



Population Changes and Industrial Development of Bactrian Camel in China: A Review

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ABSTRACT

The Bactrian camel is an ecologically friendly domestic animal native to the desert regions of Southern Eastern Europe, West Asia, Southern South Asia, Central Asia and Northern East Asia. It has played a vital role in both Chinese history and livestock production. Currently, the total population of Bactrian camels in China is relatively small compared to other livestock, but they are widely distributed and critically important to their ecological environment. This paper compiles and analyzes historical data on Chinese Bactrian camels over the past 30 years, along with relevant policies. It reveals that the population distribution of Chinese Bactrian camels follows a geographical pattern centered on the Alashan region of Inner Mongolia. A detailed analysis is conducted on the distribution and population changes of Bactrian camels in two core administrative regions of China, along with an explanation of the distribution of scattered small populations in areas such as Qinghai and Gansu provinces. The factors contributing to the changes in the distribution and population of Chinese Bactrian camels are thoroughly discussed. Among these factors, national livestock policy orientation, interactions among large livestock populations, regional human population and disposable income are all correlated with the number of Bactrian camels. The paper also compiles and analyzes some issues in the Chinese Bactrian camel industry and its development, offering reasonable prospects for the future. The data presented in this article is sourced from the China Statistical Yearbook and various local government statistical yearbooks.

Key words: Bactrian camel industry, Bactrian camel, Influencing factors, Population dynamics, Population.

Throughout their long evolutionary history, animals of the family Camelidae have developed unique distribution patterns and ecological roles. This paper systematically reviews the global geographical distribution of extant camelid species. By analyzing changes in the population size and distribution of Bactrian camels within China over the past three decades, it investigates the driving mechanisms behind the spatiotemporal population dynamics of Chinese Bactrian camels. This includes examining the interrelationships between the population sizes of horses, cattle, sheep and Bactrian camels, as well as the influence of anthropogenic factors such as human demographic and economic activities. Furthermore, the study summarizes the current status and challenges facing the Bactrian camel industry in China, offering pertinent recommendations. Given the current state of Bactrian camel populations, it is imperative to intensify research on this species to provide a scientific foundation for the conservation and sustainable utilization of this key livestock animal in arid ecosystems.

Distribution of old world and new world camelids

New World camelids (Sequencing and Consortium, 2012) comprise one genus with four species: the llama (*Lama glama*), the guanaco (*Lama guanicoe*), the alpaca (*Lama pacos*) and the vicuña (*Vicugna vicugna*) (Ji *et al.*, 2021). Llamas are distributed in tropical regions of Peru, southern Bolivia and northern Argentina (1999). Guanacos range from the Andean regions of southern Peru, Chile and Argentina southward to Tierra del Fuego, with a partial distribution also found in western Paraguay (2000). Alpacas

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are native to areas such as Peru and have since been successfully introduced to many countries including Australia, the United Kingdom, the United States and China (1999). Vicuñas are currently found in the Andes mountains of southern Peru, western Bolivia, western and northern Argentina and northern Chile (Chen and Dong, 2007).

Old World camelids (Sequencing and Consortium, 2012) consist of one genus with three species: The dromedary (Khanna, 1997) (*Camelus dromedarius*), the Bactrian camel (*Camelus bactrianus*) and the wild camel

(*Camelus ferus*). Dromedaries are highly adapted to high-temperature and arid environments, distributed across the hot desert regions of Africa, the Arabian Peninsula and the arid plains of northern India (Su, 1981). Bactrian camels are adapted to high-altitude semi-desert or desert steppe climates, primarily found in northern and northwestern China, Mongolia, the five Central Asian countries (Dioli, 2020), parts of Russia, Ukraine and the cold, dry regions of the Caucasus (Faye, 2020).

The term “wild camel” specifically refers to the wild Bactrian camel (wild dromedaries became extinct around the Common Era). Their main habitats include China’s Xinjiang Altun Mountain region and Mongolia’s Gobi-Altai region (Yadamsuren *et al.*, 2019). According to statistics, the global population numbers fewer than 1000 individuals (Yadamsuren *et al.*, 2019), worldwide, about 500 heads (Ming *et al.*, 2017) in Mongolia and about 640-670 heads (Yadamsuren *et al.*, 2019) in China. In 2017, confirmed a genomic difference of approximately 2% between domestic Bactrian camels and wild camels (Yi *et al.*, 2017). They are determined not to have formed reproductive isolation due to reported hybridization with Bactrian camels. While no reproductive isolation exists between Bactrian camels and dromedaries and there are no reports of hybridization between wild camels and dromedaries, it is hypothesized that no reproductive isolation exists between dromedaries and wild camels, though this awaits confirmation.

Introduction of camelidae animals in the old and new continents

Australia initially introduced dromedaries from the Canary Islands in 1840, followed by subsequent introductions from regions such as Palestine and India until 1907. After being introduced to the hot deserts of Australia, these camels thrived and multiplied. The population, almost exclusively composed of dromedaries, proved highly adaptable to the local climate and is now primarily distributed across the arid inland regions of Australia (Fu, 2017). In the absence of natural predators, a suitable environment and vast, sparsely populated areas, their numbers surged to approximately one million (Saalfeld and Edwards, 2010), exerting significant pressure on the ecosystem. Australia’s unique and isolated environment provides conditions for their evolution; however, genetic frequency has remained stable in the short term. Whether this will lead to the formation of a new subspecies in the future remains debatable.

Alpacas have been widely introduced to the Old World, particularly Europe, primarily for the wool industry (Gutiérrez, 2023). Vicuña wild populations are protected (Karandikar *et al.*, 2023); however, due to their high-quality fibre, domestication programs exist in countries like Peru and small numbers have been introduced to Europe for specialty fibre production. Llamas, serving as pack and fibre animals, are raised in Europe, America and other regions as ornamental animals or on small-scale farms.

In recent years, New World camelids have been introduced for pilot farming programs in regions such as Inner Mongolia and Xinjiang in China (Yang *et al.*, 2024), primarily to explore the diversification of economic animals in high-altitude or cold regions.

The origin of Chinese bactrian camel

It is generally believed that the Bactrian camel was domesticated in northeastern Iran and Turkmenistan, spread northward to Kazakhstan and the Urals between 1700 and 1200 BC. By the 10th century BC, it had spread westward to Siberia, reaching Ukraine by the 9th century BC and finally arriving in China around 300 BC (Ji *et al.*, 2021). However, some scholars argue that the geographic range of Bactrian camel domestication extended further east than previously thought, potentially including southern Kazakhstan, northwestern Mongolia and northern regions of China (Peters and Driesch, 1997). This hypothesis is primarily based on the presence of wild Bactrian camels in these areas and the assumption that domestic Bactrian camels were descended from their wild counterparts. Nevertheless, molecular biological studies indicate that the extant wild Bactrian camel (*Camelus ferus*) is not directly related to the domestic Bactrian camel (*Camelus bactrianus*); they are distinct species. Their evolutionary lineages began to diverge during the early Pleistocene (approximately 700,000 years ago) and do not share a maternal origin (Quan *et al.*, 2000). Therefore, the former view is more desirable.

Chinese bactrian camel breeds and standards

The primary breeds of Bactrian camels in China include the Alashan Bactrian camel, the Sunite Bactrian camel, Urat Gobi Red Camel, the Tarim Bactrian camel, the Junggar Bactrian camel and the Qinghai camel (Qinghai Bactrian camel) (Ji *et al.*, 2021; Ai and Yan, 2018; Committee, 2012) as shown in Fig 1. Along with the internationally recognized subspecies, the wild camel. Consequently, China stands as one of the countries with the richest diversity of Bactrian camel breeds, distribution and genetic resources.

The Alashan Bactrian camel is a representative breed in China. Its formation began around the turn of the 17th and 18th centuries and was largely finalized by the mid-19th century (Sarentuya *et al.*, 2015). The national standard for the Alashan Bactrian camel was issued on June 16, 2011 and it was included in the China-EU Agreement on Geographical Indications in July 2020. A local standard for the Qinghai camel was released on February 28, 2012 and a new revision local standard for the Sunite Bactrian camel was issued on December 24, 2020. These standards uniformly specify the breed characteristics, production performance, grade standards and assessment methods for their respective Bactrian camel breeds (2011), providing definitions for terminology, geographical origin and physical appearance. In July 2025,

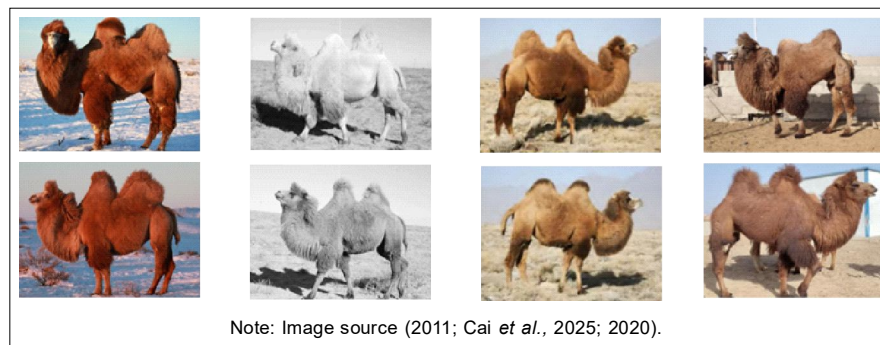


Fig 1: Alashan bactrian camel, sunite bactrian camel, tarim bactrian camel, junggar bactrian camel (male and female) from left to right.

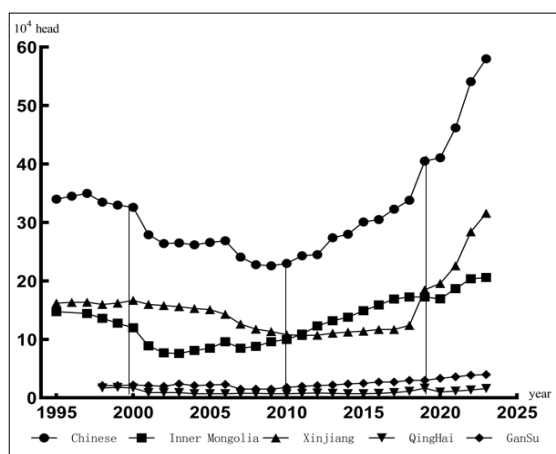


Fig 2: Changes in the number of bactrian camels nationwide and in each distribution region.

the “Announcement No. 934 of the Ministry of Agriculture and Rural Affairs of the People’s Republic of China” designated the Urat Gobi Red Camel as a new livestock breeds. However, official standards for the Urat Gobi Red Camel are still pending. Its primary distinctions from the Alasha Bactrian camel lie in its reddish coat color and longer hair.

Xinjiang is also the main producing area of Bactrian camels. There are two main varieties of Junggar and Tarim Bactrian camels, with a large number and more developed related industries, especially the camel milk industry. Xinjiang has established systematic standards for camel milk and camel milk-related products (Wu *et al.*, 2024), but lacks standards for Bactrian camel breeds.

Distribution of Chinese bactrian camel

The distribution of Bactrian camels in China exhibits a gradual transition from the steppe zone to the desert zone and to some extent, a higher degree of desertification correlates with a larger Bactrian camel populations (Geng *et al.*, 2022) though their numbers begin to decrease as one moves closer to the sandy desert core. According to 1981 statistics, Chinese Bactrian camels were distributed

within latitude 32° - 50° N and longitude 73° - 122° E, encompassing Northwest China, the northern part of North China and the western part of Northeast China, specifically in Inner Mongolia, Xinjiang, Gansu, Qinghai, Ningxia and adjacent regions (Su, 1988). An analysis of the 2024 distribution data (China, 2024) from the compared with the 1981 statistics, reveals that the overall distribution range has not changed significantly. However, the population size has experienced substantial, non-natural fluctuations. As shown in Fig 2, the national Bactrian camel population initially decreased and then increased. A general decline was observed from 1995 to 2010, followed by continuous growth from 2011 to 2023, with the rate of increase becoming progressively more pronounced. The number change of Bactrian camels in China is mainly affected by the two Bactrian camel producing areas of Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region. From Fig 2, it can be seen that there are two intersections in the number change curve of the two regions. Before the first intersection, the number of Bactrian camels in Inner Mongolia Autonomous Region has a greater impact on the overall number and after the second intersection, the number of Bactrian camels in Xinjiang Uygur Autonomous Region has a more obvious impact on the overall number.

The distribution of Bactrian camel in China is characterized by the Alashan Plateau as its largest core concentration area. From this core, the distribution extends westward (towards Xinjiang), where the range gradually expands and the population density decreases, however, the total number of individuals across the broader regional increases. In contrast, the distribution extends eastward (towards Bayannur, Xilin Gol and Hulunbuir), where both the range and population density gradually diminish, leading to a reduction in the total number of individuals in those eastern regions. The population distribution of Bactrian camels stretches along the semi-desert to desert areas of China’s border regions, connects with the Gobi Desert of Mongolia to form an extensive core distribution area for the species. The specific west-to-east distribution of Bactrian camels is detailed in Appendix 1.

Distribution of wild camels in China

Historically, the wild Bactrian camel was distributed across vast territories, including the Qaidam Basin, Hexi Corridor and western Inner Mongolia. However, within just a few millennia, its range has drastically contracted to a few small, isolated areas in southeastern Xinjiang and western Inner Mongolia. The surviving population, now numbering only slightly over a thousand individuals, continues to face deteriorating living conditions. The remaining wild camels are most concentrated in the Suo Valley of the Lop Nur region (Wen, 1990; Tulgat and Schaller, 1992). In history, these small areas were once linked together, but were separated by human activities. Today, wild bactrian camels are mainly distributed in four regions. Three of them are located in Xinjiang, China. One is located on the border between China and Mongolia. It is located in the Taklimakan Desert in Xinjiang, the northern part of Lop Nur, the northern foothills of the Gobi and Altun Mountains (Xue *et al.*, 2021) and the Altai region on the border between China and Mongolia (Ji *et al.*, 2021). In response to this critical situation, China has established the “Lop Nur Wild Camel National Nature Reserve” (Yadamsuren *et al.*, 2019) and Mongolia has designated the “Great Gobi Reserve Strictly Protected Area (Part A)” (Xue *et al.*, 2024). The severe fragmentation of the wild Bactrian camel’s habitat is evident, making the restoration of habitat connectivity an urgent priority.

Ecological value of the Chinese bactrian camel

Compared to other large livestock such as cattle, horses and donkeys, the overall population of Chinese Bactrian camels is relatively small. According to the China Statistical Yearbook 2024, there are currently about 580,000 Bactrian camels in China, accounting for 0.52% of the total number of large livestock. This represents 0.55% of the cattle population, 16.15% of the horse population and 39.72% of the donkey population. However, unlike cattle, horses and donkeys, Bactrian camels have long adapted to extreme environments and inhabit arid (Ji, 2009), cold and barren semi-desert to desert grasslands as large mammals

(Mohammed *et al.*, 2025). Traditional herders raise them almost entirely through year-round grazing without supplementary feeding. Across the vast desert grasslands of individual herders, spanning thousands to tens of thousands of acres, the camels exist in a semi-wild state. Additionally, the Bactrian camel is the only livestock allowed in limited numbers on grazing-restricted grasslands in Inner Mongolia. Their presence has a direct and significant impact on the ecology of semi-desert and desert regions. The behavior of Bactrian camels profoundly influences vegetation and the survival of small animals: their foraging affects plant regeneration and seed dispersal, thereby shaping the composition, distribution and density of vegetation in these areas; their lying and rising behaviors alter surface soil and microclimates, indirectly creating living conditions for small animals.

The feces of Bactrian camels can improve soil quality. Desert soils are typically highly impoverished, but camel dung is rich in nutrients and moisture, providing food and habitat for soil microorganisms and insects, thereby promoting material cycling in desert ecosystems. When Bactrian camel populations gather, their dung enhances local soil fertility and stimulates plant growth. In terms of resource utilization, Bactrian camels are highly drought-tolerant and adaptable to coarse forage. As primary consumers in desert grasslands, they consume large quantities of low-quality desert plants, transferring energy to higher trophic levels (*e.g.*, wolves). Their efficient use of water resources reduces pressure on water supplies in semi-desert and desert regions. These characteristics play a crucial role in maintaining the balance and sustainable development of desert grassland ecosystems.

Temporal population dynamics of bactrian camels in China’s inner mongolia autonomous region inner

Mongolia is a key Bactrian camel production area, supporting local livelihoods through open grazing with significant genetic and economic value (Yuan *et al.*, 2023). As shown in Fig 2 and Appendix 2, national and regional Bactrian camel trends from 1995 to 2023 followed four

Appendix Table 1: Breed distribution of bactrian camels.

Breed	Number/104	Distribution
Sunite bactrian camel	1.6	Inner Mongolia Xilin Gol League Sonid Left Banner and Right Banner, Ulanqab City, Baotou City, Chifeng City, <i>etc.</i> (Yi, 2018).
Alashan bactrian camel	18	Inner Mongolia Alashan League, Bayannur City, Ordos City, <i>etc.</i> (B <i>et al.</i> , 2014).
Tarim bactrian camel	10	Bazhou area, Aksu area, Kashgar and Hotan area in southern Xinjiang (Sarentuya <i>et al.</i> , 2015).
Junggar bactrian camel	11	Tacheng area, Fuhai County in Altay area and Mulei County in Changji Hui Autonomous Prefecture are widely distributed in the western mountains of Jungar, Jungar Basin, Balikun, Yiwu Basin, Ili River Valley, the southern foothills of Altay and the northern slope of Tianshan Mountains (Sarentuya <i>et al.</i> , 2015).
Qinghai camel	1.6	The three counties of Wulan, Dulan and Golmud in the Qaidam Basin, the Mohe Ranch and the Xiangride camel farm in Haixi Prefecture are also concentrated in Xinghai and Gonghe counties in the eastern Hainan Tibetan Autonomous Prefecture (Sarentuya <i>et al.</i> , 2015).
Camelus bactrianus ferus	0.06	Taklimakan Desert, Lop Nur, Kashun Gobi and Altun Mountains, Xinjiang (Yadamsuren <i>et al.</i> , 2019).

Appendix Table 2: Bactrian camel count in China and Inner Mongolia Autonomous Region from 1995 to 2023.

Year	Chinese	Inner mongolia	Alashan	Bayannur	Ordos	Xilingl	Wulanhabu	Chifeng	Hulunbuir	Hohhot	Baotou
1995	34.0	14.75	9.52	1.47	0.2	2.19	0.24	0.10	0.16	0.40	0.46
1996	34.5	-	-	-	0.2	-	-	-	0.17	-	-
1997	35.0	14.44	9.53	1.60	0.2	1.79	0.19	0.07	0.16	0.37	0.53
1998	33.5	13.60	9.16	1.45	0.1	1.55	0.21	0.06	0.15	0.36	0.48
1999	33.0	12.80	8.81	1.30	0.1	1.39	0.13	0.06	0.15	0.35	0.50
2000	32.6	12.00	8.19	1.48	0.1	1.04	0.18	0.05	0.13	0.33	0.33
2001	27.9	8.90	6.28	0.80	0.1	0.55	0.14	0.04	0.42	0.32	0.52
2002	26.4	7.70	5.62	0.46	0.1	0.48	0.17	0.03	0.13	0.23	0.46
2003	26.5	7.60	5.60	0.51	0.10	0.46	0.19	0.03	0.14	0.21	0.35
2004	26.2	8.10	6.00	0.65	0.10	0.52	0.20	0.03	0.14	0.16	0.33
2005	26.6	8.50	6.40	0.73	0.10	0.53	0.19	0.03	0.17	0.14	0.28
2006	26.9	9.60	7.31	0.79	0.10	0.57	0.29	0.03	0.16	0.16	0.23
2007	24.1	8.50	5.97	0.92	0.10	0.60	0.28	0.04	0.17	0.16	0.25
2008	22.8	8.80	5.85	1.21	0.10	0.75	0.28	0.05	0.17	0.16	0.24
2009	22.6	9.60	6.31	1.31	0.10	0.85	0.39	0.06	0.18	0.15	0.24
2010	23.0	10.00	6.36	1.55	0.10	0.88	0.39	0.03	0.21	0.14	0.23
2011	24.3	10.90	7.03	1.80	0.10	1.01	0.49	0.12	0.22	0.14	0.21
2012	24.5	12.30	7.83	1.94	0.20	1.25	0.55	0.11	0.23	0.13	0.22
2013	27.4	13.20	8.56	1.95	0.30	1.28	0.74	0.11	0.24	0.10	0.24
2014	28.0	13.80	8.83	1.93	0.30	1.34	0.73	0.11	0.27	0.06	0.26
2015	30.1	14.90	9.87	2.00	0.30	1.53	0.55	0.10	0.29	0.05	0.20
2016	30.5	15.90	10.26	2.07	0.40	1.25	1.33	0.11	0.18	0.01	0.16
2017	32.3	16.90	11.43	-	0.60	1.41	-	0.13	0.27	0.02	-
2018	33.8	17.27	11.82	2.87	0.65	1.25	0.60	0.13	0.28	0.02	0.13
2019	40.5	17.26	12.27	2.84	0.64	1.20	0.49	0.12	0.28	0.02	0.11
2020	41.1	16.96	11.63	2.48	0.54	1.14	0.57	0.11	0.29	0.03	0.09
2021	46.2	18.68	12.40	2.90	0.97	1.18	0.53	0.21	0.34	0.02	0.08
2022	54.1	20.37	14.09	2.96	0.80	1.24	0.57	0.21	0.36	0.02	0.09
2023	58.0	20.60	15.50	2.19	0.53	1.11	0.51	0.25	0.34	0.03	0.09

Note: Unit/10⁴head;-denotes missing data.

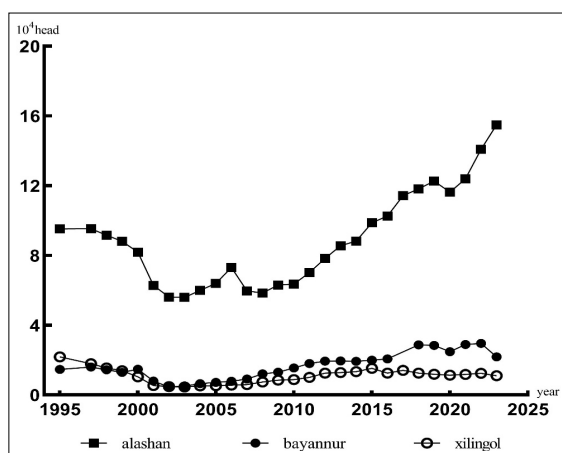
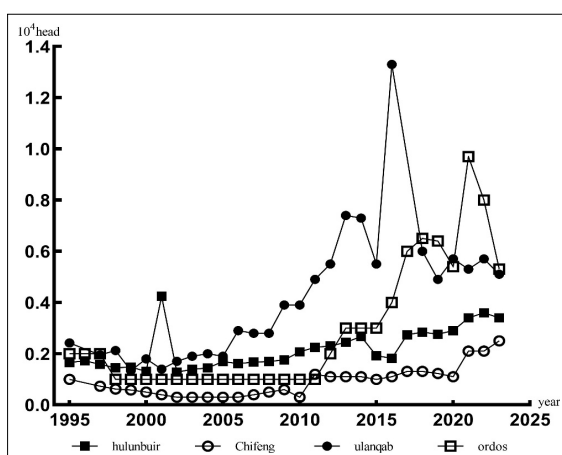
Table 1: The average annual growth rate and correlation of Bactrian camels in China and inner mongolia at different time periods.

Time frame	Average annual growth rate in Inner mongolia	National average annual growth rate	r	P value
1995-2003	-7.95%	-3.07%	0.98	0.0001
2004-2011	3.78%	-0.94%	0.32	0.4377
2012-2018	4.97%	4.70%	0.98	0.0001
2019-2023	3.60%	7.45%	0.98	0.0027

Note: $|r| > 0.7$: Strong correlation; $0.3 < |r| < 0.7$: Moderate correlation; $|r| < 0.3$: Weak correlation. P-value < 0.05 effective.

Appendix Table 3: Classification of bactrian camels in inner mongolia autonomous region.

Bactrian camels number/ 10^4 head	Area	Grade division
10-20	Alashan	Core area
5-10	-	Core area
1-5	Xilingol League Bayannur City	Chief producing area
0.1-1	Chifeng, Ulanqab, Hulunbuir, Ordos City	Small-scale populations
0.01-0.1	Baotou Tongliao Hohhot Wuhai City	Sporadic populations
0-0.01	Xing'an league	Very few populations

**Fig 3:** Changes in the number of core production areas of bactrian camel from in inner mongolia 1995 to 2023.**Fig 4:** Changes in the number of bactrian camels in hulunbuir, chifeng, ordos and ulanqab from 1995 to 2023.

phases: a Sharp Decline (1995-2003), a Divergent Trend (2004-2011) where national numbers fell but Inner Mongolia's recovered, a period of Steady Growth (2012-2018) and finally Rapid Expansion (2019-2023) where the national herd surged past its 1986 peak. Inner Mongolia's herd grew steadily to 206,000, reaching 76% of its own 1986 peak. Correlations between growth rates and population sizes are detailed in Table 1.

The Bactrian camel population in Inner Mongolia has followed a U-shaped trend, declining initially before recovering with steady growth over the past decade, though numbers remain below historical peaks. Its distribution is now concentrated in the Alashan and Sunite areas, while populations in regions like Hohhot and Baotou have sharply declined and are nearing local extinction.

Variation of time and quantity in the core producing area of bactrian camel in China's inner mongolia autonomous region

Based on historical data, Inner Mongolia's Bactrian camels can be categorized into four types, as illustrated in Fig 3 and Appendix 3. As the core production area, Alashan's population plummeted from 95,200 (1995) to 56,000 (2003) before recovering to 155,000 by 2023. In the major Sunite region, numbers crashed from nearly 50,000 (1986) to 4,600 (2003), only partially recovering to just over 12,000, far below its historical peak.

Temporal variation of small-scale population in China's inner mongolia

Small-scale Bactrian camel populations (shown in Fig 4) underwent two phases: a sharp decline until 2010, with numbers in Ordos, Hulunbuir and Chifeng falling to 1,000, 1,200 and 300, respectively, followed by a recovery. Populations have since rebounded, with Chifeng exceeding its historical peak, potentially due to tourism. Anomalous

data points may stem from methodological differences. The Hulunbuir Bactrian camel population, analogous to Australian dromedaries, faces debatable breed status and future prospects (Guo *et al.*, 2015).

Discussion on the distribution of bactrian camel in China's xinjiang uygur autonomous region and the change of time and quantity

Based on statistical data, Appendix 4 shows that Xinjiang's Bactrian camels are divided into two varieties: the Junggar type in the north and the Tarim type in the south. The Junggar camel population is highly concentrated in Altay, Changji, Hami and Tacheng, totaling 103,700 individuals-accounting for 53% of the regional total-with an average density of 0.245 heads/km². In contrast, the Tarim camel is sparsely distributed across southern Xinjiang at a much lower density of 0.074 heads/km², without forming a clear core area. Overall, the Junggar camel exhibits a clustered distribution, while the Tarim type remains dispersed.

Xinjiang's Bactrian camels are primarily distributed in the Junggar and Tarim Basins, with the Junggar population being more concentrated and dense. Recent years have seen rapid industrial development and population growth. From 1995 to 2012, the number declined from 162,200 to 107,300 (avg. -2.4% growth). From 2013 to 2018, it recovered to 124,000 (avg. 2.9% growth). Subsequently, from 2019 to 2023, numbers surged from 124,000 to 316,000 (avg. 26.4% growth), exceeding previous peaks, as shown in Fig 2. As a major production region, Xinjiang's population fluctuations strongly correlate with and significantly influence the national trend of Bactrian camels in China.

Temporal population dynamics in the core production areas of bactrian camels in China's xinjiang uygur autonomous region

The temporal population trends in Xinjiang's core Bactrian camel production areas, Altay and Changji, both underwent four distinct phases but followed different specific trajectories, shown in Fig 5. Altay, hosting the largest population, experienced initial stability, a sustained decline from 2002-2011, a recovery until 2017 and then significant fluctuations between 30,000 and 50,000 heads up to 2020. Conversely, Changji saw slow growth, then a decline until 2007, followed by sustained recovery and a sharp fluctuation in 2018 before rapidly rebounding to around 28,500 by 2020.

The population trends of Bactrian camels in Tacheng and Hami were broadly similar. After initial declines from 1995-1999 and a slight rebound in 2000, both experienced sustained decreases until 2010. From 2011-2017, Tacheng's population grew significantly while Hami's stabilized. Both regions then showed sharp fluctuations from 2018-2020. Overall, trends across Xinjiang's core distribution areas were consistent after 2000, though the timing of fluctuations varied locally.

The development and changes of scattered bactrian camel population in China's xinjiang uygur autonomous region

The population trends of scattered Bactrian camel populations in Xinjiang, as shown in Fig 6, also followed four phases, broadly mirroring the concentrated areas. Most regions declined slowly from 1998-2000, except Ili and Aksu. A general decline occurred from 2001-2010, though Ili and Aksu showed brief growth mid-period. Populations stabilized and grew from 2011-2017. Notably, from 2018-2020, these scattered groups experienced explosive, non-natural growth, with some doubling in just two years.

Changes in the number of bactrian camels in China's qinghai, gansu and other regions

Bactrian camels in Qinghai and Gansu Provinces are regionally concentrated. Qinghai's population, nearly all in Haixi Prefecture, currently numbers around 16,000 heads, having dropped sharply in 2001, stabilized, grown until 2019 and recovered after a 2020 dip. In Gansu, primarily distributed across Zhangye, Jiuquan and Wuwei, the population remained above 20,000 until 2006, fell in 2007 and then grew steadily to about 40,000 by 2023. As shown in Fig 2. In Ningxia, recent official counts are near zero, though camels are imported from Alashan for slaughter. For future research, it is suggested to classify Qinghai's camels (Bai *et al.*, 2019) with the Xinjiang/Tarim group and Gansu's with the Inner Mongolia/Alashan group.

Influencing factors of quantity change of Chinese bactrian camel core producing areas

The population dynamics of Chinese Bactrian camels are primarily influenced by two factors: ecological environment and social factors. Ecological factors include the adaptability of Bactrian camels to their living environment and competition with other livestock, while social factors

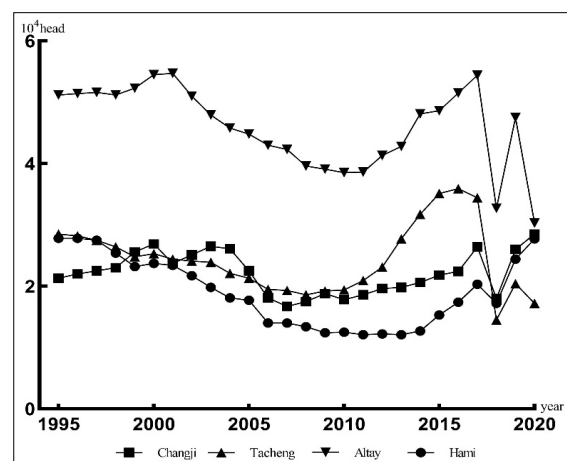


Fig 5: Population number curve of the bactrian camel concentration distribution area in xinjiang uygur autonomous region from 1995 to 2020.

Appendix Table 4: Number of bactrian camels in various regions of xinjiang.

Year	Chinese	Xinjiang	urumqi	karamay	Turpan	Hami	Changji	Yili	Tacheng	Altay	Bozhou	Bazhou	Aksu	Kezhou	Kashi	Hotan
1995	34	16.22	0.21	0.04	0.67	2.78	2.13	0.58	2.85	5.12	0.37	0.85	1.59	0.91	0.49	0.93
1996	34.5	16.34	0.22	0.04	0.61	2.78	2.2	0.61	2.82	5.14	0.38	0.83	1.65	0.88	0.5	0.94
1997	35	16.38	0.21	0.04	0.64	2.75	2.25	0.59	2.75	5.16	0.38	0.87	1.76	0.9	0.49	0.94
1998	33.5	15.99	0.21	0.04	0.54	2.54	2.3	0.62	2.64	5.12	0.38	0.74	1.8	0.92	0.48	0.89
1999	33	16.2	0.21	0.03	0.51	2.32	2.56	0.61	2.48	5.23	0.36	0.74	1.91	0.91	0.44	0.82
2000	32.6	16.7	0.21	0.03	0.53	2.37	2.69	0.69	2.53	5.45	0.36	0.77	1.88	0.89	0.44	0.74
2001	27.9	16	0.16	0.02	0.55	2.34	2.37	0.62	2.44	5.47	0.33	0.63	2.12	0.82	0.42	0.72
2002	26.4	15.8	0.2	0.02	0.54	2.17	2.51	0.62	2.41	5.1	0.33	0.64	1.97	0.81	0.4	0.68
2003	26.5	15.6	0.16	0.01	0.54	1.98	2.65	0.62	2.39	4.79	0.33	0.69	2.03	0.74	0.42	0.62
2004	26.2	15.3	0.15	0	0.54	1.81	2.61	0.63	2.21	4.58	0.36	0.68	2.07	0.75	0.41	0.64
2005	26.6	15.1	0.18	0	0.63	1.77	2.25	0.67	2.13	4.48	0.34	0.72	2.19	0.76	0.4	0.64
2006	26.9	14.3	0.18	0.02	0.48	1.4	1.81	0.67	1.95	4.3	0.33	0.73	2.23	0.84	0.4	0.64
2007	24.1	12.63	0.22	0.03	0.49	1.4	1.67	0.68	1.93	4.23	0.33	0.7	1.74	0.86	0.4	0.62
2008	22.8	11.78	0.23	0.03	0.43	1.34	1.75	0.54	1.86	3.96	0.24	0.67	1.28	0.69	0.42	0.62
2009	22.6	11.35	0.26	0.03	0.44	1.24	1.88	0.57	1.92	3.91	0.25	0.71	1.09	0.68	0.38	0.68
2010	23	10.83	0.29	0.03	0.41	1.25	1.78	0.61	1.94	3.85	0.23	0.62	0.99	0.8	0.38	0.62
2011	24.3	10.70	0.34	0.03	0.42	1.21	1.86	0.63	2.09	3.86	0.23	0.7	0.96	0.8	0.39	0.65
2012	24.5	10.73	0.39	0.03	0.49	1.22	1.96	0.62	2.31	4.13	0.24	0.64	1.01	0.86	0.41	0.67
2013	27.4	11.06	0.45	0.03	0.5	1.21	1.98	0.65	2.77	4.28	0.24	0.74	0.97	0.89	0.53	0.67
2014	28	11.25	0.38	0.07	0.44	1.27	2.06	0.68	3.17	4.81	0.31	0.76	0.99	0.78	0.54	0.69
2015	30.1	11.42	0.45	0.1	0.33	1.53	2.18	0.69	3.51	4.86	0.33	0.75	0.98	0.69	0.6	0.74
2016	30.5	11.70	0.59	0.12	0.44	1.74	2.24	0.73	3.59	5.15	0.35	0.79	1.03	0.77	0.61	0.79
2017	32.3	12.40	0.78	0.12	0.26	2.03	2.64	0.68	3.44	5.44	0.38	0.93	0.99	0.84	0.51	1.08
2018	33.8	12.4	0.55	0.09	0.09	1.72	1.8	0.44	1.45	3.27	0.26	0.76	0.55	0.56	0.48	0.88
2019	40.5	18.5	0.73	0.13	0.16	2.44	2.6	0.59	2.04	4.75	0.42	1	0.89	0.94	0.44	2.08
2020	41.1	19.58	0.84	0.2	0.19	2.77	2.85	0.6	1.72	3.03	0.61	1.06	1.2	0.86	1.02	2.6
2021	46.2	22.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2022	54.1	28.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2023	58	31.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: Unit/10⁴head;-denotes missing data.

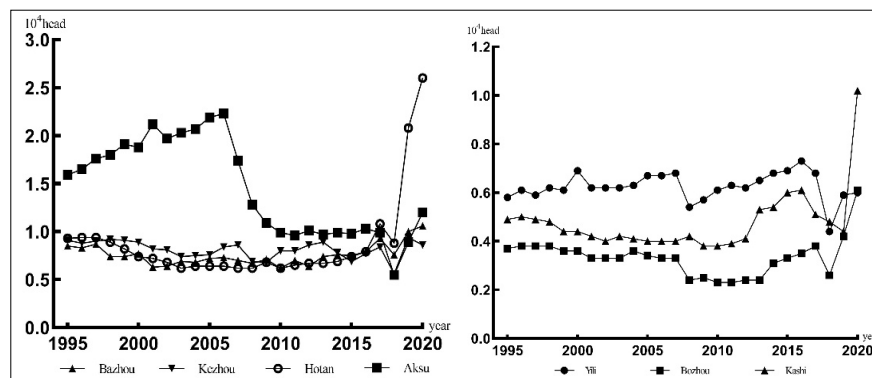


Fig 6: 1995-2020 changes in the population of the bactrian camel distributed in the xinjiang uygur autonomous region.

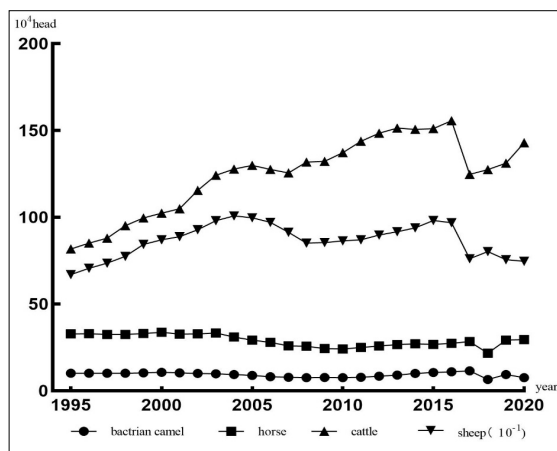


Fig 7: Changes in the number of cattle, horses, sheep and bactrian camels in the alashan league from 1995 to 2023.

encompass national policies, demographic shifts and economic development, among others.

The fluctuations in the population of Chinese Bactrian camels result from the interplay of national regulations on animal husbandry, various socio-economic factors and natural ecological conditions. Among these, national regulations on animal husbandry play a decisive and bidirectional role. The “Grassland-Livestock Dual Contract System” implemented in the 1980s and 1990s integrated the primary production (grasslands) and secondary production (livestock) of animal husbandry into an organic whole, significantly boosting the development of the industry. However, driven by economic benefits, herders prioritized high-yield livestock such as cattle and sheep, leading to a sharp decline in the Bactrian camel population and causing severe damage to grassland ecology, with pastures degrading into semi-desert and desert lands. After 2000, to protect the grassland environment, China introduced ecological conservation policies centered on the *Grassland Law* and measures like grass-livestock balance and grazing bans or rotations. These policies made Bactrian camels, which exert less pressure on grasslands and have lower carrying capacity, a suitable choice,

enabling their population to recover and grow slowly under ecological constraints. From the 2010s to the present, policies oriented toward industrial upgrading and high-quality development, such as standardized large-scale breeding, have directly driven the modernization of the Bactrian camel breeding industry, leading to a phase of significant population growth.

Demographic shifts and regional economic development under national husbandry policies have indirectly influenced Bactrian camel populations. Following grassland contracting, rising productivity and incomes led many herders to migrate, reducing the pastoral workforce. This spurred low-labor practices such as pasture leasing and semi-intensive, semi-free-range models, which improved efficiency and supported herd growth. Additionally, Bactrian camels, valued for their resilience and low investment, are seen by herders as a “safety nets” asset. As disposable incomes rise, herders tend to expand their herds to enhance economic resilience, further contributing to population growth.

In summary, Bactrian camel population changes are primarily driven by national husbandry policies, reshaping production, ecology and herder decisions.

Impact of ecological environment on the population of bactrian camels

Long-term overgrazing has degraded grasslands into semi-deserts, unsuitable for most livestock. Bactrian camels thrive here due to their adaptability: they consume drought-resistant plants, tolerate salty water (Kaczensky *et al.*, 2014) and can go 30 days without drinking (Burger *et al.*, 2019). This resilience makes them the dominant livestock in such areas (Roba *et al.*, 2024) and supports their stable or growing population (Amina *et al.*, 2024).

The effect of the number change of cattle, horse and sheep on the number of bactrian camel in the core producing area of inner mongolia

An analysis of livestock data over the past 30 years in Alashan League, Inner Mongolia's core Bactrian camel region, reveals distinct population correlations, as shown in Fig 7. Statistical analysis shows the number of Bactrian

camels has a strong positive correlation with cattle and horses, but a strong negative correlation with sheep. As shown in Table 2.

Effects of changes in the number of cattle and horse sheep on the number of bactrian camels in the core producing areas of xinjiang

An analysis of the past 25 years of data from Xinjiang's concentrated Bactrian camel production areas reveals key livestock correlations. as shown in Fig 8, a strong positive correlation was found between Bactrian camel and horse numbers, while no significant link existed with cattle or sheep. Notably, cattle and sheep numbers were strongly correlated with each other, reflecting the local practice of pen-feeding these animals, whereas horses and camels are both primarily free-ranging.

National policy

National policies have profoundly shaped Bactrian camel population trends. Following reform and opening up, the "grass-livestock double contracting" (Mu, 2024), policy boosted productivity but led herders to favor faster-reproducing sheep, causing camel numbers to decline. After 2000, ecological restoration policies like grazing bans were implemented (Song and Zhang, 2025). While most areas saw further declines, Inner Mongolia experienced a slight increase, as camels were recognized as low-impact grazers beneficial to desert grassland recovery. From 2010 onward, nationwide population growth resumed, supported by successive Five-Year Plans promoting high-quality livestock development. Notably, Xinjiang's rapid surge since 2017 is linked to the establishment of green industrial clusters and large-scale, industrialized camel farming, driving unnatural, accelerated growth.

Impact of population and per capita disposable income on the number of bactrian camels in the core producing areas: A case study of China's inner mongolia and xinjiang uygur autonomous regions

Statistical analysis using Prism 9.5.1 (as shown in Table 3) reveals a negative correlation after 2010 between the pastoral population and Bactrian camel numbers in core areas like Alashan League, with human numbers declining as camel herds increase.

Using Prism 9.5.1, linear regression analysis of data from Inner Mongolia and Alashan League over 30 years shows a highly significant positive correlation between the Bactrian camel population and the total disposable income of permanent rural residents. The population trends closely align with the income curves in both Fig 9 (Inner Mongolia) and Fig 10 (Alashan), indicating that higher herder income is strongly associated with larger camel herds in these core production areas.

Analysis with Prism 9.5.1 shows a moderate correlation between Bactrian camel numbers and population changes in Xinjiang's Changji, Tacheng and Altay prefectures. The correlation is strongest in Altay,

indicating it strengthens with larger herd sizes (as shown in Table 4).

Analysis with Prism 9.5.1 shows data from Xinjiang's core regions over 25 years shows no significant correlation between Bactrian camel population changes and local per capita disposable income, as shown in Fig 11. This is due to the region's smaller camel herds and its diversified agricultural economy, where income is not primarily dependent on animal husbandry.

The interaction between policy, population, disposable income and the number of bactrian camels

Over the past three decades, policies have been the driving force behind the development of core Bactrian camel

Table 2: Correlation analysis between the number of bactrian camels and the number of cattle, horses and sheep in alashan league.

Breed	r	P value
Cattle	0.88	0.0031
Horse	0.93	0.0001
Sheep (including goats)	0.83	0.0004

Note: $|r| > 0.7$: Strong correlation; $0.3 < |r| < 0.7$: Moderate correlation; $|r| < 0.3$: Weak correlation. P-value < 0.05 effective.

Table 3: Correlation data between the number of bactrian camels and population in core producing areas from 2010 to 2023.

Area	r	P value
Alashan	0.80	0.0006
Bayannur	0.70	0.0086
Ordos	0.84	0.0002
Sunit	0.44	0.1100

Note: $|r| > 0.7$: Strong correlation; $0.3 < |r| < 0.7$: Moderate correlation; $|r| < 0.3$: Weak correlation. P-value < 0.05 effective.

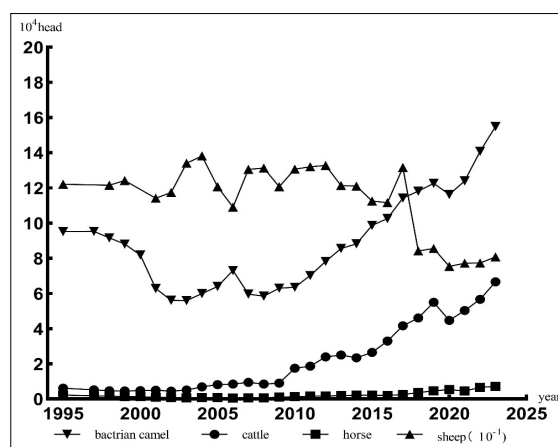


Fig 8: 1995-2020 curve of the number of cattle, horses, sheep and bactrian camels in the core production area of xinjiang uygur autonomous region.

production areas. Under the guidance of “grassland-livestock balance” and ecological priorities, the species’ strong resilience and low grazing pressure have made it an adaptable livestock choice in areas with grazing bans or rotations, leading to a significant increase in its population. The declining population in pastoral areas has spurred a shift toward low-labor, free-range farming models, while the development of products such as camel milk recognized for its :oxidation (Soleymanzadeh *et al.*, 2016), hypoglycemic (Baba *et al.*, 2021; Nongonierma *et al.*, 2018), antihypertensive (Soleymanzadeh *et al.*, 2019) anti-cancer (Homayouni-Tabrizi *et al.*, 2017) and remission of autism (Faye, 2020) -has enhanced its economic value. (Mirmiran *et al.*, 2017; Sultan, 2021). Regional responses have varied: Inner Mongolia has positioned it as an economic supplement under ecological constraints through policy regulation; Northern Xinjiang has achieved intensive growth through captive breeding; while Southern Xinjiang, with its relatively low proportion of Bactrian camels, has seen minimal impact. Overall, a dynamic cycle of “policy-local implementation-industry feedback” has emerged, striving to achieve a sustainable balance between ecological conservation and economic development.

Present situation of Chinese bactrian camel industry

China’s Bactrian camel primary industry has developed rapidly with national policy support, evidenced by continuous growth in herd size and camel milk output, while camel meat and down production remain stable. From 1994 to 2023, the average annual milk yield reached 484 tons per 10,000 camels. In Alashan, milk production exceeds 12,000 tons with an output value of 1.5 billion yuan, significantly increasing herder income. The scale of farming in Xinjiang has expanded rapidly with clear regional agglomeration, as shown in Fig 12 detailing national camel milk and meat production over the past 14 years.

China’s Bactrian camel secondary industry is concentrated in Inner Mongolia and Xinjiang, exemplified by companies like Yili Fengcao Ranch Dairy and Xinjiang Wangyuan Bio-Technology Group. Established post-2020, they primarily produce camel milk (Yamina *et al.*, 2024) products, while deep processing of camel meat and hair remains underdeveloped.

China’s Bactrian camel tertiary industry is nascent but poised for growth. Future integration of camel culture with tourism resources is expected to drive its development (Luo *et al.*, 2024). The government currently encourages cultural festivals and related events to promote the convergence of primary, secondary and tertiary industries.

Development challenges in the primary industry of Chinese bactrian camels

Breed standard issues

Currently, among Chinese Bactrian camels, only the Alashan Bactrian camel has a national breed standard. Local breed standards exist for the Sonid Bactrian camel

and the Qinghai camel (Bactrian camel), while breeds such as the Urad Gobi Red camel and the Mulei Long-Eyebrow camel lack established standards. Additionally, the existing standards have not been updated for a considerable period.

Selective Breeding Issues: There is a lack of functionally specialized breeds in Bactrian camels. At present, no breeds are specifically developed for high milk or meat production, resulting in low efficiency in these areas. There is an urgent need to cultivate dairy-purpose

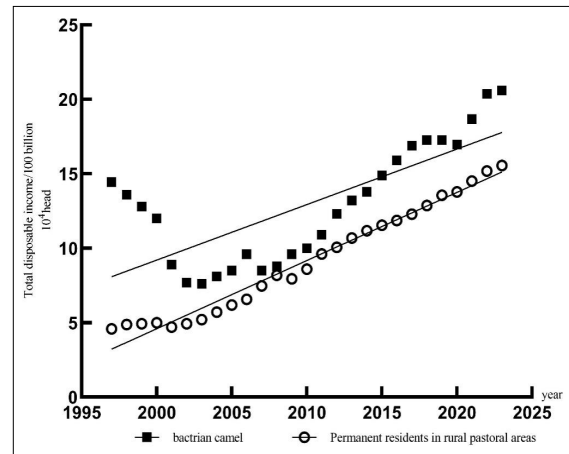


Fig 9: Changes in the number of bactrian camels and total disposable income in inner mongolia.

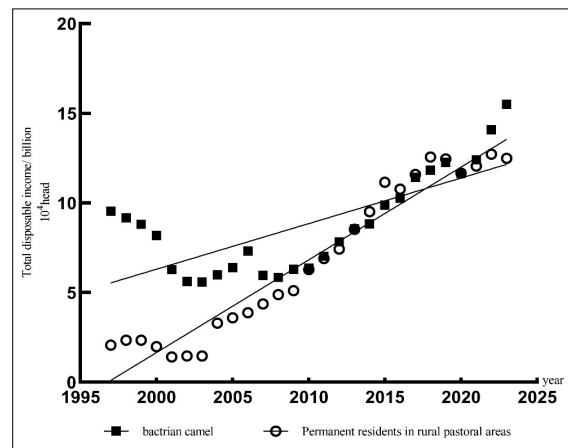


Fig 10: Changes in the number of bactrian camels and disposable total income in alashan.

Table 4: Correlation data between the number of bactrian camels and population in core producing areas from 1995 to 2020.

Area	r	P value
Changji	0.43	0.036
Tacheng	0.46	0.020
Altay	0.56	0.003

Note: $|r| > 0.7$: Strong correlation; $0.3 < |r| < 0.7$: Moderate correlation; $|r| < 0.3$: Weak correlation. P-value < 0.05 effective.

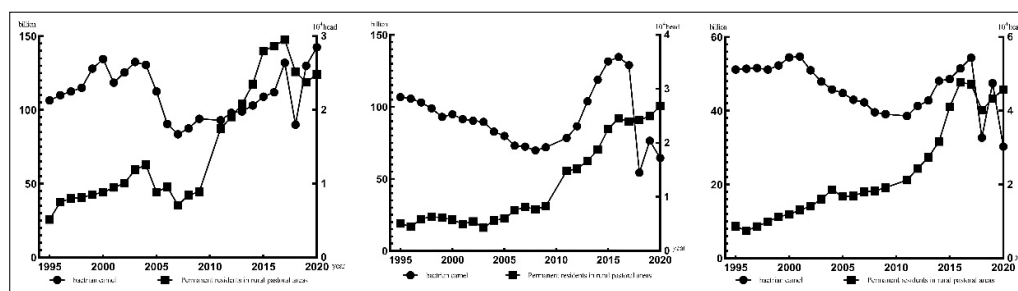


Fig 11: Number of Bactrian camels in the core production area of xinjiang from 1995 to 2020 and the curve of disposable income in agricultural and pastoral areas (from left to right: Changji hui autonomous prefecture, tacheng prefecture, altay prefecture).

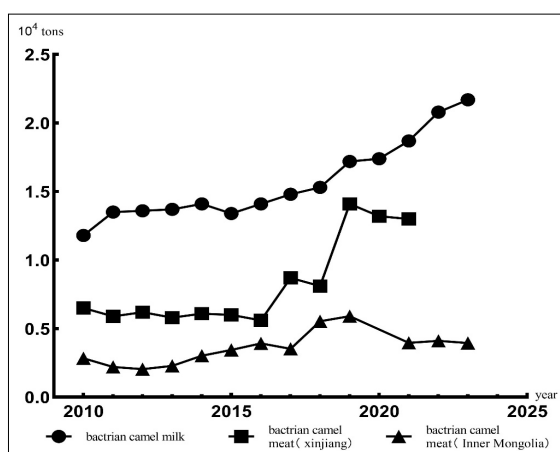


Fig 12: China 's bactrian camel milkd and meat production from 2010 to 2023.

and meat-purpose Bactrian camel breeds. Selective breeding efficiency can be significantly enhanced through both traditional breeding techniques and modern biotechnology (Wang *et al.*, 2025).

Feeding management issues

Traditional animal husbandry primarily relies on grazing. However, with the high-quality development of the livestock industry, large-scale intensive farming of Bactrian camels has begun in some regions. This necessitates the establishment of feeding management protocols as well as disease and infectious risk control procedures to ensure the health and safety of the camels. Currently, such regulations are either incomplete or lacking and require timely supplementation.

Development challenges in the secondary industry of Chinese bactrian camels

Product standard issues

The standardization of the Bactrian camel industry is an urgent priority. Currently, the standards for camel milk powder vary among enterprises, leading to inconsistent product quality in the market and requiring consumers to invest significant effort in evaluation. Among existing standards, those for camel wool are relatively well-developed, with national and local standards in place and

ongoing revisions. In contrast, standards for camel milk are insufficient. Raw camel milk, as the foundation of the camel milk industry, should be prioritized for the revision, updating, or establishment of a dedicated national standard. Additionally, national standards for products such as pasteurized camel milk, fermented camel milk and camel milk tablets should be formulated with reference to existing national standards for cow's milk. Currently, there are no specific national or local standards for camel meat, which is primarily regulated under general livestock and poultry standards.

Industrial layout issues

Chinese Bactrian camels are mainly distributed in the northern and northwestern regions. For the development of this high-end consumer industry and its supporting sectors, production must be transformed toward densely populated areas and products need to be absorbed by high-end markets. However, the Bactrian camel industries in the Xinjiang Uygur Autonomous Region and the Inner Mongolia Autonomous Region face challenges such as underdeveloped human and intellectual resources, remoteness from industrial cities and distance from core consumption areas. The absence of water transport and high land transportation costs directly hinder the long-term development of the industry.

Product layout issues

The primary products of China's Bactrian camel secondary industry are camel milk and its derivatives, representing a highly singular product range. Although industries related to camel meat and camel wool have seen some development, they remain underdeveloped or are treated as by-products without deep processing. Furthermore, high-value-added products related to Bactrian camels, such as cosmetics and healthcare products, are scarce and largely remain at the research or exploratory stages.

Lag in technological innovation

In Inner Mongolia, traditional free-range grazing dominates, resulting in low breeding efficiency. A small number of cooperatives have adopted housed breeding and mechanized milking, but leading enterprises lack sufficient driving force. In Xinjiang, intensive farming has significantly

improved production efficiency, yet breeding technology remains relatively backward, with many techniques and standards lacking systematic frameworks and requiring refinement. Both regions suffer from low integration of the industrial chain. The linkage models among enterprises, cooperatives and herders are weak (Bai, 2024), with loose interest connections and profits are primarily derived from primary products rather than deep processing. Lastly, the transformation of scientific and technological research achievements into practical applications lags, as research outcomes have not been effectively converted into high-value-added products.

Development challenges in the tertiary industry of Chinese bactrian camels

Insufficient cultural promotion

The Bactrian camel possesses profound historical and cultural significance. However, in densely populated southern regions, there is limited awareness of its characteristics and advantages. Products such as camel milk, camel meat and camel wool remain novel animal-derived products to many. Therefore, efforts should be made to enhance the public understanding and promotion of Bactrian camels. The development of this industry should begin with cultural education, enabling consumers to gain a more comprehensive understanding of the Bactrian camel.

Emphasizing the concept of bactrian camels

As an endemic species in China, the concept of the "Bactrian camel" should be strongly emphasized nationwide. During educational and cultural outreach activities, a clear distinction must be made between Bactrian camels and dromedaries from tropical regions. Focus should be placed on highlighting the unique spiritual and cultural significance of Chinese Bactrian camels, embodiment China's long-standing history and culture.

Outlook

Driven by ecological priorities and livestock industry transformation, Bactrian camels are poised to become a key pillar for sustainable grassland husbandry due to their unique adaptability to arid pastures. Based on linear regression analysis of Fig 2, the national herd is projected to exceed 700,000 by 2030 and steadily advance toward 820,000 by 2035. As shown in Fig 12, both camel milk and meat production are increasing, reflecting the industry's significant potential. Systematic planning and multi-stakeholder collaboration are essential to upgrade the entire industry chain.

China's Bactrian camel primary industry, efforts should accelerate breed standardization, integrating traditional and biotech breeding to cultivate functional milk/meat varieties. Scientific feeding management and disease prevention protocols must also be established to ensure herd health and industry safety amid intensification.

China's Bactrian camel secondary industry, establishing product standardization for camel milk and meat is a priority, referencing existing dairy standards. Industrial layout should focus on deep-processing bases near consumer markets and cold-chain logistics. Product lines must expand beyond dairy to include value-added camel meat, hair and innovative goods like cosmetics and health products. Strengthening partnerships among enterprises, cooperatives and herders is essential for applying research and enhancing industry competitiveness.

China's Bactrian camel tertiary industry should focus on exploring the cultural significance of Bactrian camels and promoting their brand value. Nationwide promotion, especially in southern China, can highlight their uniqueness as a species endemic to China, distinguish them from dromedaries and boost public awareness and consumption.

Looking ahead, China's Bactrian camel industry is expected to establish a high-quality, distinctive and efficient development system driven by breed optimization, standardization and cultural promotion, providing strong support for rural revitalization and border-region economies.

CONCLUSION

China's Bactrian camels inhabit hot-summer, cold-winter deserts, where their behavior shapes vegetation and habitats. Their population has grown steadily since 2010, showing dynamic expansion and contraction around core areas. Numbers correlate negatively with sheep in Alashan but positively with horses in Xinjiang. The industry has expanded in primary/secondary sectors like milk processing, yet faces challenges in breeding and standardization. Scientific research lags behind this key species for grassland-livestock balance. Future work should prioritize studying Bactrian camel-environment interactions and determining optimal stocking ratios for desert pastures, balancing economic and ecological restoration goals.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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