

## ECONOMIC VIABILITY OF YAK FARMING IN HIGHLAND AREAS OF THIMPHU DZONGKHAG: AN ASSESSMENT OF OPTIMAL HERD SIZE UNDER CHANGING LIVELIHOOD CONDITIONS

SONAM LODAY<sup>1\*</sup>, KUL BDR GURUNG<sup>1</sup>, SONAM PENJORE<sup>1</sup>, AND JIGME WANGDI<sup>2</sup>

<sup>1</sup>Livestock sector, Thimphu Dzongkhag Administration, Thimphu, Bhutan

<sup>2</sup>Department of Livestock, Ministry of Agriculture and Livestock, Thimphu, Bhutan

\*Author for correspondence: [sloday@thimphu.gov.bt](mailto:sloday@thimphu.gov.bt)

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**ABSTRACT:** *Yak husbandry is a vital source of livelihood for highland communities in Bhutan, deeply rooted in tradition and contributing significantly to local economies, cultures, and ecosystems. This study was conducted to determine the optimal Yak herd size required for household economic viability in Thimphu Dzongkhag. A total of 108 Yak herding households were surveyed across Soe, Naro, Lingzhi, and Dagala Gewogs. The study concluded that the "break-even herd size" based on income–expenditure parity ( $\text{income} \geq \text{expenditure}$  from Tables 5 and 6), as well as equating annual household income to the mean rural household income, it is approximated that an average of 23 milch Yaks in a herd will sustain the Yak pastoralist household year-round. However, the estimated herd size should be interpreted as a rough proxy, not an optimised herd size. It is derived from descriptive comparisons between mean annual income, expenditure and mean rural household income reported in the Bhutan Living Standard Survey. Dagala Gewog demonstrated the highest average income from Yak husbandry (Nu. 451,797), while other Gewogs relied more heavily on off-farm income sources such as cordyceps harvesting, non-wood forest products, and porter services. The study also observed that Yak herding is predominantly sustained by older, less-educated individuals, with minimal participation from younger generations, denoting a potential future decline of the practice. Productivity indicators, including a mean daily milk yield of  $1.05 \pm 0.04$  kg and a mean lactation length of  $183 \pm 13$  days, were consistent with regional standards. However, variations in bull replacement intervals and breeding management raised concerns about potential inbreeding. Additionally, climate change emerged as a critical stressor, manifesting through glacial retreat, pasture degradation, drying water sources, and increased livestock predation. Around 70% of Yak mortality was attributed to wildlife depredation. Despite these challenges, herders across all Gewogs recognised Yak husbandry as the most reliable and sustainable livelihood option. The study recommends interventions, including human-wildlife coexistence programs, rangeland restoration and management, genetic improvement programs, climate change adaptation strategies, and support that encourages youths' participation in Yak husbandry to enhance the viability of Yak herding and preserve this essential highland livelihood system.*

**Keywords:** Climate change; Cordyceps collection; Economic viability; Highland livelihoods; Human-wildlife conflict; Optimal herd size; Pastoralism; Yak husbandry

### 1. INTRODUCTION

Yak herding is an important traditional livelihood practice in the highland regions of Asia, including Bhutan. Yak herding is a predominantly age-old pastoral practice in all mountain communities of the Himalayan Kingdom of Bhutan (Wangdi and Norbu

2018). It involves the seasonal migration of Yaks to high-altitude alpine pastures during summer and their return to lower elevations in winter (Wangdi 2025), a practice that enables access to sufficient forage while reducing exposure to severe climatic conditions.

Yak herding is distributed across ten districts along the northern belt of Bhutan, albeit sparsely. There are 143 Yak herding households and 9545 Yaks in Thimphu Dzongkhag (National Statistics Bureau 2025). These pastoral households are distributed across four Gewogs and are predominantly located within the temperate and sub-alpine ecological zones. Yaks provide essential products such as milk, meat, fur, manure, draught, and as a symbol of social status (Shah et al. 2023). Yet, products derived from Yaks, including meat, butter, and cheese, account for roughly 3% of the livestock products market share in Bhutan (Derville and Bonnemaire 2010). The importance of Yak herding extends beyond economic factors, as it is deeply intertwined with the traditions, cultures, and rituals of herding communities (Joshi et al. 2020).

Amidst the rapid advancement of economic development, highland communities are undergoing substantial socio-economic transformations. Wangdi et al. (2024) mentioned that access to natural resources such as cordyceps (medicinal fungus), *Paris polyphyla* (medical plants), and *Exidia* spp (mushroom) further enhanced herders' livelihoods. Hence, these alternative economic opportunities have become formidable competitors for Yak farming (Wangdi 2016), thus challenging the continuity of the age-old Yak farming system. This paradigm shift significantly affected the livelihoods of communities involved in Yak herding, notably reducing their reliance on Yaks.

Yak herding has been a crucial part of the domestic economy and cultural identity of many ethnic communities in Asian highlands. The study by Wangdi et al. (2024) and Wangdi (2025) revealed that Yak farming generates sufficient income to

support the herders' livelihood, even though the profit margin is minimal. Interestingly, Yak herding generates substantial social and ecological benefits. These include preserving culture, maintaining rangeland ecosystems, and curbing illegal activities (Rai et al. 2023). Considering these positive externalities, the benefit-cost ratio and internal rate of return become more appreciable (Rai et al. 2023), which highlights the importance of considering the broader impacts of Yak herding beyond its direct economic value.

However, recent trends indicate that this traditional practice faces significant challenges, leading to its abandonment by some highlanders (Joshi et al. 2020; Rai et al. 2023). The decline in Yak herding can be attributed to several factors: poverty, environmental degradation, and climate change have altered traditional pastoralism practices, isolating herders and fragmenting pastures (Joshi et al. 2020). Furthermore, the economics of Yak herding are not financially attractive due to high mortality rates, degrading rangelands, increasing costs (Rai et al. 2023), and livestock depredation; which are ranked among the most significant challenges encountered by Yak herders (Dorji and Powrel 2022). These challenges, coupled with the need to stay in remote areas, make Yak herding less appealing to younger generations, who are increasingly shifting towards alternative occupations (Rai et al. 2023).

Therefore, with the emergence of better economic prospects, the highlanders of Soe, Naro, and Lingzhi are increasingly shifting their reliance on livelihood towards cordyceps and activities outside of Yak herding (Wangchuk and Wangdi 2015). Despite challenges, the highlanders of Dagala Gewog continue to rely on Yak herding as their primary source of livelihood

(Bhutan Foundation 2024). Considering an appreciable benefit-cost ratio and internal rate of return of Yak herding (Rai et al. 2023), and to preserve the traditional pastoral Yak herding system, this study seeks to determine the optimal herd size required to ensure year-round sustenance for highland pastoral households in Thimphu Dzongkhag. This study also assesses the contribution of Yak husbandry relative to off-farm income sources sustaining household livelihoods across different highland Gewogs. Furthermore, it examines the key biophysical and socio-economic constraints affecting Yak husbandry, including production performance, breeding management, climate change impacts and human-wildlife conflict (Joshi et al. 2020).

## 2. MATERIALS AND METHODS

### 2.1 Study area

The study was conducted in four Gewogs (sub-districts- English translation is ‘block’-administratively demarcated region constituted by many villages): Soe, Naro, Lingzhi, and Dagala in Thimphu Dzongkhag (district- English translation is ‘district’-administratively demarcated region constituted by many sub-districts). Soe,

Naro, and Lingzhi are located in the northern part of Bhutan, situated above 2500 meters above sea level (masl) (UNDP Bhutan 2024), while Dagala Gewog is located south of Thimphu, situated above 2330 masl (Thimphu Dzongkhag, n.d.). Yak herding is a significant part of the culture and livelihood for residents of these Gewogs. The people of these Gewogs are commonly referred to as *Bjob*, and they are semi-nomadic, synonymous with herdsmen and shepherds (Wangdi et al. 2024). The vegetation of the study area ranges from wet-subtropical to alpine zone with meadows, rhododendron shrubs, berries, and conifer forests. Temperature varies with the rise in elevation, from extreme cold winters to abundant summer rain. The communal utilities like power, telecommunication, health, and education are available to all Gewogs, but road connectivity is only available in Dagala and Naro Gewogs.

These Gewogs were selected for this study as they fall under Thimphu Dzongkhag. The settlements are pasture-based villages, and conventional agricultural farming is limited due to extreme climatic conditions.

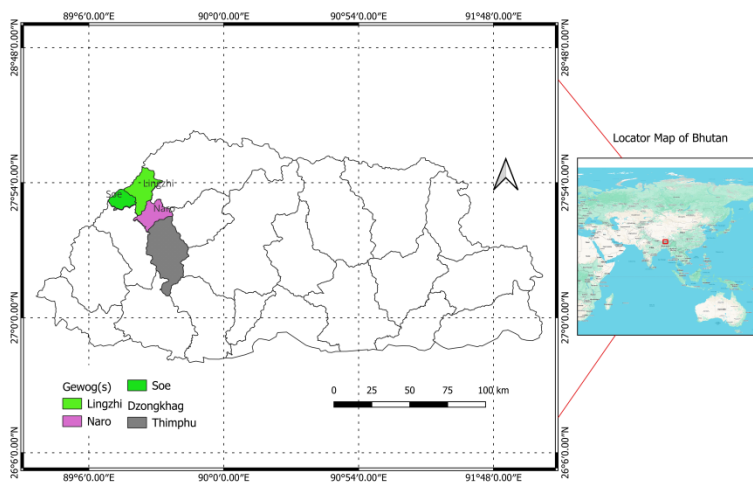


Figure 1: Study area.

**Table 1:** Basic information of the study areas.

Category	Soe	Naro	Lingzhi	Dagala
Gewog area (sq.km)	190.72	281.368	386.789	204.242
Total household (number)	182	250	490	2094
Population (inhabitants)	182	249	477	2043
Household herding Yaks	18	26	40	37

Source: (National Statistics Bureau 2017; Tenzin 2021)

## 2.2 Data collection and analysis

A total of 108 Yak herding households were interviewed: Soe (n=18), Naro (n=24), Lingzhi (n=40), Dagala (n=26). The survey was conducted during January-February 2025, when the herds migrate to lower altitudes in winter. A structured questionnaire was developed on Epicollect5. Total population sampling was used to include every member of a defined population. Before conducting interviews, the questionnaire was discussed and validated among the livestock officials and local leaders of the Dzongkhag. Interviews were conducted via telephone calls. The study objectives were explained, and informed consent was obtained from the respondent before the interview.

Data were entered, cleaned, and analysed using Microsoft Excel 2019. Descriptive statistics were used to summarise the survey findings. Continuous variables were summarised as mean  $\pm$  standard deviation (SD), whereas categorical variables were summarised as frequencies and percentages. A chi-square test of independence was performed to examine the association between levels of education and participation in Yak herding. The test was used because both variables were categorical. Statistical significance was assessed at a  $p$ -value  $\leq$  0.05. To determine the "break-even herd size" required for year-round sustenance of Yak pastoralist households, estimates of annual income from Yak husbandry and off-farm activities,

as well as annual household expenditure, were calculated based on information provided by the herders. Household annual sustenance requirements were estimated based on income–expenditure parity (income  $\geq$  expenditure), as well as equating annual household income to the mean rural household income. In addition, data on the current number of Yaks and other domesticated animals were collected to examine herd composition, production performance, and management practices. Qualitative information was also gathered to capture herders' perspectives on the impacts of climate change on Yak husbandry, with particular attention to emerging challenges. The data were collected through self-reported binary and pre-defined questions. The data only represents stated awareness and does not assess the in-depth knowledge and understanding of climate change.

## 3. RESULTS AND DISCUSSION

### 3.1 Demographic characteristics of respondents

All survey respondents were Yak herders. Among the 349 individuals reported to be living in Yak-herding households, ages ranged from 1 to 84 years old. The majority of herders were found to be illiterate (63.90%), while there are negligible number of graduates (0.57%) herding the Yaks (Table 2). This pattern suggests that Yak herding is largely practised by individuals with low levels of education, whereas participation by individuals of higher education is limited. The declining participation by graduates

suggests that youths with higher education are less likely to continue Yak herding as a primary activity for livelihood. Nonetheless, the chi-square test indicates that there is statistically significant association between levels of education and herders ( $p < 0.001$ ). This may suggest Yak herding differed significantly across levels of education. The average household size in the herd recorded the highest in Dagala Gewog, at 3.89, reflecting the continued dependence on Yak herding as a primary means of livelihood, as highlighted by Bhutan Foundation (2024). Nonetheless, the average household size in these Gewogs remains below the national rural average of 4.1 (National Statistics Bureau 2022).

### 3.2 Livestock holdings

Among the 108 Yak herding households surveyed, Dagala Gewog had the largest herd, consisting of 89 Yaks. In contrast, Naro Gewog had the highest number of milch Yaks (25) and calves under 1 year old (19) across its herds. Similarly, the number

of horses was recorded highest (8) in Naro Gewog, whereas the numbers of mule were recorded highest (6) in Soe Gewog (Table 3). The number of Yak per herd and horses were recorded as higher than the study conducted by Dorji et al. (2022), where they recorded 70 Yaks per herd and 4 horses, respectively. It is also recorded that a total of 1053 Yaks belonging to the Central Monastic Body were managed by 44 herds across the four Gewogs (Table 4), indicating institutional engagement in Yak herding practices (Derville and Bonnemaire 2010).

The study recorded that Yaks owned by the Central Monastic Body are managed by herders without financial compensation, although these herders are permitted to utilise and manage Tsamdro (pastureland-English translation is 'pastureland'- it is an open area without forest coverage where domestic animals graze) that belongs to the Central Monastic Body.

**Table 2:** Demographic characteristics of the herders.

Description(s)	Number of people residing with the herd (%)				
	Soe	Naro	Lingzhi	Dagala	Total
Female	26 (7.45)	24 (6.88)	67 (19.20)	51 (14.61)	168
Male	25 (7.16)	40 (11.46)	66 (18.91)	50 (14.33)	181
<i>Education</i>					
Illiterate	30 (8.60)	31 (8.88)	89 (25.50)	73 (20.92)	223
Primary education	11 (3.15)	13 (3.72)	13 (3.72)	15 (4.30)	52
Secondary education	5 (1.43)	11 (3.15)	6 (1.72)	12 (3.44)	34
Bachelor	1 (0.29)	0	1 (0.29)	0	2
Non-formal education	3 (0.86)	7 (2.01)	2 (0.57)	1 (0.29)	13
Monastic education	1 (0.29)	2 (0.57)	22 (6.30)	0	25
<i>Average</i>					
Average age	37.61	38.84	40.19	33.11	
Average member in the herd	2.83	2.67	3.35	3.89	

**Table 3:** Average livestock holding per herd of four Gewogs.

Livestock Categories	Livestock holding (average)			
	Soe	Naro	Lingzhi	Dagala
Average number of Yaks/herd	88	79	73	89
Average number of milch Yaks/herd	24	25	20	23
Average number of calves (<1 years)/herd	17	19	13	16
Average number of dry Yaks/ herd	7	25	4	12
Average number of heifers/herd	13	10	9	8
Average number of grower bull (1-2 years)/herd	11	8	8	10
Average number of breeding bulls	2	2	1	2
Average number of adult bulls	19	11	18	11
Average number of horse	5	8	5	4
Average number of mule	6	3	4	0
Average number of mastiff dog	2	2	1	1

**Table 4:** Number of herds and the corresponding Yak population of the Central Monastic Body.

Gewog(s)	No. of herd	No. of Yaks
Soe	10	115
Naro	10	352
Lingzhi	8	241
Dagala	16	345
Total	44	1053

In return, herders are mandated to provide one kilogram of butter per Yak each year. When they are unable to meet this obligation, they must pay a cash equivalent to the prevailing market price. If a herder decides to discontinue herding, they are required to return the same number of Yaks that were initially entrusted to them, even in cases where animals have died. Despite these strict conditions, many herders continue to manage monastic Yaks because the most productive and extensive Tsamdro are under the ownership of the Central Monastic Body.

### 3.3 Production and breeding

The mean milch Yaks per herd is  $21.39 \pm 2$  (Table 3) with peak production spanning

from June to October, owing to a conducive environment in terms of both favourable climate and availability of an abundant supply of fodder for grazing (Wangdi and Wangchuk 2018). In contrast to Wangdi (2025), the herders of the four Gewogs reported that the practice of milking Yaks does not occur year-round, as the milking of Yaks is discontinued to conserve maternal nutrition and prioritise calf nourishment during the lean season. Among Yak herders, a traditional method of managing herds involves the partial milking of lactating Yaks intentionally. Herders typically avoid extracting all the milk, consistently leaving at least one teat for the calf's nourishment. This allocation of milk aims to improve calf survival rates and promote optimal herd growth by ensuring sufficient nutrition during the early stages of growth.

The average daily milk production was 1.06, 1.10, 1.03, and 1.02 kg for Soe, Naro, Lingzhi, and Dagala, respectively, which compares well with the study conducted by Wangdi (2015) who reported average daily milk production was 1.09 kg for Yak. The mean lactation yield per milch Yak is 193 kg, which is significantly higher than the annual lactation yield reported by Wangdi and Wangchuk (2018) of 153 kg. The daily milk production recorded in the study is comparable to the milk production of Yak at 1.2 kg in July and 0.90 kg in October, as reported by Gyamtsho (1996). The overall mean lactation length as per the survey recorded  $183 \pm 13$  days, which is significantly lower than the 234 mean lactation length recorded by Wangdi and Wangchuk (2018). The mean lactation length was  $172 \pm 7$ ,  $179 \pm 6$ ,  $180 \pm 3$ , and  $202 \pm 27$  days for Soe, Naro, Lingzhi, and Dagala, respectively. Although non-significant amongst the Gewogs, the lactation length was longer for Dagala. This could be largely attributed to the practice of migrating herds to lower altitudes before the onset of the lean season.

The study found out that the mean calving interval is  $482 \pm 7$  days, close to 1.3 years reported by (Wangdi and Wangchuk 2018). In contrast, Gyaltshen and Bhattarai (2003) reported a calving interval of about two years for Yaks of western Bhutan. Across all surveyed Gewogs, the study found that breeding bulls typically reach reproductive maturity at five years of age. However, the replacement intervals for breeding bulls vary by Gewog: every six years in Soe, five years in Naro, four years in Lingzhi, and seven years in Dagala. Additionally, heifers are generally bred at four years of age in all Gewogs. Given these breeding and replacement patterns, there is a potential risk of inbreeding in the Gewogs of Soe, Naro, and Dagala. The study recorded that the mean conception rate is  $88.37\% \pm 2.6$ , which

is higher than the 80% conception rate estimated in the Yak herds of eastern Bhutan (Gyamtsho 1996) and lower than the conception rates of over 94% observed in China (Yu et al. 1993).

### **3.4 Financial analysis of Yak husbandry and off-farm activities**

The annual income and expenditure of herds are estimated as a means to understand the financial statement of Yak pastoralists. On average, the annual income generated from Yak husbandry per herd was highest in Dagala Gewog (Nu. 451,797), followed by Lingzhi Gewog (Nu. 337,831) and Naro Gewog (Nu. 305,686), whereas the annual income generated from Yak husbandry per herd was recorded lowest in Soe Gewog (Nu. 242,892). The sale of Yaks was the major source of income for Naro and Dagala Gewog, whereas the sale of hard cheese and butter is a major source of income for Lingzhi Gewog (Table 5). The estimated annual household income from Yak husbandry was found close to the mean rural household income of Nu. 276,398 recorded during the Bhutan Living Standard Survey (BLSS) in the year 2022 (NSB 2022). Therefore, the estimated "break-even herd size" based on income–expenditure parity (income  $\geq$  expenditure from Tables 5 and 6), as well as equating annual household income to the mean rural household income, it is approximated that an average of 23 milch Yaks in a herd will sustain the Yak pastoralist household year-round. However, the estimated herd size should be interpreted as a rough proxy, not an optimised herd size. It is derived from descriptive comparisons between mean annual income, expenditure and mean rural household income reported in BLSS.

Income generated from the sale of cordyceps accounts for the highest income amongst the off-farm activities in all the Gewogs, except

in Dagala Gewog, followed by potter/pony services and sale of non-wood forest products (Table 5). The study showed that the average annual income from the sale of cordyceps is about Nu. 152,097 per household, recording Nu. 89,167 for Soe, Nu. 157,000 for Naro and Nu. 210,125 for Lingzhi, which is higher than the average annual income of Nu. 23,000 per household

from the sale of cordyceps (Wangchuk et al. 2015). The income generated from off-farm activities in Dagala Gewog is considerably lower (Nu. 19,481) compared to the other three Gewogs, with Lingzhi recording the highest (Nu. 386,875). This indicates that Yak husbandry remains the main source of livelihood for herders in Dagala Gewog.

**Table 5:** Estimated annual income based on the sale of dairy, products and other activities (Nu.).

Description(s)	Soe	Naro	Lingzhi	Dagala
<b>A. Income from sale of dairy and other products (Nu.)</b>				
Butter	915,167	379,706	4,230,503	2,494,615
Hard cheese	121,689	1,674,698	6,169,498	4,019,885
Dry hard cheese	1,433,550	464,991	2,003,708	2,362,855
Fermented cheese (fresh)	75,200	13,650	277,235	2,924,152
Fermented cheese (dry)	1,333	389,688	181,525	77,285
Meat (fresh)	4,750	94,875	31,500	704,192
Meat (dry)	66,750	44,600	153,125	167,538
Wool	0	0	0	6,827
Sale of Yaks	1,753,611	4,274,250	466,132	3,959,146
Total income	4,372,050	7,336,458	13,513,224	16,716,496
Average income per herd	242,892	305,686	337,831	451,797
<b>B. Income from off-farm activities (Nu.)</b>				
Homestay (lumpsum)	0	30,000	10,000	0
Business (lumpsum)	0	0	3,90,000	0
Potter/pony services (lumpsum)	1,967,000	627,000	5,170,000	155,000
NWFP (lumpsum)	30,000	1,301,000	1,435,000	283,000
Cordyceps (lumpsum)	1,605,000	3,768,000	8,405,000	0
Labour (lumpsum)	0	25,000	65,000	50,000
Handicraft products (lumpsum)	0	0	0	18,500
Total income	3,602,000	5,751,000	15,475,000	506,500
Average income per herd	200,111	239,625	386,875	19,481
Total income per hh (A+B)	443,003	545,311	724,706	471,278

**Table 6:** Estimated annual expenditure.

Gewog(s)	Soe	Naro	Lingzhi	Dagala
Average annual household expenditure (Nu)	218,000	317,496	405,000	188,772

On average, annual household expenditure is highest in Lingzhi Gewog and lowest in Dagala Gewog (Table 6), with the elevated costs in Lingzhi potentially attributed to its geographical remoteness and distance from the nearest market. According to the herders, purchasing groceries and household goods incurs the highest expenditure, followed by labour and pottery services, and annual rituals. Notably, education accounted for the lowest share of expenditure, corresponding with a minimal number of graduates (Table 2).

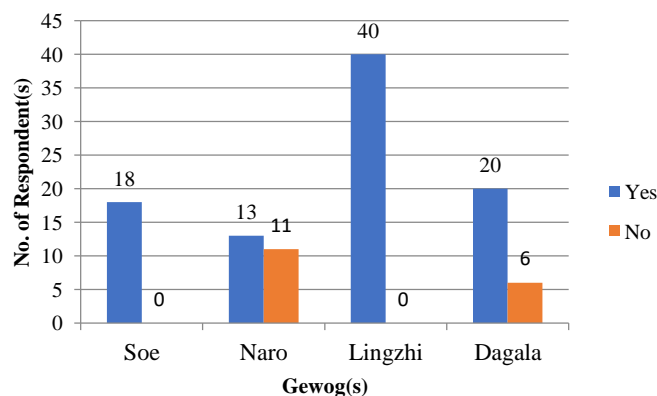
The Gewogs of Soe, Naro, and Lingzhi, benefiting from alternative lucrative income sources such as cordyceps harvesting, NWFP, and potter pony services, appear to have a substantial impact on Yak husbandry practices. The emergence of alternative income sources has a significant impact on the Yak population, the number of households owning Yaks, and the traditional practice of transhumance, leading to the gradual decline of Yak farming in most mountain communities (Wangdi et al. 2024). Dorji et al. (2020) mentioned that highlanders preferred collecting cordyceps and medicinal plants over Yak herding due to greater financial benefits. Therefore, the herders opined that the future of Yak husbandry in Soe, Naro, and Lingzhi Gewogs may depend on the sustainability of cordyceps and NWFP, whereas herders of Dagala may continue to rely on Yak husbandry for their livelihood.

According to herders, they consider cordyceps collection as the primary source of income in Soe, Naro, and Lingzhi

Gewogs. In contrast, the herders of Dagala Gewog mentioned Yak husbandry as their main source of livelihood. The motivation to continue Yak husbandry is likely to be influenced by the availability of alternative rewarding economic opportunities (Wangdi et al. 2024). The COVID-19 pandemic may have adversely impacted the livelihoods dependent on alternative livelihood sources, prompting a critical reassessment of the resilience and sustainability of such income sources. In view of these challenges, the majority of the herders perceived Yak husbandry as the most sustainable source of income, followed by non-wood forest products (NWFPs), cordyceps collection, and porter or pony services.

### **3.5 The impact of climate change on Yak husbandry: challenges and adaptations**

The respondents reported experiencing significant climate changes over the years, which have led to alterations in their traditional pastoral practices. Among the 108 herders surveyed, 91 Yak herders (Figure 2) expressed a general awareness of climate change and its impacts, with many having noticed distinct shifts in climate patterns over the last ten years. These changes include glacier melting, pasture degradation, altered snowfall patterns, minimal snowfall, intense rainfall, violent storms, and the drying up of water sources (Figure 3). These alterations have had a direct impact on pastures by changing the composition of vegetation and decreasing the amount of available forage, which subsequently influences the health and productivity of Yaks (Joshi et al. 2013, 2020).



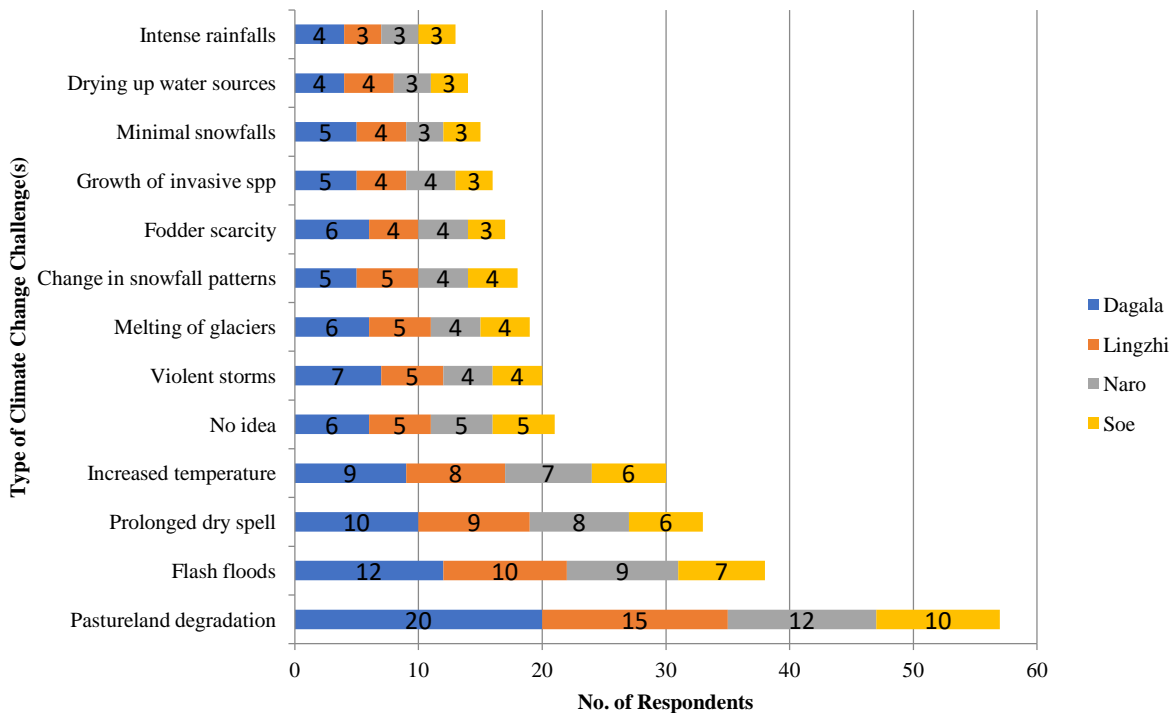
**Figure 2:** Awareness of climate change and its impact among the respondents.

Furthermore, herders reported that rising temperatures have accelerated glacier melting at an unprecedented rate, while pastureland degradation has made it increasingly difficult to manage Yak movements, given their heightened responsiveness to environmental cues and innate migratory behavior (Wangdi 2025). Higher temperatures and changes in precipitation patterns influence the thermal optima, prompting wildlife, including Yaks, to migrate towards higher altitudes where conditions may be more favorable for their survival and foraging (Quratulann et al. 2021). These trends pose significant concerns about the future availability of summer grazing pastureland, particularly if temperatures continue to rise, as there are no alternative high-altitude pastures beyond the current grazing areas. Moreover, with degraded pasturelands, the ability of herders to manage Yak movements becomes increasingly challenging, as traditional grazing lands become less productive. These findings reflect herders' perceptions and may not directly correspond to measured climatic trends.

Subsequently, human-wildlife conflicts have increased. The herders reported that mortality caused by wildlife depredation is the greatest impediment to Yak husbandry,

and around 70% of the mortality is caused by wildlife depredation (Figure 4). Moreover, the rise of the tree line might have expanded the habitat for other predators, and shrub encroachment restricts the growth of grasses, prompting livestock to wander further in search of food, making them more susceptible to predators (Wangchuk and Wangdi 2018).

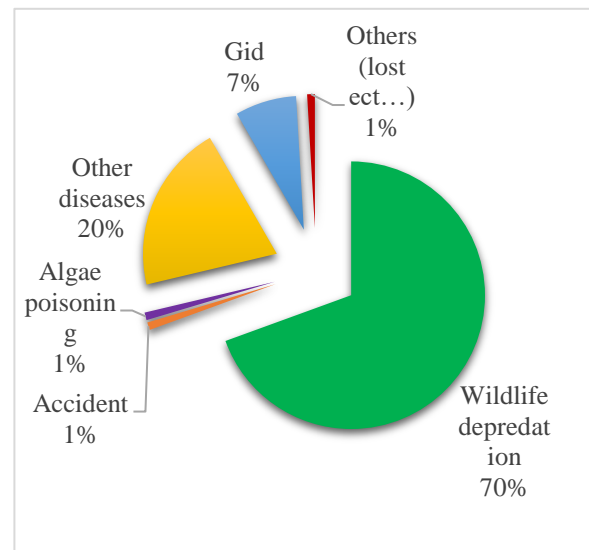
According to herders, the increase in temperatures and growth of invasive species has resulted them to use commercial feed to calves, milch Yak, bred heifer, dry Yak, and breeding bull as a supplement, to prevent loss of body weight in the winter season, and to augment production during summer (Krishnan et al. 2016). However, Yaks typically rely entirely on natural alpine pastures with little to no supplementary feeding, highlighting the importance of grazing management to enhance fodder quality in high-altitude rangelands (Paul et al. 2010). The survey also noted drying up of water sources, an observation that aligns with the findings of (Chaudhary and Bawa 2011). Herders associate the drying up of water sources with the more frequent dry spells and accelerated melting of glaciers. The drying up of water sources likely indicates shortages of drinking water, a prominent effect of global warming (Sudmeier-Rieux et al. 2012). The decrease in water availability might also result from shifts in seasonal patterns, increased temperatures and evapotranspiration (Wangchuk and Wangdi 2018).



**Figure 3:** Observed changes in climate pattern.

The results of this survey align with existing empirical research indicating that climate warming in alpine regions contributes to erratic weather conditions, accelerated glacial retreat, diminishing snow cover (Eriksson et al. 2009), more frequent drought, and escalating water scarcity (Morrison et al. 2009). Baker and Moseley (2007) documented declines in soil fertility and the ascent of snow and tree lines due to warming. Additionally, Sudmeier-Rieux et al. (2012) reported increased occurrences of landslides and flash floods associated with rising temperatures. The study identified several key interventions essential for promoting and sustaining Yak husbandry in the future, including improved rangeland management and fodder conservation, supply of superior breeding bulls to enhance genetic quality, mitigation of human-wildlife conflict, and the establishment of

basic modern infrastructure such as cellular connectivity and reliable power at the herd.



**Figure 4:** The causes of mortality.

#### 4. CONCLUSION AND RECOMMENDATION

This study assessed the optimal Yak herd size needed to sustain the livelihoods of highland pastoral households in Thimphu Dzongkhag, Bhutan. The study approximated that maintaining 23 milch Yaks in a herd is financially viable to support pastoral household livelihood year-round. The estimated "break-even herd size" based on income–expenditure parity (income  $\geq$  expenditure), as well as equating annual household income to the mean rural household income. However, in Soe, Naro, and Lingzhi, many herders are shifting towards more lucrative alternatives such as cordyceps collection and porter services, leading to a decline in traditional Yak farming. The findings also found that Yak herding is largely maintained by older, less-educated individuals, with minimal youth involvement, raising concerns about the long-term continuity of this cultural and economic practice.

Herders perceive climate-related changes, including glacial melt and pasture degradation, as significant threats to the sustainability of Yak herding. Among these, wildlife depredation and pasture degradation were reported as the most critical constraints. Despite these challenges, herders across all Gewogs still perceive Yak husbandry as the most stable and reliable livelihood option. To ensure its continuity, key interventions are necessary. The study recommends the following interventions: rangeland management, supply of superior breeding bulls, mitigation of human-wildlife conflict, and provision of essential infrastructure like power and cellular connectivity. The policy support that enables Yak husbandry is not just an economic imperative but a means to safeguard the cultural heritage and ecological integrity of Bhutan's highland communities.

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