause of yak mortality. In fact, all stakeholder groups expressed that the loss of yaks to wild predators has continued to increase over the years. In addition, one forest official and two livestock officials viewed that the number of stray dogs in yak farming has increased, and these dogs attacked young animals during food scarcity. The water poisoning was another important cause to yak morality because they mentioned that water sources are either contaminated by wild boars (*Sus scrofa*) or drying up. Other causes of yak mortality were forage shortage, intake of poisonous plants and bad weather condition.

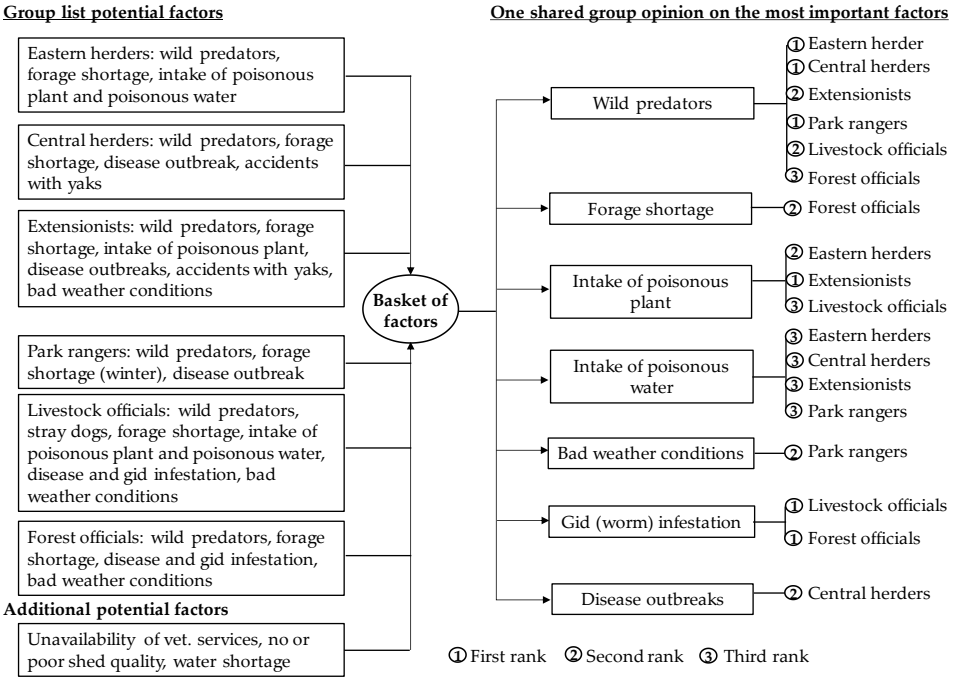

Figure 4. Process involved during group consensus ranking the first three most important causes of yak mortality. Participants listed factors (left side) and the facilitator provided potential factors (bottom-left side) to form a basket of factors (central). From the basket of factors the different stakeholder groups ranked the first three most important factors (right side).

Labour availability and rural-urban migration

Herders think that the available family labour is sufficient to contribute to yak farming. In contrast, all government officials believed that yak farming families experienced labour shortage due to socioeconomic developments (e.g. access to education for children, better facilities offered in towns). All stakeholder groups acknowledged that socioeconomic developments triggered young pastoralists to migrate to towns and consequently caused labour shortage (Figure 5). In yak farming villages the schools are at primary-level and most children leave their village to pursue higher education in other regions. Besides impact of access to education, four stakeholder groups (central herders, park rangers, livestock officials, forest officials) stated the hardship in yak farming combined with lucrative alternative sources of income greatly affected both young and adult pastoralists' interest in yak farming. Consequently, the number of successors to take up yak farming was said to decline over the years (all stakeholder groups).

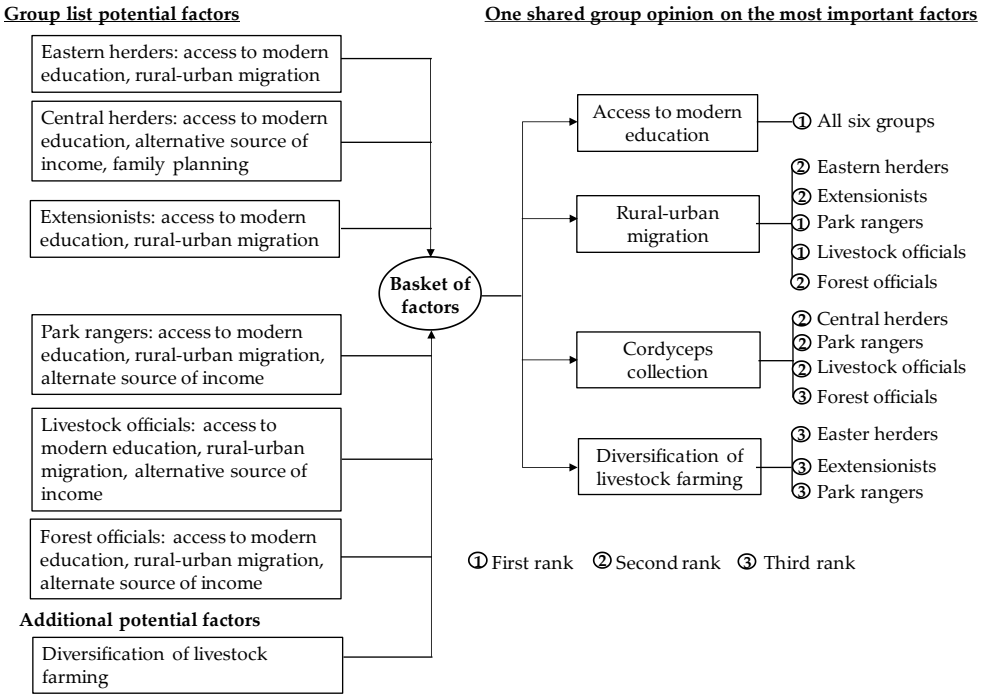

Figure 5. Process involved during group consensus ranking the first three most important factors affecting labour availability. Participants listed factors (left side) and the facilitator provided potential factors (bottom-left side) to form a basket of factors (central). From the basket of factors the different stakeholder groups ranked the first three most important factors (right side).

Market situation

Herders mentioned that they were able to sell their yak products, which was also supported by the extensionists and park rangers. Four livestock officials and one forest official believed that herders experienced problems in selling yak products. Factors that were mentioned to affect sales of yak products were: distance to reach urban market, poor or no road infrastructure, no outlet to sell yak products, and competition with cheap imported dairy products such as margarine from India (Figure 6).

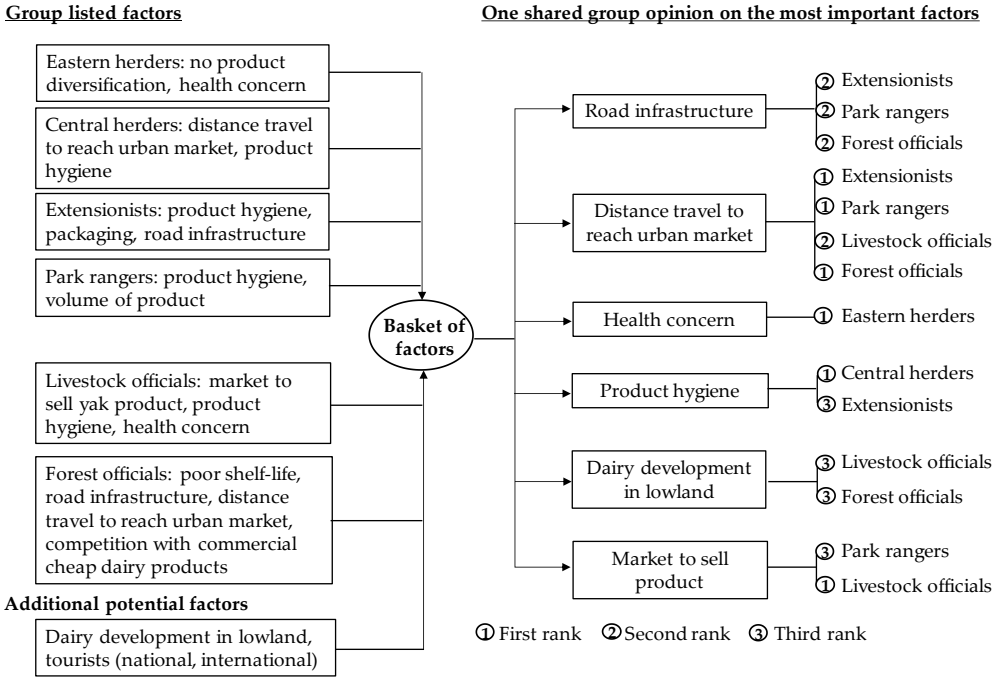

Figure 6. Process involved during group consensus ranking the first three most important factors affecting the sales of yak products. Participants listed factors (left side) and the facilitator provided potential factors (bottom-left side) to form a basket of factors (central). From the basket of factors the different stakeholder groups ranked the first three most important factors (right side).

According to most stakeholder groups, a combination of the road infrastructure and long distances to reach markets were the main factors that limit the sale of yak products because most yak farming regions are not connected with motorable roads. The yak butter has a low shelf-life while herds are located far from the markets affecting the sale of products. Poor hygiene in processing yak products and competition with cheap imported dairy products and dairy development in the lowlands was also considered to negatively affect the sales of yak products. Furthermore, the eastern herders

rated the increased consumer awareness of the health effects of blood pressure due to intake of butter as a threat to the sales of yak butter. Another reason was that yak products are considered the same as the products their ancestors produced, though more expensive than the butter from dairy cow and imported dairy products (livestock officials, forest officials).

Solutions to the most important issues

Solutions proposed to forage shortage

The basket of solutions for the most important issues suggested by stakeholder groups is presented in Table 4. Stakeholder groups suggested to improve pasture to alleviate forage shortage. In winter rangelands where yaks graze, many unproductive local cattle are said to be owned by families who do not own yaks, which could be replaced by a few improved, productive cattle breeds (central herders, extensionists, park rangers, livestock officials).

Table 4. Proposed solutions for the three most important factors affecting forage availability in rangelands by the different stakeholder groups.

Factor	Solution (source)
Increased livestock population	Develop improved pasture (all stakeholder groups)
	Keep improved cattle breed by non-yak farming families (CH, EA, PR, LO, FO)
	Limit horse population when road is connected (LO)
	Awareness programme, e.g. not allowing animals to stray (CH, EA, LO)
Forest Act 1995	Allow to clear twigs and branches of shrubs on rangelands (EH) and burn shrubs (LO)
Rangeland division among family member	Develop improved pasture (EH, LO, FO)
	Redistribute rangeland to herders (LO)
	Combined use of rangeland (EH, EA)
Less precipitation	Practice forage storage (FO)

EH, eastern herders; CH, central herders; EA, extensionists; PR, park rangers; LO, livestock officials; FO, forest officials.

There is a clear evidence of conflicting opinions between and within the stakeholder groups on revising the *Forest Act* 1995. Herders of the eastern region and livestock officials expressed that this act should be revised. Livestock officials proposed to negotiate with other stakeholders, for example the DoFPS, to increase the rangeland areas with the argument that livelihood of communities may be more important than conservation of nature. However, a few participants also suspected that revising the *Forest Act* 1995 may lead to misuse of the natural resources (livestock officials, eastern herders). Furthermore, allowing the clearing of shrubs around the rangelands would increase soil erosion (extensionists) and affect mountain ecosystems, including downstream water sources (park rangers).

Solutions proposed to yak mortality

Strategies proposed by stakeholder groups to mitigate predation on yaks were to corral weak and young animal and engage herders more in herding, keep a guard dog with the yak herd, and interventions by the government (Table 5).

With regard to controlling parasite and disease outbreaks preventive measures were mentioned as the most effective strategy by livestock officials and forest officials. They stated that an awareness programme and regular deworming of animals would be effective in combatting the worm infestation and disease outbreaks. A straightforward strategy to water poisoning was to guard yaks by not allowing them to drink dirty water and drain out stagnant water (Table 5).

Table 5. Proposed solutions for the three most important factors causing yak mortality by the different stakeholder groups.

Factor	Solution (source)
Wild predator and stray dog	Corral weak and young yaks (EA, PR, FO)
	Spend more time on herding (EA, PR, FO)
	Keep guard dog (PR)
	Install solar lighting system to keep nocturnal predators away (FO)
	Government interventions (EH, CH, LO)
	Awareness not to hunt wild prey (CH)
	Area solution to forage shortage (LO)
Gid (*Coenurus multiceps multiceps*)	Promote preventive measures, e.g. reduce stray dogs (LO, FO)
infestation and disease outbreaks	Make veterinary services available (CH, EA, PR)
	Train local health workers (CH)
Forage shortage and plant poisoning	Revise the *Forest Act* 1995 (EH, LO)
	Develop improve pasture (EA)
	Research on plant poisoning (EH)
Water poisoning	Guard the yaks (EH, CH, EA, PR)
	Drain out dirty water (EH, EA, PR)
Cold and bad weather condition	Practice hay making (FO)

EH, eastern herders; CH, central herders; EA, extensionists; PR, park rangers; LO, livestock officials; FO, forest officials.

Solutions proposed to labour shortage and rural-urban migration

Strategies to mitigate rural-urban migration were focused on making basic facilities, including health, communication and other services, available in yak farming villages (Table 6). Herders of the central region think that upgrading the existing primary-level school may bring down the number of young pastoralists migrating to elsewhere to pursue higher studies. Besides, herders believed that they also should encourage their children to take up yak farming in the future. Therefore, formulating a separate policy to support yak farming is required such as providing

product packaging materials, communication services and tents for herders (central herders, extensionists, park rangers, livestock officials, forest officials).

Table 6. Proposed solutions for the three most important factors affecting labour availability and rural-urban migration by the different stakeholder groups.

Factor	Solution (source)
Access to modern education	Policy to support yak farming (CH, LO, FO)
	Encourage young pastoralists in yak farming (EH, EA, FO)
	Incorporate subject related to yak farming (EA, LO)
	Upgrade the existing schools (CH)
Rural-urban migration	Provide basic facilities, such as communication services (EA, PR, FO)
	Awareness programme on importance of yak farming and its opportunities (PR, LO)
	Provide subsidy to yak herders (FO)
Cordyceps collection	Establish a quota system for the amount to collect (FO)
Livestock farming diversification	Keep less but more productive cattle breeds by farming families (EA, PR)

EH, eastern herders; CH, central herders; EA, extensionists; PR, park rangers; LO, livestock officials; FO, forest officials.

Solution proposed to the market situation

Solutions proposed by the stakeholder groups to promote the sales of yak products are presented in Table 7. Practice of standard hygiene was mentioned to stimulate sales of yak products (park rangers, livestock officials), which was seen as limited due to poor hygiene in processing yak products and competition with dairy development in the lowlands and import of commercial dairy products.

Table 7. Proposed solutions for the three most important factors affecting sale of yak products by the different stakeholder groups.

Factor	Solution (source)
Market to sell product and dairy development in lowlands	Maintain good hygiene (PR, LO)
	Diversify yak products (LO, FO)
	Improve packaging of yak products (FO)
	Establish a cooperation (EH, FO)
Road infrastructure and travel distance to reach urban markets	Use cable crane system (FO)
	Improve packaging of yak products (EA)

EH, eastern herders; CH, central herders; EA, extensionists; PR, park rangers; LO, livestock officials; FO, forest officials.

Improved packaging of yak products to prolong shelf-life of yak butter was suggested (extensionists, park rangers). In addition, use of cable cranes as a means of transporting yak products was proposed as a solution to longer distances (forest officials). Another strategy would

be to form a cooperative similar to that of dairy groups that could promote sales of yak products (eastern herders, forest officials).

3.4. Convergence/divergence on issues

We categorised the factors that affected each theme into converging/diverging views (Wanzenböck et al., 2019). The importance of most factors that cause forage shortage, yak mortality, labour shortage, and limited sale of yak products (hereafter referred as problems) were diverging among stakeholder groups (Table 8). Differences in opinions between the two herder groups may be attributed to differences in tradition practices of yak farming, alternate source of income, and the location of yak farming villages. For example, the traditional method of rangeland division among family members is a cause for forage shortage in the eastern yak farming region, but not in the central region.

Table 8. Classification of the problems to diverging and converging views among stakeholder groups.

Theme	Diverging views on the problem	Converging views on the problem
Forage availability	*Forest Act* 1995 *Land Act* 2007 Rangeland division Horse population Increased number of yak communities Increased wild herbivore population Cordyceps collection sites Less precipitation Soil erosion	Increased cattle and cattle-yak hybrid population
Yak mortality	Unavailability of veterinary care services Intake of poisonous plants Water shortage Bad and harsh weather No or poor shed quality Accidents with yaks	Predation on yaks Intake of contaminated water Disease outbreaks Forage shortage
Labour availability	Increase size of family yak herd Alternative sources of income (tourism, cordyceps collection, diversification of livestock farming)	Access to education Youth rural-urban migration
Market situation	Market to sell yak products Road infrastructure Distance travel to reach urban market Tourists	Dairy development in lowlands

3.5. Convergence/divergence views on problems and solutions

The mission-oriented innovation policy framework of convergence/divergence (Wanzenböck et al., 2019) was used to assess whether the views on problems and solutions converged or diverged among stakeholder groups in order to explore opportunities to promote yak farming. The problems and the solutions for each theme related to yak farming are categorised (Figure 7) and are placed

in four quadrants depending on converging/diverging views among stakeholder groups (Wanzenböck et al., 2019). The four quadrants are: i) disorientation: diverging views on a problem and proposed solutions among stakeholder groups, for example, effect of enactment of the *Forest Act* 1995 on forage availability and impact of alternative sources of income on labour availability; ii) problem in search of a solution: stakeholder groups have converging views on the problem, but there are several vague and/or disputed solutions to approach the problem (e.g. all stakeholder groups identified that predators are the main cause for yak mortality, but lacked a clear strategy on how to deal with it); iii) solution in search of a problem: although stakeholder groups have diverging views on the problems, they have a clear and feasible solution (e.g. the herders said that the increased yak population in a community causes forage shortage while the government officials did not think this is a cause for forage shortage. All stakeholder groups proposed to develop improved pasture); and iv) alignment: stakeholder groups acknowledge the problems and have a clear view on the solution. The negative effect of the increased cattle population on forage availability was broadly supported by all stakeholder groups, and their solution to develop improved pasture also converged.

4. Discussion

We studied the challenges and opportunities to sustainable yak farming and the trade-offs around problems and solutions as experienced by different stakeholders. The individual interviews and FGIs revealed that socioeconomic developments and strong nature conservation policies have an impact on yak-based communities. The convergence/divergence policy framework further provided new insights in, and captured perceptions of different stakeholder groups on yak farming practices. A few problems and solutions had converging views among different stakeholder groups, but in most cases they were diverging.

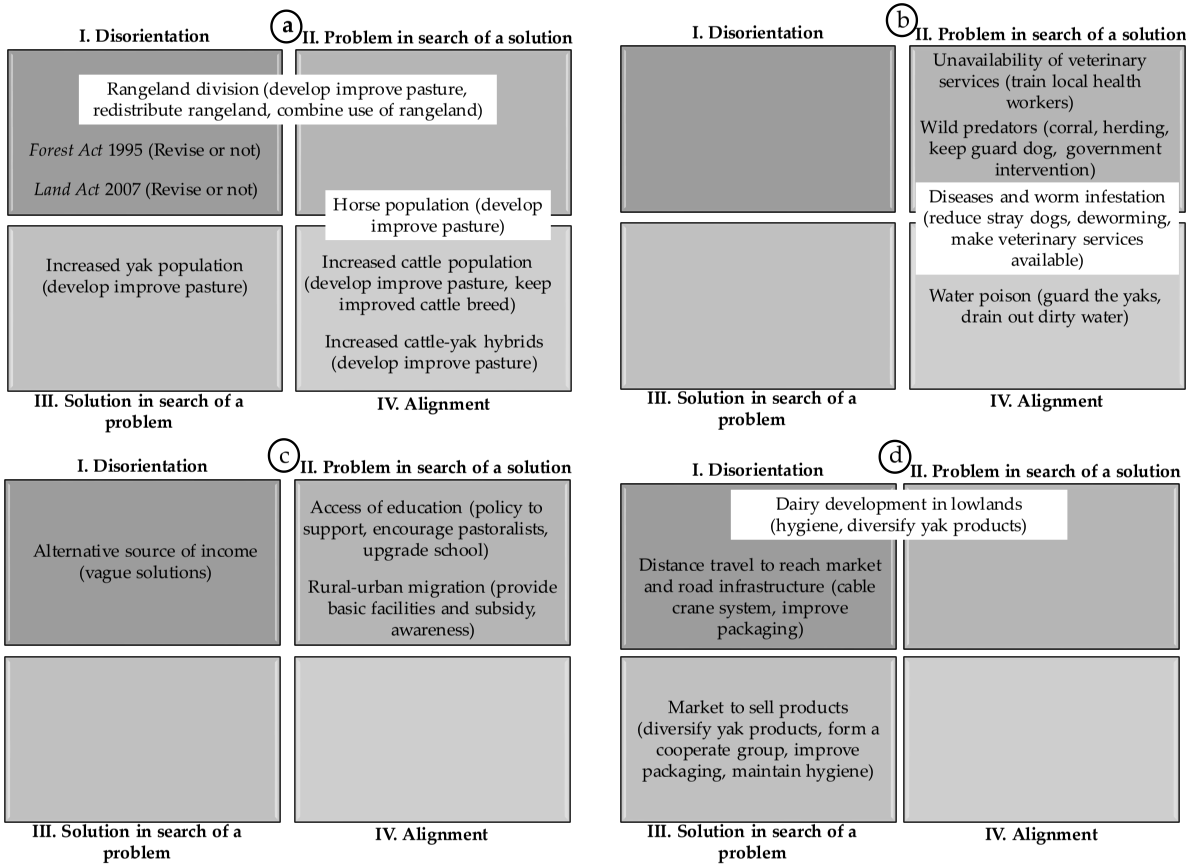

Figure 7. A two-dimensional problem-solution classification of items of each theme (solutions are given between brackets). a, forage availability in rangelands; b, yak mortality; c, labour availability; d, Market situation. Some problems and solutions are placed between the two quadrants because of, for instance increased horse population (central region) and horse trespassing although horse population has decreased (eastern region) caused forage shortage. Similarly, the dairy development in lowlands affects the sales of yak butter, but not of hard dry cheese.

Contestation among different stakeholder groups on problems and solutions may hamper sustainable future development. With respect to the existing *Forest Act* 1995, for example, the herders would like to have it changed while the governmental institutions do not support a revision because nature conservation is one of the highest priorities for the governmental institutions. The diverging views on such problems and/or solutions among stakeholder groups exist probably due to differences in knowledge levels, personalities and interests, but also due to conflicting goals and values among organizations and among farmers (Moura and Teixeira, 2010, Gyan and Ampomah, 2016, Wanzenböck et al., 2019). Thus, potential barriers and deadlocks are evident to problems and solutions with diverging views. In parallel, the diverging views on problems and solutions among stakeholder groups will also open a 'window of opportunity' for niche innovations through multi-stakeholder dialogue. This, however, can only work when there is an appropriate platform for deliberation and collective acknowledgment and definition of problems whereby stakeholder groups work together to find ways to generate solutions for the problems (Loorbach, 2010, Wanzenböck et al., 2019, Vogel et al., 2020).

4.1. Converging views on problems and solutions

When a problem is clearly framed with a high degree of consensus and the solutions to that problem also converge (Wanzenböck et al., 2019), there is a higher chance of success when the solution is applied in practice. In this context, the strategy proposed by the stakeholder groups to work on developing improved pasture areas to reduce forage shortages is promising as both herders and the governmental institutions support it. A similar strategy was applied in 1985 but failed (Phuntsho and Dorji, 2016). Three crucial factors may explain this failure: i) the policies are not always clear-cut and contradict each other at points. For example, the *Forest Act* 1995 restricts any cultivation activity within a protected area (national parks and sanctuaries), while the *Land Act* 2007 allows herders to improve quality of the rangelands; ii) initial investments for land preparation, sowing and operation costs (e.g. periodic weeding are required during the first season) were not covered. The benefits of improving pasture areas counteract the costs when the government aims to promote yak farming; and iii) collaboration among herders, extensionists and park rangers was not organised and facilitated. Also, extensionists should have sufficient knowledge to provide technical inputs on developing improved pastures. For the future, overcoming these challenges is essential to make a success of pasture improvement. Stakeholders should be aligned and the division of roles between parties must be clear. Improving pasture should be done with care, for example because of ecological consequences. Introduction of exotic species might give unforeseen consequences as has happened in Australia where exotic grasses have become invasive weeds

(Driscoll et al., 2014, Norton et al., 2016). Such an example indicates that trade-offs should be prevented by studying a problem extensively taking all aspects into account before a new policy is implemented.

Another converging view on a problem and a solution among stakeholder groups was to encourage the non-yak farming families to keep a few heads of an improved cattle breed (high productive) instead of many heads of a local breed (low productive) to reduce forage competition. Most dairy farmers in Bhutan seem to prefer improved cattle breeds over the local breeds (Choden and Tamang, 2018), so the government may adopt this strategy. However, keeping improved cattle breed by non-yak farming families also comes with wicked links. Earlier studies demonstrated that the dairy developments (e.g. crossbreeding of local Siri cattle with Jersey) in the lowlands of Bhutan together with imported dairy products from India has affected the sales of yak products (Derville and Bonnemaire, 2010, Phuntsho and Dorji, 2016). Furthermore, the National Biodiversity Centre of Bhutan focuses on conserving and utilizing animal genetic resources sustainably because local cattle breeds are increasingly under threat. These local breeds should be conserved because they may contain genes to be adapted to the local conditions and are potentially required for future breeding work (Hoffmann, 2010). Again, potential trade-offs of choices in policy making should be considered carefully.

4.2. Converging views on problems but diverging views on solutions

Although there are multiple solutions proposed by the stakeholder groups to mitigate rural-urban migration (solution divergence), it is still uncertain whether these solutions will encourage young pastoralists to stay in yak farming. As for an immediate action plan, the governmental institutions should support yak-based communities in a way that their economic situation gets better (e.g. stimulate sales of yak products, diversify livelihoods). Tourism could potentially contribute to the economic situation of yak based communities. So far, however, communities have hardly benefited because they not involved in tourism related activities (Suntikul and Dorji, 2016). Hence, policy makers should focus on building coalitions between the government, the tourism council and yak-based communities to ensure benefit-sharing of tourism. As an important step, policy makers could identify and categorise stakeholders based on the interest-influence matrix, which would assist policy makers to negotiate with different stakeholders if required in future (Heslinga et al., 2019).

From a conservationist perspective, Bhutan seems to succeed in protecting globally endangered animals such as for example, takin (*Budorcas taxicolor*), snow leopard, and Asiatic wild dog, but at the cost of livelihood of local communities. Nonetheless, the increased number of yaks as perceived

by yak herders probably displaced wild prey, in particular blue sheep (*Pseudois nayaur*), which might have led to increased human-wildlife conflicts. We have found no indication that the government intervenes to reduce yak losses to predators, though they pay a compensation fee for predation losses. To engage herders more actively into nature conservation, they need to experience the benefits. That can potentially be realised by introducing a conservation fee instead of a compensation fee, but also education and a (payed) role in conservation can be an incentive to converge solutions to problems. Such conservation performance schemes have been successfully applied in conserving endangered animals in Nepal (Dickman et al., 2011) and Sweden (Zabel and Holm-Müller, 2008). Although a conservation performance scheme requires extensive surveys to record the number of endangered animals in a locality, the forestry department regularly studies distributions and population sizes of, for example, tigers (NCD, 2019) and snow leopards (DoFPS, 2016) using camera traps. This information could be used as a basis for compensating the communities sharing habitats with these endangered species. In this way the local community will be engaged in protecting endangered wildlife and this would be a 'win-win' situation for both herders and conservationists.

The issue of reducing or removing stray dogs from yak farming regions as a means to reduce yak mortality, interferes with individual and/or community sentiments. Herders found themselves in a dilemma whether to eliminate stray dogs or face the consequence of social pressure from the community for eliminating these animals. Rather, they would rely on the governmental bodies to set regulations or to remove these dogs somehow. In order to get to a generalized solution, the governmental institutions and NGOs should plan education programmes and management targeting different stakeholders (Wierzbowska et al., 2016) using several strategies such as: i) encourage and reinforce safe disposal of wastes, to prevent that stray dogs are attracted; ii) include instructions in tourists' guidelines (e.g. not throwing away their garbage but take it away for proper disposal); and iii) encourage dog owners to register their dogs and disallow pets to roam freely, and encourage sterilisation if pets are not used for breeding (Kahn et al., 2008).

4.3. Diverging views on problems and solutions

There are trade-offs between conservation of natural resources and the traditional method of rejuvenating the rangelands. Most yak farming villages in Bhutan are within protected areas. Conservation of natural resources in these areas is the highest priority for the forest policy makers. The rangeland size has receded due to shrub proliferation as a result of enactment of the *Forest Act* 1995. As a consequence of rangeland degradation due to shrub proliferation, livestock production is affected due to low forage availability, plant richness is reduced (Pornaro et al., 2017), litter

decomposition rate in rangeland is impaired (Brigham et al., 2018), and grassland ecosystems are disturbed (Nautiyal and Kaechele, 2007, Koch et al., 2015, Archer et al., 2017, Myers-Smith and Hik, 2018). It may also be argued that shrub proliferation in rangelands would allow for other species to establish, for instance the avian diversity in the Italian Alps has increased with increased shrub proliferation. However, most of these invading bird species are common and grassland bird species are threatened with extinction (Laiolo et al., 2004). Another benefit of shrub encroachment is that woody plants provide fuel woods, materials to construct fences and corrals (Reed et al., 2015), and increase carbon sequestration (Archer et al., 2017, Li et al., 2018). These facts overshadow the revising of the *Forest Act*. A collaborative learning process is recommended because any socio-technical transformation requires involvement of both academic and non-academic stakeholders (Restrepo et al., 2018). In the context of shrubs around rangelands to maintain rangeland conditions, governmental institution needs to organize multi-stakeholder dialogue aiming to discuss and clarify problems among stakeholder groups (Hirsch Hadorn et al., 2006, Pohl and Hirsch Hadorn, 2008, Wanzenböck et al., 2019). Next, empirical evidence should to be collected to understand synergies and trade-offs around burning rangelands, such as the impact on biodiversity. A prescribed burning in areas encroached by shrubs should be experimented (theory to practice) (van den Daele and Krohn, 1998), involving all stakeholders to ensure transparency (Lindfors, 2020). Moreover, the experimentation should follow a recursive model because solutions may have unexpected side effects and this also adds knowledge to the process of innovations (Pohl and Hirsch Hadorn, 2008). Subsequently, the captured information should be disseminated to relevant organisations. This implies that policy makers may need to design a clear objective, which includes the roles and contribution of each stakeholder, for effective implementation of the regulations through collaboration (de Bruijn and Heuvelhof, 2002, Boaz et al., 2018).

The Bhutanese government aims to promote sustainable utilisation of rangelands by redistributing rangelands to yak herders and livestock farmers because of absent owners (elite societies, monk bodies) (Phuntsho and Dorji, 2016). The *Land Act* 2007 of Bhutan states that rangelands are nationalized and leased to yak herders and livestock farmers from 2017 onwards. However, because of poor explanation of the new act (Namgay et al., 2017) and a lack of coherence in the implementation strategy (Tenzing et al., 2017) confusion has arisen among different rangeland users. Consequently, the enactment of the law has led to conflicts between different rangeland users (Phuntsho and Dorji, 2016, Namgay et al., 2017, Tenzing et al., 2017) as this act affects the existing agreed norms and rules of communities on the management of rangelands. Moreover, the *Land Act* 2007 of Bhutan was drafted by a team of civil servants from different governmental institutions, while transhumance communities were rarely involved in the process (Namgay et al.,

2017). There is also supporting evidence regarding increased conflicts among pastoral communities due to disruption of the community collective rangeland management practice after nationalization of rangeland in Nepal (Dong et al., 2016) and disappearance of pastoral culture and an effect on pastoralists' livelihoods after implementation of the *Rangeland Household Contract Policy* in China (Gongbuzeren et al., 2015). This implies that relevant stakeholders should have been involved throughout the policymaking process. When this not happens pastoralists may leave their traditional way of living and look for other livelihood (Kreutzmann, 2013). This happened, for example, in China where the government applied a top-down policy by forcing pastoralists into urbanisation (e.g. pastoralists settle in towns) and modern farming (e.g. fencing rangelands, rangeland conversion into agricultural fields and applying pasture management, centralised livestock breeding).

5. Policy implication and conclusions

This research underpins experienced threats to yak farming by different stakeholders and provides insight in problems and solutions from the perspective of different stakeholders. Herders consider forage availability and yak mortality as the main threats to yak farming, while government officials perceive labour availability (park rangers, livestock officials, forest officials) and rural-urban migration (extensionists, park rangers) as the main threat. In addition, livestock officials perceive forage availability also as a threat to yak farming. The triggers that we have identified from our analysis (e.g. yak product packaging design and develop improved pasture) may be prioritised for implementation to encourage yak herders to stay active in yak farming. It will also be valuable, however, to further investigate to what extent these triggers help to overcome challenges and barriers to yak farming. We acknowledge that even if the problems and solutions for approaching a problem converge among stakeholder groups, it does not necessarily mean that it is the best solution from a sustainability perspective. Several diverging views on the problems and solutions among different stakeholder groups indicate that there are possibly several challenges and barriers to sustain yak farming. There is a need for a multi-stakeholder dialogue aiming to discuss problems and solutions together. This should take away misleading and disputed claims, and provide understanding about the approach of yak-based communities to cope with risks and uncertainty around transhumance systems. This will also ensure that any future policy intervention to promote and facilitate sustainable yak farming is aligned with stakeholders' requirements. It is hoped that with strong collaboration and appropriate policy and legislation, this would reduce or remove challenges and barriers, which simultaneously give opportunities to yak herders and their children to stay in yak farming in future

Chapter 6

General discussion

1. Introduction

Yak farming in Bhutan is under pressure due to socioeconomic developments, policy and climate change. Little was known about the impact of these pressures on yak farming, and what policies and interventions might be required to encourage herders and younger pastoralists to stay in yak farming, or in other words sustain yak farming in the future. In this thesis experiences and perceptions of yak herders, policy makers and people in the field dealing with the challenges and developments related to yak farming on a regular basis were analysed. In addition, the impact of the mentioned pressures on, for example, labour and resource availability, traditional yak management practices and yak health and welfare was explored. Therefore the aim of this thesis was to assess the impact of external factors and management on yak farming in Bhutan, with a focus on past developments, the current situation (including the health and welfare of yaks) and future perspectives in yak farming.

The chapter proceeds as follows. I will first discuss the challenges and barriers around sustainable development of yak farming with a focus on external factors (socioeconomic development, policy and climate change). Subsequently, the impact of external factors on yak health and welfare will be discussed. Finally, governance options to overcome obstacles to sustainable development of yak farming will be discussed.

2. Yak-based communities under pressures

Transhumance pastoralism is changing worldwide (Dong, 2011) and the urgency of the Bhutanese government to support yak farming is increasing as the number of yak farming families is declining over the years. The declining number of yak farming families is a concern because: i) it would mean that a unique culture of local communities disappears (Joshi et al., 2020); ii) unique products such as yak butter and cheese will not be available on the market anymore; iii) huge government financial input may be needed to safeguard the subalpine and alpine region from external exploitation (Wangdi, 2016). Yak herders migrate with their herds to higher altitudes in mountains and consequently subalpine and alpine regions are occupied and utilised; and iv) people migrating to lowland areas would also mean conversion of forest land to settlements and agricultural farming, which would affect the ecological balance in the lowlands (Pal, 1993).

Previous studies investigated the current situation of yak farming in Bhutan and these local communities are assumed to be under increasing pressure from external factors such as socioeconomic developments (Wangchuk et al., 2013a), policies and regulations (Phuntsho and Dorji, 2016) and climate change (Wangchuk et al., 2013a, Wangchuk and Wangdi, 2018). Previous

studies have looked into these pressures but often investigated one or a few aspects, for instance impact of cordyceps collection on yak farming (Wangchuk and Wangdi, 2015) and effect of climate change on yak farming (Wangchuk and Wangdi, 2018), while often external factors do not operate in isolation. For example, shrubs have proliferated in rangelands due to climate change and the prohibition of burning of bushes around rangelands. Also, these authors did not assess to what extent these external factors influence yak farming practices. Moreover, previous investigators did not take into account the possibility of a regional effect on yak farming practices (as I did in Chapter 2-4). My research further explored how different stakeholders (livestock extensionists, park rangers, policy makers of livestock department and policy makers of forestry department) view the future of yak farming based on their experience and opinions (Chapter 5). What emerges from this effort is a deeper understanding on the competing interests of yak-based families and competing interest between yak-based communities and other stakeholders (trade-offs).

Forage availability in rangelands, yak predation and labour availability are the main threats to yak farming as experienced by yak herders, while the market to sell yak products is less of a threat (Chapter 2 and 5). Based on the findings of this thesis, impacts of socioeconomic development, policy and climate change on each theme (labour availability, forage availability, yak mortality, market to sell yak products) is discussed below (Figure 1).

2.1. Impact of external factors on labour availability and successors

Two important external factors influencing labour availability are better access to education and the availability of alternative sources of income, like the collection and sales of cordyceps (*Cordyceps sinensis*, a mushroom believed to have medicinal properties). Most young and adult pastoralists of the central and western yak farming region are involved in cordyceps collection on the rangelands from May to July. The sales of this mushroom fetches good annual income to families (Wangchuk and Wangdi, 2015). Yak farming has become more important over the years in the eastern region while cordyceps business has become more important in the central and western region (Chapter 2). Cordyceps is collected in the same area as where yak farming takes place (summer rangelands). The cordyceps collection in the high altitude of Bhutan was legalised in 2004 to keep herders engaged in yak farming, but when herders became wealthy they bought houses and agricultural land in the lowlands (Derville and Bonnemaire, 2010, Wangchuk and Wangdi, 2015). These authors assumed that lucrative alternative sources of income have impacted the motivation of both youth and adult pastoralists to stay active in yak farming. In Chapter 4, however, no association between preferred choice of livelihoods for herders and their future decision and plan with yak farming was found. Nonetheless, both herders and the government officials acknowledged that the number of

young pastoralists to take up yak farming (potential successors) declined over the last 10 years as a result of socioeconomic developments (e.g. better livelihoods) (Chapter 2 and 5). The number of yak farming families will therefore most likely further decrease because of too few successors to take up yak farming. Having successors is one of the most important factors determining the sustainability of pastoralist communities (Bernués et al., 2011). A similar conclusion was drawn previously on increased engagement of young pastoralists with off-farm activities, which had triggered them to migrate to towns in Bhutan (Namgay et al., 2014, Wangchuk and Wangdi, 2015, Wangdi, 2016), in India (Pal, 1993) and in Nepal (Sharma et al., 2014, Gentle and Thwaites, 2016, Tiwari et al., 2020). Hence, there seems to be a reversed effect, the creation of alternative livelihoods for yak-based communities such as cordyceps collection resulted in a reduction of family labour available for yak farming, instead of supporting it.

Also, the access to education for children has repercussions on availability of family labour to herd yaks. Most young literate pastoralists view yak farming as a tough way of life (Chapter 2) and it is considered a job for illiterate people. These literate pastoralists migrate to towns because there are better job opportunities, higher education and other modern technologies (Chapter 2, 4 and 5) and those who remained in the villages lacked motivation to take up yak farming (Chapter 2). In summary, access to modern education for children has jeopardised yak farming.

2.2. Impact of external factors on forage availability in the rangelands

Forage availability has declined over the years, and this was seen by both herders and other stakeholders as a threat to yak farming (Chapter 2 and 5). In this thesis, four main causes for forage shortage were identified. The first cause is an increased use of the rangelands by different parties due to tourism and cordyceps collection. In Chapter 2, yak herders (18%) mentioned that they experienced a growing number of issues/conflicts between yak herders and horse owners over the use of rangelands. The increased horse population over the years in the yak farming regions as experienced by herders is in accordance with official statistics of Bhutan (DoL, 2007, 2018). Horses are widely used to transport camping items for tourists and necessities required during cordyceps collection (Chapter 2 and 5) and the increased horse population in yak farming regions has exerted more pressure on rangelands (both lower and higher areas). In Chapter 2, I showed that one of the reasons that herders started migrating from winter rangeland (subalpine and alpine zones) to summer rangeland (cool temperate zones) earlier than they did in the past, because of the increased number of horses in the rangelands where cordyceps is being collected. It therefore seems that the upcoming alternative likelihoods also have a negative impact on forage availability and thus, indirectly, on yak farming families.

Contemporary studies showed that the timing of herd migration from winter rangeland to summer rangeland was also affected by the increasing temperature due to climate change (Wangchuk and Wangdi, 2018, Feroze et al., 2019). This thesis contradicts their findings, as some herders felt forced to migrate early to winter rangelands due to unpredictable weather conditions (Chapter 2). Nonetheless, climate change thus impacts the use of the rangelands, and therefore the forage availability.

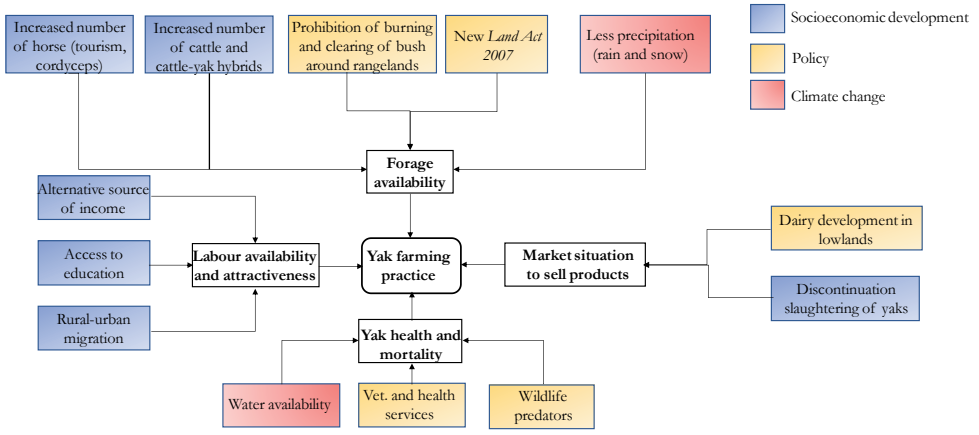

Figure 1. Summary of the external factor (in coloured boxes) identified in relation to yak farming. Arrows show the influence of external factors on the four main themes (white boxes) related to yak farming practices.

In the *Land Act 2007* of Bhutan yak herders and livestock farmers are given user rights, but not management rights for rangelands, which also means that burning and clearing of shrubs and bushes around rangelands is still prohibited. One important change is that this act allows herders to improve the pasture in rangelands (Tenzing et al., 2017), which was prohibited by the *Forest and Nature Conservation Act 1995* of Bhutan. Because this latter act has not been revised, it is unclear which act herders should follow. One important shortcoming is that implementation of this act might have disrupted the traditional collective use of common rangelands. The collective use of common rangelands probably contributed to sustainable use of rangeland resources by limiting stocking rate, ensure equal access to common resources by herders and improving social networks (Gongbuzeren et al., 2016, Yang et al., 2020). The breakdown of customary community-based grazing management led to over-grazing and degrading rangelands in Mongolia (Fratkin and Mearns, 2003, Barcus, 2018). From the results (Chapter 2), herders (37%) stated the conflicts among yak herders, and between yak herders and cattle farmers and also horse owners over the

use of rangelands has increased mainly due to implementation of the *Land Act* 2007 of Bhutan. Hence, this new land act is offering both risks and opportunities.

The strong conservation policy (e.g. *Forest and Nature Conservation Act* 1995) in combination with climate change are other important factors found in this thesis affecting forage availability in the rangelands. In the most recent decade, subalpine and alpine rangelands have degraded due to shrub proliferation which affected forage availability. Rangeland has receded due to shrub proliferation as a result of enactment of strict conservation policy in Bhutan (Chapter 2 and 5). Other authors further related the increased shrub covers in alpine regions due to climate change (Lantz et al., 2013, Myers-Smith and Hik, 2018, Wangchuk and Wangdi, 2018) and decreased livestock population and abandonment of rangelands in Nepal (Sharma et al., 2014, Su et al., 2015). Additionally, more than half of the livestock professionals (Chapter 2) and all forest officials (Chapter 5) related forage shortage to less precipitation (rain and snow) compared to the past. This illustrates that the external factors do not operate independently, but rather have intricate relations between them. Similar effect of these external factors on rangelands have been found in Nepal (Tiwari et al., 2020), Ethiopia (Mekuyie et al., 2018), and Kenya (Kimiti et al., 2018). In Chapter 2, herders (east, 76%; central, 80%) stated that implementation of the forest act has caused shrub proliferation, however, herder groups of the central region did not rate it as the most important factor (Chapter 5). A plausible explanation for contrasting results are: i) herders may feel powerless to change the act because this act has been instated more than two decades ago, with no indication of a possibility to revise; ii) shrub proliferation might be a problem only in some areas; iii) some other factors might be more important than the forest act as described in Chapter 5. A positive effect of shrub encroachment in rangelands is that biodiversity may increase (Laiolo et al., 2004), woody plants provide fuel and materials to construct fences and to corral animals (Reed et al., 2015), and that it increases carbon sequestration (Archer et al., 2017, Li et al., 2018). In summary, the benefits of burning of rangelands is subjected to scientific debate, such as rangeland versus shrub, livestock versus wildlife, and forage versus fuel wood (Fuhlendorf et al., 2017).

2.3. Impact of external factors on yak health and mortality

In Chapter 2, 3 and 5, one theme of particular importance emerges regarding the impact of strong conservation policy on increased yak predation by wild endangered animals (e.g. snow leopard, *Panthera uncia*; Asiatic wild dog, *Cuon alpinus*; Himalayan black bear, *Ursus thibetanus*), but also by stray dogs over the years. However, a decline in wild prey or an increase of the yak population perhaps contribute to increased yak predation (Chapter 2). In addition, Feroze et al. (2019) also linked the increased number of yak loss to wild animals to environmental change in Sikkim, India.

Predation of yaks may happen when they stray away and move further up in the high mountains to escape heat stress and in search for better forage where wild predators are also found. Additionally, habitat overlap between yaks and wild herbivores such as Himalayan musk deer (*Moschus chrysogaster leucogaster*) and takin (*Budorcas taxicolor*) would also mean increased competition for forage and consequently wild herbivores would be displaced (Mishra et al., 2004).

In addition to competition between yaks and wild herbivores on forage resources, diseases and parasites (e.g. bovine tuberculosis, foot and mouth disease) may have "spilled over" from livestock to wildlife and vice versa (Rhyan and Spraker, 2010, Wiethoelter et al., 2015). If disease and parasite transmission happen between livestock and wild animals, it may have significant impact on the health of animals (both livestock and wild animals), livelihoods of yak-based families, achievements of conservationists, and possibly cause zoonotic diseases. In this regard, the livestock department, forestry department, and public health department should jointly work to identify diseases and parasites at the wildlife-livestock interface, which have received little attention so far.

It is clear that policies and climate change will not only increase human-wildlife conflicts, it also increases the risk for disease and parasite transmission between livestock, wild animals, and potentially humans, as we recently experienced with covid-19.

2.4. Impact of external factors on market to sell yak products

The overall market to sell yak products has improved over the years with road infrastructure developments in yak farming regions (Chapter 2) as herders could transport yak products in short time to urban markets further away. Again, further improving infrastructure also means that people will travel more easily and potentially leave the yak communities. The market to sell yak butter has remained the same or has even deteriorated over the years (Chapter 2). Reasons for changes in market situation to sell yak products that can be derived from this thesis are: i) a change in customers, for instance in the past herder and/or family members bartered their yak products with lowland farmers, while nowadays citizens in towns are also customers (Chapter 2); ii) most herders have discontinued slaughtering of yaks due to increasing religious sentiments among yak-based communities (Chapter 2); iii) consumers' negative image of yak dairy products as they are believed to be processed in an unhygienic manner (Chapter 5). Yet, additional information regarding consumer beliefs, attitudes and behaviour towards yak dairy products may be helpful to make the products more attractive and in that way stimulating the sales of products.

2.5. Future prospects of yak farming

In general, farmers are more likely to give up farming when they experience several constraints and challenges in farming (Kumar et al., 2019) and also have a better alternative source of income (Derville and Bonnemaire, 2010, Wangdi, 2016). In Chapter 4, herders' perceived concerns around yak farming are used to determine future prospects of yak farming (plans and decisions). In addition, relationship between herders' preferred source of income and their future plans and decisions related to yak farming were analysed. These analyses described in Chapter 4 showed a positive association between herders' perceived level of concerns and their wish for children to continue yak farming. Most herders wish their children to continue yak farming in the future (Chapter 4). The herders have confidence that yak farming will remain a reliable source of income (Chapter 2 and 4) but also give importance to the traditional way of life (Chapter 4). Conversely, no association was found between herders' perceived concerns and their future plan with herd size and with the opinions on the number of yak farming in the future. More than half of the herders and most livestock professionals indicated that the number of yak farming families will decline in the future due to several constraints and challenges (Chapter 4). This is confirmed by a review showing a rapid decline of yak farming in Bhutan with 31% from 1400 families in 1996 to 968 in 2013 (Wangdi, 2016). Likewise, transhumance pastoralism is changing worldwide due to socioeconomic developments, policy and climate change (Oteros-Rozas et al., 2013b, Aryal et al., 2014, Jurt et al., 2015, Gentle and Thwaites, 2016, Tiwari et al., 2020).

In conclusion, the number of yak-based farming families will continue to decline if constraints to yak farming are not overcome and possible strategies are not applied to nurture yak farming. Moreover, the challenges faced by yak-based communities differ from one region to another (Chapter 2), the policies and interventions have to be a location-specific in order to support yak farming in Bhutan.

3. Yak health and welfare under free-ranging systems

Despite several potential risk factors for yak health and welfare such as forage shortage, unavailability of veterinary services, and painful practices, the health and welfare of yaks under existing management practices was assessed to be good during the time of visit (autumn / early winter; Chapter 3). Under transhumance systems, yaks are reared under free-ranging conditions and herders interact with lactating yak cows and calves on a regular basis for milking and feeding. Moreover, milking by hand is also a close interaction between herders and cows. In only a few occasions, close interactions happen between a herder and the rest of the herd members (bulls,

heifers, non-lactating cows): for instance, when gathered and restrained for sheering, salt feeding and castrating. When these close interactions happen this may be stressful for both the animal and the herder and therefore increase the risk of injury for both of them (Waiblinger et al., 2006). As for future work, the risk factors associated with poor health and welfare of yaks need to be investigated in more detail. Moreover, the health and welfare of yaks could be under threat in other periods of the year, especially at the end of winter period and beginning of spring when feed resources are scarce.

Positive impact on health and welfare of yaks might be driven by socioeconomic developments. Globally, consumers and other stakeholders are becoming more concerned about animal health and welfare (Thornton, 2010, Toma et al., 2012, Vanhonacker and Verbeke, 2014). Also in Bhutan more awareness is developed, for example a few animal interest organisations have become active (e.g. Bhutan Animal Rescue and Care, Royal Society for Protection and Care of Animals, Jangsa Animal Saving Trust). On the longer term, this may lead to regulations around health and welfare and the transhumant herders will be pushed to meet these requirements (e.g., provision of shelter and additional winter feed, vaccination of animals). This may increase the input costs for farming (Jurt et al., 2015), but the benefits for health and welfare of the animals and improve herd productivity will probably outweigh the financial cost of meeting such legal requirements.

Another positive consequence of socioeconomic developments was observed in yak farming practices. First, the families' living standards have improved over the years due to livelihood diversification such as cordyceps collection (western and central region). As discussed in Chapter 2, some herders provide cattle concentrate purchased in the towns and supplementary forage such as improved mixture forage, turnips and radish to lactating yak cows and calves, which indicates herders attempt to maintain the body condition of yaks during feed shortage in winter. However, the amount of concentrate and forage provided to animals varies depending on how much they can afford to invest in yak farming. Second, with road infrastructure developments veterinary services has become more accessible over the years (Chapter 2) thereby improving the health care of animals. Third, most men are predominately involved in off-farm activities, while women take responsibility to look after the yaks (Chapter 2). This probably improve the confidence of the animals towards human i.e. positive human-animal relationships. It has been suggested that female farmers have a more positive attitude and behaviour towards animals than male farmers (Lensink et al., 2000). Future studies should assess the relationships between herders' characteristics (e.g. gender, age, education level, number of herders, yak herd size own) and their attitudes and behaviour towards animals to confirm above findings under free-ranging systems.

On the other hand, the availability of labour to herd yaks is decreasing over the years as a result of socioeconomic developments (e.g. access to education, alternative source of income) (Chapter 2). Labour shortage to herd yaks could mean that there will be less interactions between herders and animals, which will reduce the confidence of the animals towards humans (Lensink et al., 2000, Leruste et al., 2012). Wiener et al. (2003) further posit that herders can give more individual care and more forage is available for animals when the herd size is small. This implies that ratio of stockpersons to herd size is important to ensure positive human-animal relationships.

A potential threat to health and welfare of yak is climate change. In the greater Himalayas, the annual mean temperature is projected to rise by at least 0.3–0.7 ◦C more than the global temperature expected increase of 1.5 ◦C (Krishnan et al., 2019). Since yaks are adapted to low temperatures, higher temperatures might affect their health and welfare. An experiment conducted at an altitude of 3000 masl in Arunachal Pradesh, India showed that the ambient temperature of more than 14 ◦C causes heat stress to yaks (Krishnan et al., 2018). When animals are heat stressed, the feed intake is reduced, while water intake and respiration rate increase (Nardone et al., 2010), and the reproduction performance of animals is negatively affected (Collier et al., 2006, Dash et al., 2016). The rising temperatures would also create a more favourable environment for ticks and flies to thrive in subalpine zones (Wangchuk et al., 2013a), which will have irritant effect on yaks.

4. Nurturing yak farming practices through policy

Realising the crucial role the yak-based communities have, the Bhutanese government aims to improve the livelihood of these communities to make yak farming an attractive occupation (Twelfth Five Year Plan, 2018-2023). Besides, the government should also address forage shortage and yak mortality, which are the important issues as part of improving livelihoods (Chapter 5). Efforts to improve yak farming practices also have the potential to improve the health and welfare of yaks by improving their living conditions. In this section, I discuss the most important strategies that could help to tackle issues related to labour shortage (potential successors), yak predation by wild animals and forage shortage.

4.1. Livelihood opportunities for yak-based communities

One of the main reasons for the young pastoralists to migrate to towns and cities is the lack of basic amenities and infrastructure in yak farming regions (Chapter 2, 4 and 5). However, having facilities in villages does not fully guarantee that it would reduce youth outmigration. In addition, stakeholder groups suggested that the young pastoralists should be encouraged to take up yak farming (Chapter 5). While there are several strategies, I will highlight the three most important

local alternative sources of income, namely payment for ecosystem services, tourism associations, and providing better market opportunities.

First, in discussions with stakeholders a payment for ecosystem services was mentioned as a solution. Although government officials acknowledge yak-based communities play a role in preserving the local mountain ecosystems (from stakeholder groups interviews), it was not mentioned whether these communities should also be compensated for the sustainable management of mountain resources. Mountain ecosystems offer various benefits of goods and services to these communities, including materials (food, water, fuel, timber) and non-materials (spiritual well-being, aesthetic value, cultural identity) (FAO, 2011, Naudiyal and Schmerbeck, 2017, Dorji et al., 2019b). They also support communities living downstream with the provisioning of ecotourism services (Goldstein and Messerschmidt, 1980, FAO, 2011, Rasul, 2014). However, the communities residing at this high altitude are deprived of developmental activities and benefits of socioeconomic developments. Thus, yak-based communities should be rewarded for the societal benefits of sustainable management of resources (Reed et al., 2017). However, in practice, ecosystem services incentive schemes require willingness from the beneficiaries to pay for the services (e.g. hydropower department, forestry department, tourism industry). Research is needed to identify the ecosystem services of yak farming, and evaluate the conflicts and trade-offs among different stakeholders associated with it (Oteros-Rozas et al., 2012). These authors have proposed a framework to evaluate the ecosystem services for transhumance pastoralism using an interdisciplinary and participatory approach. This could be a cornerstone for building knowledge to get insight into the perceptions of different stakeholders regarding ecosystem services provided by transhumance yak farming.

A second option is the formation of yak-based tourism associations. So far, a few tourism operators (e.g. elite societies) living in urban areas have benefited from tourism even though most tourists trek in yak farming regions (Suntikul and Dorji, 2016). There is a need to build a coalition between the government, the tourism council of Bhutan and yak-based communities (Chapter 5) to, for example, encourage the use of yaks to transport camping and trekking items. Aside, use of yaks in tourism activities would also remove pressure from the rangelands due to the increasing horse population in yak farming regions (Chapter 2 and 5). However, tourism also has a negative impact on sociocultural traditions of these local communities such as change in dietary culture, dress codes, moral values and beliefs, and lifestyles (Woosnam and Aleshinloye, 2018, Zhuang et al., 2019).

Third, stimulating sales of yak products. The cheap imported dairy products from India come nicely packaged with given nutrients content labels and this has gained customers' trust on the safety of

this product (Derville and Bonnemaire, 2010). This has affected the sales of yak dairy products, especially yak butter (Chapter 2). As a way forward the government institutions could explore improving the packaging of the yak products that would stimulate the sales of products (Chapter 5). The packaging design could be a simplified version of product labels as commonly found in commercial imported products to make yak products visually attractive and to assist consumers in making choice of similar products, yak butter versus imported dairy butter (Ferrazzi et al., 2017). Moreover, government institutions may also focus to arrange a contract between herders and hotels and restaurants on marketing yak products. This type of arrangement could reduce risks of herders related to fluctuating prices of yak products.

4.2. Measures to mitigate human-wildlife conflicts

Despite predators are being said to be the leading cause of yak mortality, especially for young and weak animals (Chapter 2 and 5), it appears that herders have limited options to cope with predation. A high level of yak predation by wild predators seems to occur during forage shortage when the animals stray away from the main herds and walk in the remote areas to obtain forage. Additionally, making veterinary and health services accessible to animals would improve the health of animals. Thus, taking better care of animals (e.g. improve feeding, better veterinary and health services) might reduce the number of yak predations to wild animals by improving animals' health. Other preventive measures such as corralling weak and young stock at night, using guard dogs (Chapter 5), or visual or auditory deterrents to frighten predators and encouraging herders to spend more time in guarding could be applied by herders to mitigate yak predation by wild animals. The government institutions and NGOs (e.g. conservation agencies) may have to divert funds to investigate the effectiveness of aforementioned interventions to reduce predations considering the cost of implementing measures versus reduction of livestock losses, types of predators in a locality (Eklund et al., 2017) and herders' acceptance to interventions. For example, herders should be encouraged to spend more time guarding their yaks instead of leaving them unattended most time of the year to mitigate human-wildlife conflicts. However, the feasibility of herders guarding animals for extended periods of time would highly depend on the availability of labour.

Another common strategy to support conservation of endangered animals is compensating the herders for damage caused by wild predators (Mishra, 1997, Bagchi and Mishra, 2006, Tiwari et al., 2020). The main drawback of having a compensation programme is that herders would be tempted to not apply preventive actions (e.g. spend more time in herding yaks, corralling weak animals) (Bulte and Rondeau, 2005, Zabel et al., 2011) and better care (e.g. feed and health care services). In addition, a few herders plan to increase the current herd size in response to high mortality due to

predation (Chapter 4). Moreover, herders mentioned the number of yaks in the community has increased over the last 10 years (Chapter 2 and 5). This would mean that stocking rate in the rangelands has increased and probably wild herbivores would be displaced, which is the primary prey for wild predators. As a consequence, human-wildlife conflicts will increase (see section 2.3). In order to encourage yak-based communities, they need to experience the benefits for conserving endangered habitats and species. Further, I suggest to replace the compensation scheme with a conservation scheme to liberate herders from collecting evidence to ascertain predation on their livestock, which often is a burden for them (Eklund et al., 2017, Lee et al., 2017). Such initiatives have been successfully applied in protecting snow leopards and generate income for the local community of Ladakh, India (Maheshwari and Sathyakumar, 2019). The government institutions and NGOs may have to work closely with communities to encourage local communities to actively engage in conservation activity. Thus, educating herders and their children about the importance of protecting the predators as a key role to ecosystem survival should be a priority of the governmental strategy.

4.3. Solution to forage shortage

The detailed discussion on solutions to forage shortage can be found in Chapter 5. To this end, policies around developing improved pasture need to be implemented to address forage shortage (Chapter 5). Pasture development entails collaboration among herders, extensionists and park rangers through shared activity. Furthermore, pasture development can improve the degraded alpine rangelands as shown in Qinghai-Tibetan Plateau, China (Dong et al., 2007b). However, introduced pasture species, especially grasses, are sometimes likely to become an invasive weed (Driscoll et al., 2014, Norton et al., 2016). So, an initial step for the livestock department of Bhutan is to identify potential threats of improved pasture species to local plant species, and to conduct a field trial under restriction to evaluate performance of introduced species (Lonsdale, 1994).

Aside from developing improved pasture areas to reduce forage shortages, prescribed burning was also suggested by livestock professionals and herders (Chapter 5). Fire is the cheapest method to control shrubs in rangelands to make forage available in rangelands (Wangchuk et al., 2013b, Valkó et al., 2014), but it has trade-offs with other ecosystem services (e.g. soil erosion, fuel wood, carbon sequestration). To allow or not to allow the prescribed burning to control shrub proliferation in rangelands requires an interdisciplinary approach involving all stakeholders to discuss and clarify problems/issues related to it (Chapter 5). Prescribed burning should be experimented to get insight into impacts of burning on rangeland ecosystems. If prescribed burning is to be allowed, the number of burns suggested is every six years in Bhutan (Wangchuk et al., 2013b) depending on

types of vegetation. The reason to conduct burning of rangeland after every few years is to allow plants to regenerate between the burns, as otherwise some plant species may dominant resulting to decrease in plant richness (Valkó et al., 2014). Herders should be trained by researchers and field assistants (e.g. park rangers, extensionists) to perform a prescribed burning in the rangelands.

4.4. Enhancing multi-stakeholder dialogue

There was contestation among different stakeholder groups on the factors affecting forage availability, labour availability and market to sell yak products (which I refer to as problems), as well as on the solutions to approach those problems (Chapter 5). Some problems such as prohibition of burning and clearing shrubs and bushes around the rangelands have existed already for a long time, but have not been addressed so far, possibly because of contrasting views about impact of burning shrubs on ecosystems and conflicting goals and values among organizations. There is a need for a multi-stakeholder dialogue aiming to discuss and build consensus on the problems around yak farming, and to try to align interventions with requirements and needs of different stakeholders. For example, the recent Land Act 2007 of Bhutan was drafted by a team of civil servants from different governmental institutions, while yak herders were rarely involved in this policy-making process (Namgay et al., 2017). Moreover, the new land act disrupted the community collection rangeland management practices (i.e. rangeland users do not follow agreed norms and rules of communities on the use of rangelands), and consequently has led to conflicts between different rangeland users (see section 2.2). Therefore, this exemplifies that yak herders should be given an opportunity to share their views and opinions, and also allow them to debate on rangeland related issues as highlighted in this thesis.

Based on the results of this thesis and the existing literature, without taking measures yak farming will continue to decline in the near future due to several constraints and challenges. In this chapter, I suggest governmental institutions to tackle these issues by exploring alternative sources of income to at least give a chance for this unique age-old tradition to survive and thrive under increasing pressures. However, a deeper understanding of factors affecting yak farming practices in different regions is also required because a one blanket-policy will not be effective to preserve yak farming for the future. Moreover, to a large extent current herders, as parents, have a pivotal role and possibly should motivate their children to take up yak farming in the future. In addition, yak herders within and between regions should share their experiences on yak farming. With this, I hope the findings from my work will promote and nurture yak farming in Bhutan, as well as yak farming in other regions.

5. Conclusions

This thesis contributes to the scientific knowledge of challenges and opportunities to yak farming in Bhutan. The main conclusions are:

- Forage shortage, yak predation and labour availability are the main threats to yak farming, while market to sell yak products is the least threat.
- Yaks experience relatively high levels of welfare under existing management practices in autumn/early winter, but they are also exposed to welfare risks due to forage shortage, predator attacks, and painful management practices.
- Herders' perceived level of concerns was positively associated with their wish for children to continue yak farming, but was not associated with their future plan with herd size and with the opinions on the number of yak farming in the future.
- Yak herders and government officials think that the number of yak farming families will decline in the future.
- Differences in opinions between herders of different regions are attributed to differences in tradition practices of yak farming and alternative source of income.
- Stakeholder groups did not always have a converging view on problems and solutions related to yak farming. This indicate that there are possibly several challenges and barriers to sustain yak farming.
- There is a need for a multi-stakeholder dialogue aiming to discuss problems and solutions together to ensure that any future policy intervention to promote sustainable yak farming align with the requirements and needs of different stakeholders.
- Governance policies and interventions to encourage yak-based communities should mainly focus on exploring alternative livelihoods, solution to forage shortage and yak predation.

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Summary

In the high altitude of Bhutan, yak farming is the main livelihood of transhumant pastoralist communities living 2500 m above sea level. Yak farming in Bhutan, however, is under pressure due to socioeconomic developments, policy and climate change. There is a lack of knowledge on: i) how and to what extent these pressures affect yak farming practices and the health and welfare of yaks; ii) what factors influence the future plans and decisions of the herders on yak farming, and iii) what solutions may be needed to sustain yak farming under these pressures. Therefore, the aim of this thesis was to assess the impact of external factors and management on yak farming in Bhutan, with a focus on past developments, the current situation (including the health and welfare of yaks) and future perspectives in yak farming.

The future of yak farming in Bhutan is unsure or might even be at risk because its current situation and recent developments are not very well known to policy makers. Chapter 2 provides a comprehensive overview of the current situation and developments of yak farming practices over the years from the perspective of livestock professionals (n = 28) and yak herders in three regions (east, n = 25; central, n = 20; west, n = 22). Overall, yak-based communities experienced several threats to their way of living, which are exacerbated by external factors and may include, but are not restricted to, i) socioeconomic developments in the form of access to modern education for children, and alternative sources of income affecting the motivation and interest of young pastoralists to stay in yak farming; ii) nature conservation policy (e.g. *Forest and Nature Conservation Act* 1995 of Bhutan) in the form of shrub proliferation in the rangelands causing forage shortage; and iii) nature conservation policy in the form of predators attacking and/or killing yaks. Additionally, some factors affecting forage availability were specific to certain regions, for example, competition with the horse population (west), cordyceps collection (west and central), cattle and cattle-yak hybrids (east) and prohibited burning of shrubs around rangelands (east and central). These findings demonstrated that a one blanket-policy will be not effective to preserve yak farming for the future.

The health and welfare conditions of yaks are unknown and are presumably at risk due to feed scarcity, predators, out breaks of diseases and parasites, limited possibilities for monitoring, and limited accessibility to veterinary and health services. In order to improve the living conditions of yaks, health and welfare assessments are necessary. In Chapter 3, a welfare protocol and assessment procedure based on elements of the Welfare Quality® protocol for cattle was applied, which allowed assessment in the open field under mountainous conditions. In general, yaks in Bhutan

experience high levels of welfare under existing management systems during autumn and early winter. In the visited yak herds, clinical issues, such as dirty body parts, lesions, ocular and nasal discharge, diarrhoea, lameness and subclinical mastitis were virtually absent. In some herds a relatively high level of self-grooming, scratching and rubbing was observed, which may be associated with limited treatments against ectoparasites. Moreover, the traditional bull castration and piercing the nasal septum of animals around weaning without the use of analgesic were prominent identified welfare issues that needs attention. This chapter also emphasises a need to assess health and welfare of yaks in spring / early summer after a challenging winter period with poor forage and weather conditions.

In general, farmers are more likely to give up farming when they experience several constraints and challenges in farming and also have a better alternative source of income. In Chapter 4, therefore, associations between perceived concerns around yak farming and preferred source(s) of income of herders and their future plans and decisions were investigated. Although concerns of herders around yak farming have increased over the years, most herders (82%) wish their children to continue yak farming in the future. Nonetheless, over half of herders (58%) and most livestock professionals (96%) think that the number of yak farming families will decline in the future. Furthermore, herders' preferred source(s) of income had no relation with herders' opinion on the number of yak farming families in the future and herders' wish for their children to continue yak farming. This suggests that the herders have confidence that yak farming will remain a reliable source of income.

Although the Bhutanese government aims to support yak farming in transition, there are several cross-cutting policies and issues that probably affect successful implementation of interventions. In Chapter 5, the challenges and opportunities to sustain yak farming and related trade-offs around problems and solutions were assessed through individual and focus group interviews with six stakeholder groups (i.e. yak herders from two regions, livestock extensionists, park rangers, livestock officials and forest officials). The results reiterate the decreasing labour availability (i.e. successors), decreasing forage availability in the rangelands, and increasing yak predation by wild animals were the main threats to sustainable yak farming; the market to sell yak products was the least threat. However, most problems and solutions that were identified in the focus group interviews differed between, and sometimes within, the stakeholder groups. This implies that there are several challenges and barriers to sustaining yak farming. There is a need for a multi-stakeholder dialogue aiming to discuss problems and solutions together with different stakeholders. Also, stakeholder groups mentioned that the government should streamline socioeconomic development

by supporting and improving basic facilities in yak farming villages (e.g. better access to communication and health services), pay attention to human-wildlife conflicts and forage shortage, and explore sustainable income based on yak farming. These policy and interventions to encourage yak farming probably also improve the living conditions of the yaks.

In Chapter 6 the constraints, challenges, and opportunities to sustainable of yak farming are discussed. Yak farming is increasingly challenged due to socioeconomic developments, policy and climate change. Moreover, most problems and solutions to approach problems around yak farming diverged among stakeholders. This highlights the importance of having a strong collaboration among different stakeholders to ensure that any future policy intervention to promote yak farming aligns with requirements of stakeholders. Furthermore, I reflect on the impact of external factors on the health and welfare of yaks. For example, socioeconomic developments such as alternative sources of incomes for the yak-based families affect yak farming practices. On the one hand, increased involvement of family members in off-farm activities had caused labour shortage to herd yaks and this would also mean less positive interaction between herders and yaks. On the other hand, with increased family income from diversified sources herders can afford to purchase more feed for their yaks in winter time.

To conclude, without change in policies yak farming will continue to decline in the near future due to several constraints and challenges. The government institutions efforts to promote yak farming should be around tackling issues related to labour shortage (potential successors), yak predation by wild animals and forage shortage. Moreover, there is a need for a multi-stakeholder dialogue aiming to discuss problems and solutions together with different stakeholders to take away misleading and disputed claims. This probably will give a chance for yak farming to survive and thrive under increasing pressures. With this, I hope the findings from my work help to overcome challenges and to promote sustainable yak farming in Bhutan.

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Wageningen

Nedup Dorji

About the author

Nedup Dorji was born in1984 in Deothang, Bhutan. He obtained his BSc degree in Biological Life Sciences in December 2005 from Sherubtse College, which was affiliated to Delhi University, India. During his BSc, Nedup studied stored grain pests and pest control.

After his graduation, he was selected through national open examination by the Royal Civil Service Commission of Bhutan as Lecturer at the College of Natural Resources, The Royal University of Bhutan in 2007. In 2008, he was awarded for the Thai International Cooperation Agency to pursue a MSc in Agriculture at Khon Kane University, Thailand (graduated in 2010). During his MSc, he assessed genetic variations of Bhutanese indigenous chickens, and compared with Thai native chickens and commercial chicken lines. In 2016, Nedup was awarded the Netherlands University Foundation for International Cooperation in Higher Education to pursue a PhD study at the Farm Technology group in collaboration with the Animal Production Systems group of Wageningen University. His study focused on transhumant yak farming in Bhutan. The results of this work were presented at the yearly meeting of the International Society for Applied Ethology (ISAE) in 2019, the 75th Annual meeting of European Federation of Animal Production (EAAP) in 2019, and the WIAS Annual Conference in 2020.

Currently, he is the editorial board member of the Bhutan Journal of Natural Resources and Development (BJNRD) and till date he has been working as the Lecturer at the College of Natural Resources, The Royal University of Bhutan.

Publications

In refereed scientific journals

Dorji, N., Derks, M., Dorji, P., Groot Koerkamp, P.W.G. and Bokkers, E.A.M. 2020. Herders and livestock professionals' experiences and perceptions on developments and challenges in yak farming in Bhutan. Animal Production Science. https://doi.org/10.1071/AN19090.

Dorji, N., Derks, M., Groot Koerkamp, P.W.G. and Bokkers, E.A.M. 2020. The future of yak farming from the perspective of yak herders and livestock professionals. Sustainability, 12(10), 4217. https://doi.org/10.3390/su12104217.

Dorji, N., Derks, M., Groot Koerkamp, P.W.G. and Bokkers, E.A.M. Transition towards sustainable yak farming in Bhutan: stakeholders' viewpoints and recommendations for future steps. (Submitted)

Dorji, N., Derks, M., Groot Koerkamp, P.W.G. and Bokkers, E.A.M. Welfare and management practices of free-ranging yaks in Bhutan. (Submitted)

In conference proceedings

Dorji, N., Derks, M., Groot Koerkamp, P.W.G. and Bokkers, E.A.M., 2019. Behaviour and sociability of yaks among different regions in Bhutan. In: Book of abstracts of 53rd Congress of the International Society for Applied Ethology (ISAE): Animal Lives Worth Living, 5-8 August, Bergen, Norway-p. 265.

Dorji, N., Derks, M., Dorji, P., Groot Koerkamp, P.W.G. and Bokkers, E.A.M., 2019. Resilience of yak farming in Bhutan. In: Book of abstracts of the 70th Annual Meeting of the European Federation of Animal Science, 26-30 August, Ghent, Belgium- p. 426.

Dorji, N., Derks, M., Groot Koerkamp, P.W.G. and Bokkers, E.A.M., 2020. Herders' and livestock professionals' experiences on past and future developments in yak farming in Bhutan. In: Book of abstracts of WIAS Annual Conference: Frontiers in Animal Sciences, 13-14 February Centre, Lunteren, Netherlands- p. 48.

Education certificate

Completed training and supervision plan[1]

The Basic Package (3 ECTS)

WIAS Introduction Day (2016)

Course on research integrity and ethics in animal science (2017)

Course on essential skills (2017)

Disciplinary Competences (19.8 ECTS)

Preparing own PhD research proposal (2016-2017)

WIAS course on Design of Experiments (2016)

Sustainability Assessment of Animal Systems (2017)

Measuring and assessing animal welfare at herd level, Aarhus University (2017)

WIAS course- Statistics for the Life Science (2019)

Professional Competences (4 ECTS)

Information Literacy for PhD including EndNote introduction (2016)

WGS course- Scientific writing (2018)

WGS course- Presenting with impact (2019)

WGS course- Poster and Pitching (2018)

Presentation Skills (3 ECTS)

Poster presentation at ISAE, Bergen, Norway (2019)

Oral presentation at EAAP, Ghent, Belgium (2019)

Oral presentation at WIAS Science day, Wageningen, The Netherlands (2020)

Teaching competences (1 ECTS)

Supervision of BSc student (2017-2018)

[1]With the activities listed, the PhD candidate has compiled with the requirements set by the Graduate School of Wageningen University Institute of Animal Sciences (WIAS). One ECTS credit equals a study load of 28 hours.

Colophon

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