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Conservation and Management of Yak Genetic Diversity

Proceedings of a Workshop

29 - 31 October, 1996

Kathmandu, Nepal

Edited by

Daniel J. Miller
Sienna R. Craig
Greta M. Rana

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International Centre for Integrated Mountain Development
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Conservation and Use of Animal Genetic Resources
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Yak in Khumbu, Nepal, and Yak herder from Sakten, Bhutan

All plates in this publication are by Daniel J. Miller

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Foreword

The use of the yak by a variety of pastoral nomad groups, living at high altitudes, as the bases of their economic systems and rich cultures probably pre-dates the dawn of written history. The yak is an excellent example of those early bovines which could provide all the necessary inputs to sustain nomadic peoples. It is a source of deep satisfaction that , although so little research has heretofore taken place on this splendid animal, this workshop on 'Conservation and Management of Yak Genetic Diversity' has brought together so many notable experts on the yak from different corners of the world and that, through pooling our knowledge and recording the proceedings of this workshop, we will be able to disseminate knowledge on the yak beyond the borders of the Hindu Kush-Himalayan Region.

It is essential that we maintain the impetus of interest in the rangelands and herding societies of the Hindu Kush-Himalayas. In seeking to alleviate the persistent poverty in these areas, we must not lose sight of the diverse lifestyles that have sustained its inhabitants in the past. In diversity lies a wealth of knowledge that we should try our utmost to retain. It is only through developing economic opportunities that blend with both the sociocultural and economic aspirations of a people that we can ensure that self-fulfillment lies within their grasp. We cannot deem ourselves to have been successful unless we can devise means to enable them to build a future upon the successes of the past; and herein lies the importance of the yak.

The proceedings of this workshop provide us with much valuable information on yak husbandry and research . The major yak-rearing countries are represented and extra space has been provided for papers from China, because it is in China that the largest herds are to be found, where much of the experimentation on hybridisation with the yak and its succeeding hybrid generations has taken place, and where problems are being addressed concerning winter feed supplements and processing and marketing of yak products. This is not to say that each country represented does not have something of value to provide; the opposite is the case. At the end of the day, however, the problem will remain concerning what best scientists can do to not only maintain but also improve upon the circumstances in which the high altitude nomads live and rear their yaks upon some of the harshest environments on earth.

In closing, I would like to thank all the participants who worked hard to make a contribution to our understanding of the yak during the Regional Workshop on Conservation and Management of Yak Genetic Diversity held in Kathmandu, Nepal, from October 29-31, 1996. Organising this Workshop was made possible through generous financial support provided by the Conservation and Use of Animal Genetic Resources' Programme of the FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. I take this opportunity to express our great appreciation to FAO and, in particular, Mr. David Steane, Chief Technical Advisor, Conservation and Use of Animal Genetic Resources' Programme, for

this generous support to ICIMOD. I would also like to express appreciation of the efforts of Mr. Daniel Miller, ICIMOD's Rangeland Specialist, who organised the workshop. I would also like to thank Daniel Miller, Sienna Craig, and Greta Rana for editing this important monograph. Thanks are also due to the staff of ICIMOD's Publication Unit for preparing this manuscript for publication.

Egbert Pelinck
Director General

Editorial Preface

We are very much aware that there are missing links in tracing the history and development of the yak from the dawn of man until the present day. For this reason we have tried very hard to avoid dispensing with any of the material we received; and this includes references. The reader will note that some references are cited in text, others not, and yet other papers have no references at all - hence we have resorted to calling the lists bibliographies. Another missing link has been in being unable, for the most part, to trace back the documents which are incomplete or for which all author names have not been listed. This mainly applies to documents in Chinese. We hope the reader will bear in mind that most of our authors truly are rangeland specialists and that, unless they are called together for workshops like this one, they are more often than not out following the yaks and their nomadic herders on the high altitude plateaus of the Hindu Kush-Himalayas. Since the document had a certain deadline for publication, we had to be expedient in terms of letting some of the editorial stipulations lapse. Another point which might perplex the reader is the fact that two transliterations have been used, i.e., Dolpo and Dolpa, in the papers on Nepal. HMG/Nepal uses Dolpa, the Tibetan linguistic groups who inhabit the region pronounce it Dolpo. Hence, when including the inhabitants in our considerations, we use the name they give their own district, in all other instances we defer to the government spelling.

This is not to say that much has been detracted from this document. Well aware that most of our readers will have seen a yak but rarely, and others may never have seen one at all, we have followed the yak pictorially through these pages with the excellent photographs taken by Daniel Miller. This way we hope that the reader will capture in sight and in senses the atmosphere of the high plateaus where the devil winds blow and there is nothing between the nomads and infinity; the last frontier on earth.

The Editors

Abstract

This document is divided into three principal sections . Section One contains papers on yaks from Bhutan ,China, India, Mongolia, and Nepal. Topics covered include wild and domestic yaks, conservation of domestic genetic diversity, and production systems. Section Two mainly concentrates on yaks in China, particularly in relation to yak-rearing systems, research, and market development in the Tibetan Autonomous Region and the QuinghaiTibetan Plateau, Xinjiang, Gansu, and Sichuan. This section also includes an absorbing photo essay and a paper on yak cheese production in Nepal; the pioneer country in making and marketing yak cheese. Section Three is devoted to breeding strategies and chromosone evaluation. The Conclusion is also in this section, although recommendations are dealt with in the introductory essay in Part One.

Contents

SECTION

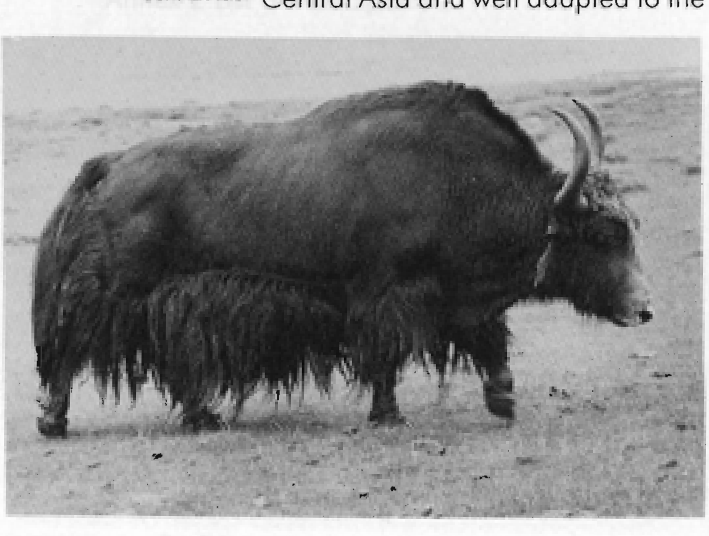
One

Conserving & Managing Yak Genetic Diversity: An Introduction

Daniel J. Miller

Background

The yak (*Bos grunniens*) is one of the most important species of livestock found in the Himalayas and on the Tibetan Plateau, as well as in pastoral areas of northwestern China, Mongolia, and southern Russia. Totalling about 14 million animals, yaks and yak-hybrid crosses provide milk and milk products, meat, hair and wool, and hides. Yaks are also used as pack and draught animals and for riding. They also provide dung, an important source of fertilizer for maintaining soil fertility in agro-pastoral areas, and valuable fuel, in an environment where firewood is not available. The yak is a unique animal, endemic to Central Asia and well adapted to the cold, high altitude environment where it is found. Without the yak, it is doubtful if man could survive in the harsh, high altitude grazing lands found in the Himalayas and on the Tibetan Plateau. As such the conservation and management of yak genetic diversity are essential for sustainable pastoral development over a large geographic area.



Yak bull in Langtang, Nepal

The yak is a unique animal endemic to the Tibetan Plateau. Yaks are vital to the survival of pastoralists in much of Central Asia. Conserving and managing yak genetic diversity is essential for sustainable development in the pastoral areas of Central Asia.

Recognising the importance of the yak, ICIMOD and the FAO Regional Office for Asia and the Pacific organised a workshop; the *Regional Workshop on Conservation and Management of Yak Genetic Diversity*, in Kathmandu, Nepal, from October 29-31, 1996. It brought together yak specialists from Bhutan, China, India, Mongolia, Nepal, and Pakistan. The purpose of the workshop was to share information about

Wild yak skull, Chang Tang Wildlife Reserve, Tibet, China
Wild yaks once numbered in the millions. Now, only an estimated 15,000 yaks are left in the wild. Preserving remaining wild yak herds is crucial for biodiversity conservation. Wild yak genetic resources are also valuable for improving domestic yak productivity as wild yak semen is being used for cross-breeding with domestic yaks.

yaks, examine existing yak production systems, and discuss issues related to managing and conserving yak genetic diversity. This report, prepared from papers presented at the workshop, includes summaries of discussions that took place during the workshop and provides valuable and timely information on the yak. It is hoped that the findings from this workshop will be used to develop programmes that can ensure that the yak's unique genetic diversity is conserved and managed as a means of improving yak production in future.

Mr. David Steane, Chief Technical Advisor, Conservation and Use of Animal Genetic Resources in Asia and the Pacific Programme, FAO Regional Office, Bangkok, Thailand, first suggested holding the workshop and provided substantial financial resources which allowed the workshop to be organised. Without Mr. Steane's interest and enthusiasm, this workshop on yaks would never have taken place. He was also able to secure funding to enable Dr. Gerald Wiener, a geneticist from Edinburgh University in Scotland, to participate in the workshop. Dr. Wiener recently collaborated with Professor Cai Li from China in preparing the book, *The Yak*, which was published by the FAO Regional Office in Bangkok, and Dr. Wiener's insights on yak breeding and conservation and management of yak genetic diversity during the workshop were extremely beneficial.

This document is divided into three parts. First, the country reports on yaks are presented. In this first part,

Yaks and rangelands near Hongyuan, Sichuan Province, China
Yaks are well adapted to the harsh environment on the Tibetan Plateau and, over thousands of years, pastoralists have perfected strategies for yak husbandry and range management.

two papers about the situation of wild yaks are also included. The second part of the proceedings includes papers dealing with yak production and conservation of yak genetic diversity from the five major provinces and autonomous regions of the People's Republic of China where yaks are found. Since China is such an important country for yaks and has the largest population of yaks in the world, it was felt that comprehensive papers from the yak-raising provinces of China, in addition to the country reports, would provide valuable information that could not be summarised in a country report alone. In addition, a paper on yak cheese production in Nepal is included in this section. The final section of the proceedings deals with breeding strategies and conservation of yak genetic diversity; it summarises many of the conclusions and recommendations from the discussions that took place.

Nomad camp in northwestern Bhutan
Yaks are found throughout the high elevation rangelands of the Himalayas. Without the yak, it is doubtful if humans could survive in these harsh mountain ecosystems.

Wild Yaks and their Conservation

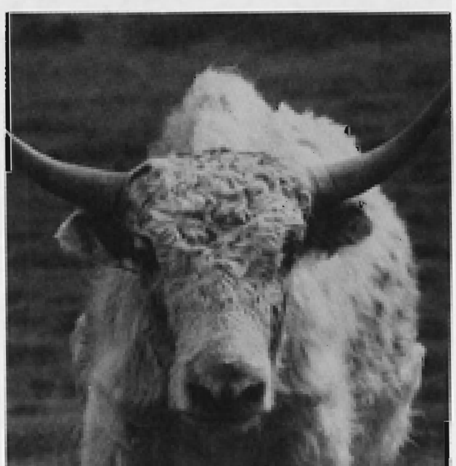
Any deliberation on the conservation of genetic diversity must start with a discussion of wild yaks. Domestic yaks (yaks were first domesticated about 4,000 years ago) are descendants of wild yaks that once roamed throughout the Tibetan Plateau. Early explorers in Tibet estimated that their numbers were in the millions. Currently, approximtely only 15,000 wild yaks survive, and these remnant populations can be found only in the most remote parts of the Tibetan Plateau in China, faraway from the hunters' guns.

We were fortunate to have Professor Cai Guiquan attend the workshop. Professor Cai and this author collaborated on research on wild yaks in Qinghai Province in 1990 and 1991 and his insight into the current situation of wild yaks was especially interesting. Wild yaks are a vital ingredient to the biological diversity of the Tibetan Plateau. Without the wild yak, the Tibetan rangelands will have lost one of its characteristic species. No other animal so evokes the wild beauty and raw energy of the Tibetan Plateau. Standing almost two metres tall, wild yak bulls can weigh up to a tonne, and their horns are so large that they are used as milk pails by nomads.

Wild yaks are facing considerable danger, and, although they are not facing extinction yet, they are under serious threat. The greatest threat to the remaining wild yak populations is from illegal hunting. Despite the fact that wild yaks are officially protected under Chinese wildlife protection laws, poaching of wild yaks still takes place and wildlife authorities are ill-equipped to control illegal hunting. With the establishment of the Chang Tang Reserve in northern Tibet, one of the major wild yak refuges is officially protected, but other wild yak populations in Qinghai Province and Xinjiang Uygur Autonomous Region are still at risk. Information on the overall distribution and status of the remaining wild yak populations is also limited. Preserving the remaining wild yak populations and developing a better understanding of their ecology should be important aspects of any strategies for conserving yak genetic diversity.

Wild yaks are not only important in terms of biodiversity conservation, but

Female yak in northern Bhutan
Yaks not only provide milk and milk products but also valuable fibre, hides, and draught power. Yak dung is used as fuel in many pastoral areas of the Himalayas and on the Tibetan Plateau.



White yak bull in Tianzhu, Gansu Province, China
Yak herders have developed special breeds of yaks - such as the Tianzhu white yak in Gansu Province, China. The white hair from these yaks is used for costumes in Chinese opera.

Yak hybrids plowing fields, Zhongdian, Yunnan Province, China

Yaks and yak hybrids help agriculturists to till their fields. Although yak hybrids cannot withstand the same altitudes as their pure-bred counterparts, they are valued for their milk production and draught power and are also used as pack animals.

their preservation is also imperative for improving the productivity of domestic yaks. Wild yak genetic resources are receiving increasing attention in cross-breeding programmes with domestic yaks. In China, efforts have been going on for some years now to collect wild yak semen from captured bulls and to then artificially inseminate domestic yak cows. The paper by Han Jianlin and Lu Zhonglin reports on some of this important cross-breeding work. Research results clearly demonstrate that the offspring of wild yak are larger and more productive. The demand for wild yak semen, both in China and in neighbouring yak-raising countries, is also growing and should stimulate further research in this area.

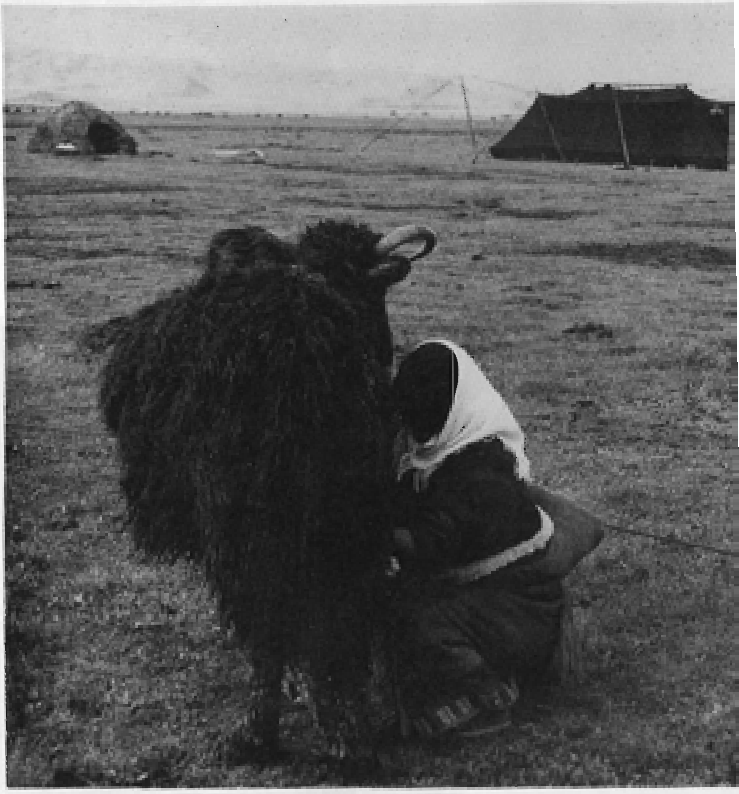
Yak Production and Management

Domestic yaks are found throughout the high-elevation areas of the Hindu Kush and Karakoram in Afghanistan and Pakistan; the Himalayas in India, Nepal, and Bhutan; the Tibetan Plateau and Tien Shan mountains of northwestern China; and western

Yak herd migrating, Maiwa, Sichuan Province, China

Mobility is a characteristic of yak production systems. Yak herds are regularly moved between different pastures to maintain rangeland productivity.

and northern Mongolia. Yaks are also found in the adjoining areas of Russia and some of the Central Independent States of the former U.S.S.R (Figure 1). Wherever they are found, yaks are an important means of livelihood for pastoralists. Yak production systems vary widely throughout the region. In some areas, herders maintain yaks only and, in other areas, both yaks and yak hybrids are kept. In many parts of the Himalayas, yak hybrids are extremely important as the country reports from Nepal and India indicate. Complex systems for cross-breeding, with specific nomenclature for the different crosses, are also found in yak-raising areas.



Female yak being milked, Hongyuan, Sichuan Province, China
Yaks provide pastoralists with many useful products, including milk which is often processed into butter and cheese. Women often do much of the milking in yak-raising areas.

The wide range of yak production practices is a testimony to the diverse animal husbandry skills yak herders have acquired and the unique adaptations they have made for survival in an environment where crop agri-

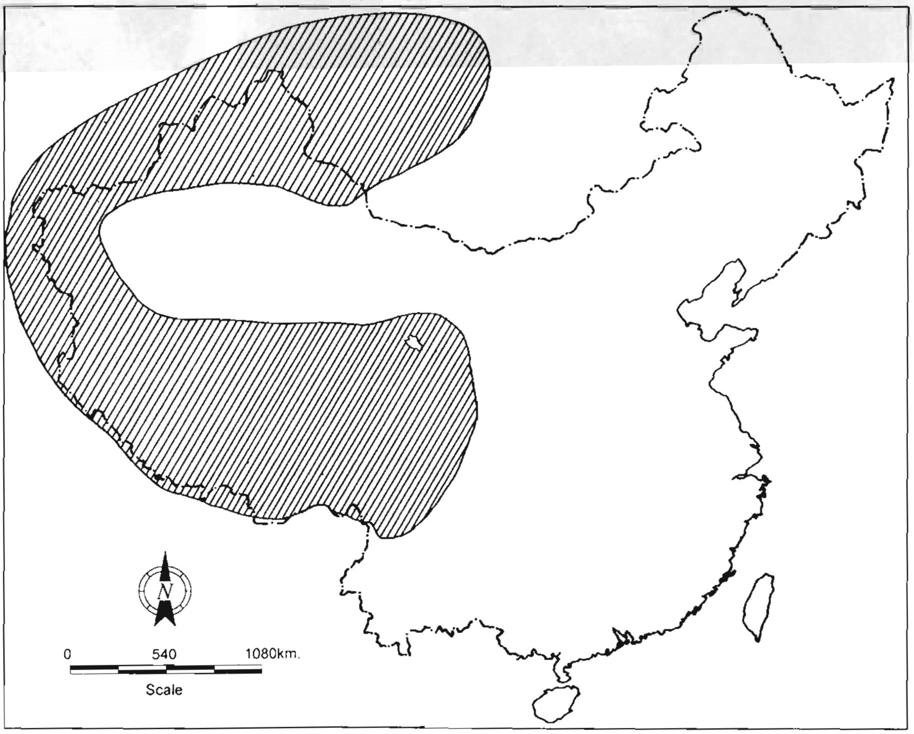
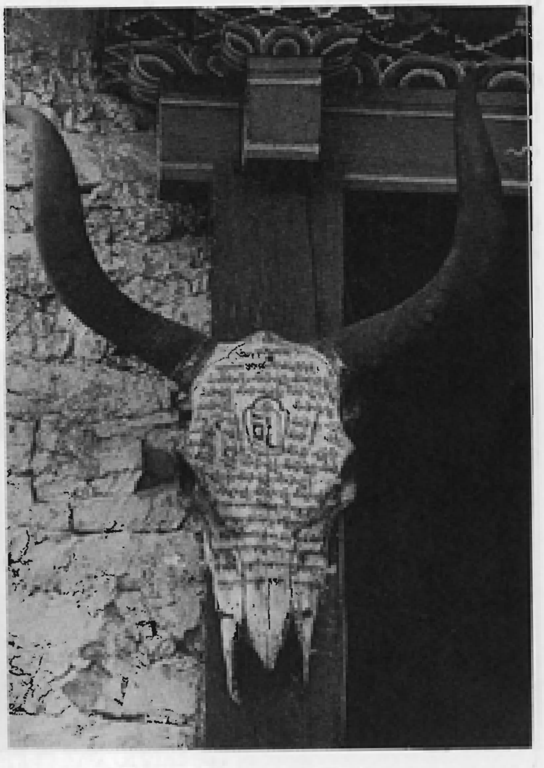


Figure 1
Distribution of Domestic Yaks

culture is generally not possible. Despite these adaptations and skills, yak production today faces numerous problems. Yak production systems are often constrained by inadequate forage, especially in the winter, and this leads to poor nutrition, health-related problems, and reduced fertility. In many areas, these problems are exacerbated by increasing livestock numbers, and this places more pressure on rangelands, often leading to overgrazing. Many of the current yak-breeding practices lead to inbreeding which lowers heterozygocity, reduces fitness (poorer reproductive capacity and lower rates of survival), and lowers yak performance — a possible reason why the wild yak provides real improvement when crossed with the domestic yak. Although access to many yak-raising areas is improving with modernisation, yak herders are still often marginalised in that social services are inadequate and outlets to markets for their animal products are limited. Finally, yak production systems, and especially their socioeconomic characteristics, are still poorly understood by researchers and livestock development planners. This often results in inappropriate yak development projects. All of these issues together combine to create considerable challenges to improving yak productivity.

All the papers on yaks emphasise the importance of yaks in the pastoral areas where they are found. Yak production will continue to be the main source of livelihood for people living in the high-elevation pastoral areas in future. As such, considerable efforts need to be expended on yak research and yak development programmes in these areas. Reports from Bhutan, India, and Nepal highlight the problems with inbreeding as a result of disruption of traditional trade networks and linkages with pastoral areas across the border in Tibet. Greater international cooperation between countries in the region should be fostered to improve the exchange of yak breeding stock. This workshop has made an important start in sharing information among yak specialists in different neighbouring countries, and it is hoped that more regional collaboration will be one eventual outcome of this workshop.

Yak in Mount Everest region, Nepal (p8)
In the Mount Everest, or 'Sagarmatha', region of Nepal, trekking and mountain climbing expeditions are popular. Yaks are increasingly being raised for pack purposes. Tourists will continue to depend on yaks to carry supplies for their expeditions.



Yak skull inscribed with Buddhist prayers, Sakten, Bhutan
In addition to providing humans with sustenance, yaks also play a role in many pastoral rituals and religious festivals. For example, sometimes a community will set a domestic yak free. This 'god yak', as it is called in Tibetan, is an offering to gods of the locale, a gift back to the environment which sustains pastoralists.

Nomad camp in Shey-Phoksumdo National Park, Dolpo, Nepal
Many yak-raising areas are now included in the protected area system in the Himalayan region. Balancing biodiversity conservation and pastoral development in these areas is a major challenge and is constrained by a lack of understanding of the yak-based pastoral production systems.

Yak Genetic Diversity

Over the centuries, yak herders have bred yaks and developed numerous, local yak types, often recognised as distinct breeds with different characteristics. However, as Gerald Wiener points out in his paper, there is little scientific evidence available about the genetic variation that exists between these different breeds. The existence of different breeds may be the solution to developing a yak genetic conservation policy and a new genetic programme for commercial yak raising.

Different yak breeds exist, for the most part, in different areas where yaks are raised. To date, no proper genetic comparison has ever been made between these different breeds in terms of their performance and general attributes. It is not known to what extent the breeds differ genetically. All that is known is that they appear to differ in their general appearance. It is necessary, therefore, to measure performance, survival, and reproductive capacities among the different breeds to determine how much one breed differs

Yearling yak calves, Langtang, Nepal
Many female yaks only give birth every other year, but, when increased forage supplies are available, they will often bear a calf every year.

Yak dance, Sakten, Bhutan

Yak dances are held by herders throughout yak-raising regions. These events signify the vital role that yaks play in pastoral society; not only as a means of daily sustenance, but also for their cultural and spiritual values.

from another. Yak breed comparisons and the crossing of yak breeds could be very valuable, as Wiener emphasises, for identifying yak genetic diversity and would provide a scientific basis for yak genetic conservation plans and, probably more importantly, for the development of improved breeding plans for yak herders to follow. This could, eventually, lead to improvements in yak performance and hopefully even ensure the long-term survival of the yak and the unique yak-herding culture which it supports.

Conclusion

The yak is a unique animal endemic to the Tibetan Plateau. Conserving the remaining populations of wild yaks should be a priority consideration for biodiversity conservation programmes. Domestic yak production practices will continue to be one of the major means of supporting pastoral populations in yak-raising areas. The demand for yak products will continue to grow as economies expand in the region. This means that greater attention to improving the management of the rangelands, upon which yak production is based, is needed, and that research programmes should be introduced to assess yak genetic diversity. While yaks are not a major species globally, their presence in this unique grazing land environment is crucial to human survival and to the maintenance of genetic diversity.

Yak herder from Sakten, Bhutan

Yak development programmes have to involve the pastoralists themselves in the initial design of interventions. Yak researchers and livestock planners need to listen to the needs and desires of the yak herders and learn from the vast knowledge they possess.

Yaks in Bhutan

Lam Tshering, Pema Gyamtsho, and Tshering Gyeltshen

YAK PRODUCTION SYSTEMS IN BHUTAN

Introduction and Background

Bhutan is a landlocked country located between 26° 41'28" and 28°21'16" North latitude and 88°44'42" and 92°07'21" East longitude in the eastern Himalayan range. It is bordered by the Indian states of Sikkim to the west, West Bengal and Assam to the south, and Arunchal Pradesh to the east. Bhutan borders on the Tibetan Autonomous Region of China to the north. Geographically, Bhutan covers an area of 40,077 square kilometres which can be divided into three distinct physiographic zones: the southern foothills, the inner Himalayas, and the greater Himalayas. The southern foothills rise from the plains along the Indian border and range in altitude from 200 to 2,000 metres above sea level (masl). The inner Himalayas are comprised of the main river valleys and steep hills, ranging in altitude from 2,000 to 4,000 metres. The greater Himalayas in the north along the Tibetan border consist of snow-capped peaks and alpine rangelands above 4,000 metres (Table 1).

Bhutan's population is approximately 0.6 million. About 90 per cent of all Bhutanese live in rural areas, and more than 80 per cent depend directly on livestock and arable agriculture to survive. However, only 7.8 per cent of the total land area is under permanent cultivation (LUPP data 1994). The agricultural sector contributes about 42.8 per cent of the Gross Domestic Product (CSO 1990), while the livestock sector contributes 10 per cent.

Yak-rearing Areas

The high elevation rangelands of Bhutan extend from the north-west of Haa District, across the country's northern belt, to Merak-Sakten in the extreme north-east of

Table 1: Agro-ecological Zones of Bhutan

Agro-ecological zone	Altitude (masl)	Annual rainfall (mm)	Annual temperature max	min	mean
Alpine	3600-4600	<650	12.0	-0.9	5.5
Cool temperate	2600-3600	650-850	22.3	0.1	9.9
Warm temperate	1800-2600	650-850	26.3	0.1	12.5
Dry subtropical	1200-1800	850-1200	28.7	3.0	17.2
Humid subtropical	600-1200	1200-2500	33.0	4.6	19.5
Wet subtropical	150-600	2500-5500	34.6	11.6	23.6

Source: MOA/ISNAR, 1992.

Tashigang District. Yak-rearing areas lie between 3,300 and 5,000masl. Most of the areas above 4,000m remain under snow from December to March. The yak-rearing districts are Haa, Paro, Thimphu, Gasa, Wangduephodrang, Trongsa, Bumthang, Lhuntse, and Tashigang.

Bhutan's climate is characterised by short, wet summers and cold, dry winters. Spring and autumn are dry and cool. The tree line varies across the landscape of Bhutan. The country's high altitude regions in 10 *dzongkhag*(s)(districts) is inhabited by semi-nomadic yak herders. Most communities have permanent settlements in the form of village clusters which serve as bases of operation for yak rearing and other socioeconomic activities.

Importance and Role of Yaks

Yaks play a very significant role in the economy and social practices of the people of Bhutan. They are an integral component of the country's pastoral system and are herded in the northern areas of the country, primarily Thimphu, Tashigang, Haa, Paro, Gasa, Wangduephodrang, and Bumthang *dzongkhag*(s) by pastoral groups known as *Zhop* in the west and *Brokpa* in the east. (Both of these words mean 'yak herder'). The *Brokpa* in the east are entirely dependant upon yaks as they have no cultivable land holdings. They lead a nomadic life and spend their entire lives tending their animals. They live in crude shelters or yak hair tents. Their migratory transhumance patterns correspond to fodder availability. The *Zhop*, in places like Haa, Laya, Lunana, and Bumthang, are agro-pastoralists. They herd yaks as part of their livelihood, although they also possess substantial areas of cultivable land.

The yak population in Bhutan is thought to be the progeny of original Tibetan stock. The yak serves many purposes, from producing milk, meat, and wool to supplying draught power. Considering the yak's ability to survive and make use of otherwise uninhabitable terrain and the high market for yak milk products and meat within Bhutan and neighbouring areas, the importance of yaks within the Bhutanese economy will continue to be significant for years to come.

Yak Population and Distribution

Official records (1994) show that Bhutan has a yak population of 30,148 (Table 2). However, it is generally understood that official records underestimate actual numbers, as they are compiled from livestock taxation records. Farmers and yak herders

Table 2: Population Numbers and Distribution of Bhutanese Yak

			Number of yaks		
No	***Dzongkhag***	**No. of *Gewogs* with yaks**	**M**	**F**	**Total**
1	Haa	3	1810	2709	4519
2	Paro	9	1153	1882	3035
3	Thimphu	6	4133	6016	10149
4	Gasa	2	780	1334	2114
5	Wangdue Phodrang	5	1326	1809	3135
6	Bumthang	4	1450	1805	3255
7	Lhuntse	1	93	202	295
8	Tashigang	4	1336	2257	3593
9	Samdrup Jongkha	1	20	33	53
	Total	**35**	**12101**	**18047**	**30148**

Source: LUPP (1995)

are prone to report lower numbers to avoid taxation, as they realise that revenue officials are not apt to conduct actual head counts of their animals. Actual head counts and official census figures often differ by more than 30 per cent (Gibson 1991). A more realistic estimate of the yak population places it at approximately 40,000 animals.

Yak distribution in Bhutan is detailed in Figure 1. The highest density is seen in western Bhutan where the average household owns more than five animals.

The yaks in Bhutan are not categorised into breeds. It is not known whether the differences in appearance between yaks of different regions within the country are due to genetic differences or other causes. However, ILRI has begun to genetically characterise the indigenous AnGR and estimate species' diversity levels.

Physical Characteristics of Bhutanese Yaks

The yak belongs to the genus *Bos* and the species *grunniens*. Although yak and cattle (*Bos indicus* and *Bos taurus*) belong to different species, their genetic similarity allows cross breeding, a common practice in some yak rearing areas.

In Bhutan, the term 'yak' is only used for castrated males. Females are called *jem* in western Bhutan, *bre* in central Bhutan, and *di* in eastern Bhutan. The neutral gendered animal is called *lanor* (lit. 'pass cattle'). This term is widely used in official records and communiques. Breeding bulls are known as *sholi* in the west, *tenzo* in central Bhutan, and *phayak* in the east. Yaks in the western part of the country are generally larger than those in the east.

Description of Bhutanese Yaks

Bhutanese yaks are often black with white dorsal and ventral markings and tail switches; black or brown with white patches on the forehead, body, legs, and tail switches; or brown with white dorsal and ventral markings and tail switches.

Male yaks average about 1.25m at the withers (range: 1.15 to 1.35m), while female yaks average 1.1m (range: 1 to 1.25m). The average weight of male yaks in eastern Bhutan is 300-400 kg, while in the west the average is 400-480 kg for fully grown yaks (castrated and breeding bulls). Female yaks weigh an average of 250-300 kg and 300-340 kg in eastern and western Bhutan, respectively.

Breed Characteristics

Bhutanese yaks exhibit several different kinds of breed characteristics. In general, they have long hair, heavy and wide foreheads, and long, narrow and slightly dished faces with curved horns and short ears. The legs of Bhutanese yaks are often short. These strong animals tend to have compact bodies and especially developed forequarters, with 15 thoracic ribs which are long and arched. Withers are high; necks are short and slender with no dewlap. The udders of female yaks tend to be small and covered with hair. Teats measure only about four to six centimetres.

Reproductive Characteristics of Bhutanese Yaks

Oestrous in yaks is seasonal. Female yaks come into heat in late spring and summer. The breeding season usually lasts from June to September. Seasonal oestrus may be due to improved nutritional status during the summer months, or perhaps due to the in-

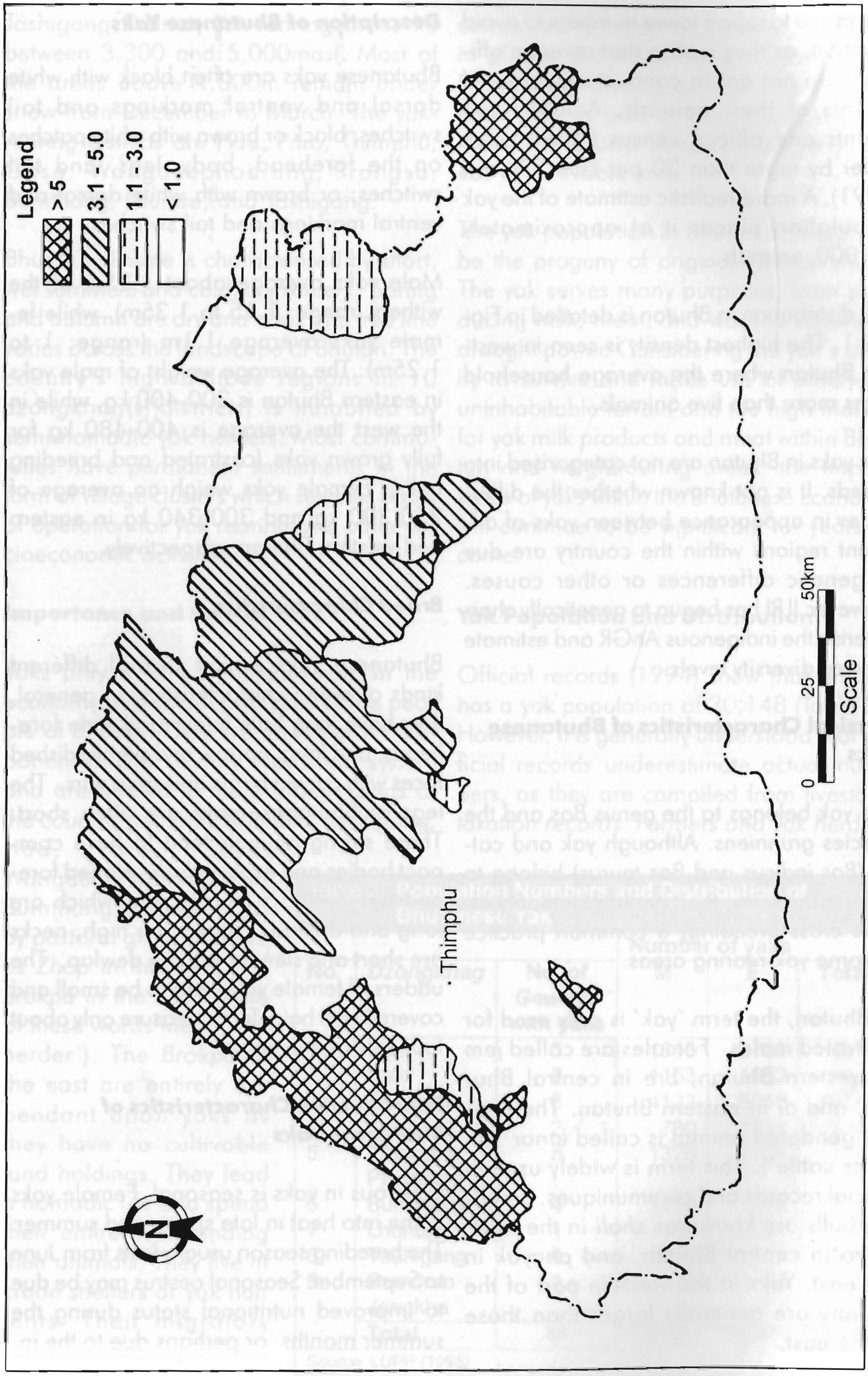


Figure 1: *Distribution and Number of Yaks Per Household (Source: MOA, RGOB 1995)*

creased daylight during this time. The signs of oestrus are not as significant in yaks as they are in ordinary cows. During oestrus, female yaks are usually seen in heat during the cool of the morning and evening or on cloudy days after rain.

Bhutanese yaks reach sexual maturity between three and four years (average 43 months). The average age of first calving is 50 months and the calving interval is 24 months. The oestrus cycle lasts from 17 to 20 days, with an oestrus duration of one day. The yak gestation period is approximately 270 days. Lactation lasts an average of seven to eight months, producing about 200 litres of milk per lactation cycle.

Once yak bulls are between three and four years of age, they begin to sire offspring. Their virility decreases once they reach seven to eight years of age. Actual male-female mating practices depend greatly on a given male's status within the herd. The presence of older and dominant bulls discourages or prevents young bulls from serving.

STATUS OF THE WILD YAK

No documentation is available about the existence of wild yaks in Bhutan.

YAK BREEDING AND CROSS-BREEDING

For several years, the Animal Husbandry Department supported local yak herders by distributing yak bulls procured from places in diverse breeding regions (Haa/Bumthang) with the aim of mitigating the level and effects of inbreeding amongst Bhutan's yak populations; this programme failed in all aspects, however. As the bulls had to be procured at a young age, they often died before reaching maturity. Herders were not selling their best bulls; and given the closure of the international border with Tibet, herders could not procure breeding bulls from Tibet. Inbreeding among yaks remains a central concern.

Ad hoc cross-breeding in the central and eastern regions of the country has led to deterioration in the genetic base of pure yaks in these areas. Determining the genetic make-up of successive generations after the first crosses between yaks and cattle proves difficult.

Three Distinct Breeding Systems Practised in Bhutan

Three distinct breeding systems are practised in Bhutan. First, 'pure line breeding' is practised in the western districts of Haa, Paro, Thimphu, Gasa, and Wangduephodrang. This system is characterised by the breeding of pure yak bulls with pure yak cows. Yak bulls are exchanged between breeding areas to avoid inbreeding.

Second, yak bulls are crossed with *siri* (*Bos indicus*) cows and their hybrids. This system is practised widely in the central region of Bumthang, particularly in Ura and eastern Bhutan. This method requires that yak bulls are crossed and back-crossed. The first filial generations are called *zo* (male) and *zom* (female). Subsequent crosses are called *tui*, *gar*, *chuk*, *zen*, and finally 'yak' (Winter and Tshewang 1989). These names are gender-neutral. The *zo* and *tui* are sterile. In all other cross-breeds mentioned above, fertility is restored from generation to generation.

Third, *goleng* (*Bos taurus*, also known in Tibetan as *glang*) are crossed with female yaks and their hybrids. This cross-breeding activity is very popular in the Merak-Sakten area (Winter and Tshewang 1989) and to a limited extent in Ura and Shinkhar (Bumthang). Female yaks are crossed with *goleng* and the first filial generation from this cross is called a zo (male) and a *zom* (female). The *zom* and subsequent female generations are always crossed with *goleng* bulls. The first back cross, regardless of gender, is called a *koi*. The subsequent females are called *shingolengma, dagolengma, bagolengma*, and *golengma*. The respective males are called *shingoleng, dagoleng, bagoleng*, and *goleng*. Only the herders, themselves with many years of experience, can differentiate between the later back-crosses. The *zom* from this breeding system is highly valued for its superior milk production. These animals are reported to produce up to seven litres of milk from two milkings per day. Milk production from subsequent generations of *koi* and *golengma* is significantly less in quantity; butter fat content also decreases. As in other systems, the zo is infertile, but the *bagoleng* is regarded as reasonably fertile (Winter and Tshewang 1989).

Herders are able to choose the breeding system that best suits their needs according to their knowledge and experience. For example, a herder would not cross a *bagoleng* with a *di* since this causes the death of the *di*. Similarly, they would only use a *bagoleng* bull for crossing with a *zom* or *koi* (Winter and Tshewang 1989). Yak and *siri* hybrid females are not crossed with a *siri* bull, as the pregnant uterus of the *di* develops a large amount of fluid and the cow dies before delivering the calf (Gyamtsho 1996).

From the above descriptions, it appears that *zom* would be an ideal animal for dairy production. However, it is difficult to maintain a stable population of *zom* since the males are infertile.

Existing Breeding and Breed Improvement Programmes

The Government of Bhutan supports yak herders by supplying yak bulls procured from Haa, as these bulls are thought to be of superior stock, to other regions.

Artificial Insemination (AI) using frozen yak semen imported from China was conducted on a trial basis in Bhutan. The main objective of this experiment was to improve the Bhutanese yak by introducing new blood lines and thereby eliminating the adverse effects of inbreeding. The first 16 inseminations produced six calves — five males and one female. Although the phenotypic differences between native Bhutanese yak and these calves were marginal, the AI progenies tended to have more hair growth on the dorsal ridge and tail. Their horns were bigger and longer and they had strong and compact limbs. These new cross-breeds were also noticeably docile.

Further trials using frozen semen from Jersey and Tarentaise cows are currently being conducted. However, since no motorable roads lead to relevant yak herds, and since yaks move to summer grazing pastures at an altitude of 5,000m during the breeding season, the implementation of AI programmes on a large scale would be very difficult.

Opportunities for Improving Yak Breeding and Cross-Breeding

As inbreeding appears to be widespread and artificial insemination is not a practical method for herd improvement, the introduction of new blood lines by the interchange of breeding bulls, both within Bhutan and from countries such as China and Mongolia, remains the only solution for mitigating the levels and effects of inbreeding.

Likewise, herders' preference for pure breeding yaks in most regions of the country must be respected in order to maintain the genetic base of pure yaks. The sustainability of *ad hoc* crossing in some regions needs to be carefully studied.

Selective breeding in China has produced excellent returns in terms of birth weight and growth rate (Lie *et al.* 1994). China's example of gradually improving animal performance presents a viable option for Bhutan. Animals that exhibit potential for the establishment of herd books should be surveyed and registered. Subsequently, herders must be urged and aided to form a "Yak Breeders' Association" that encompasses all the country's yak-rearing areas.

YAK NUTRITION AND HEALTH

The major constraint to improving yak productivity in the alpine areas of Bhutan is the lack of winter fodder (Miller 1987; Harris 1987; Gibson 1991; Johari 1993; Caron 1994; and Gyamtsho 1996). Weakness as a result of malnutrition gives rise to a high mortality rate (Gyamtsho 1996). Gid disease continues to be a major health problem despite action taken by the government to control it.

Traditional Feeding and Veterinary Care Practices

Yaks depend entirely on pasture land to meet their nutritional requirements. Supplementary feed consists of hay, barley straw, wheat straw, wheat flour, buckwheat flour, and the residual grains from alcohol production. Hay and barley straw are fed to draught yaks. Milch yaks and calves are given supplementary hay in winter in the mornings and evenings. Other concentrates (wheat flour, buckwheat flour) are given only to calves going through their first winter or to very weak females in early spring. Rates of supplementary feeding remain very low and are inadequate to meet the nutrient requirements of animals in winter. Salt is given to every animal once in three months at the rate of 300-350g per adult and 150-200g for each yearling.

Opportunities for Improvement

The tradition of hay making already exists in Bhutan; the possibility for expanding hay cultivation through the introduction of high-yielding species and better husbandry practices in winter pasture is promising (Gyamtsho 1996).

Although vaccination against Foot and Mouth Disease (FMD) and Gid control measures are regularly employed, permanent veterinary staff should be stationed in yak-rearing areas to undertake health care programmes on a wider scale.

YAK MANAGEMENT SYSTEMS

Yak herding involves the annual transhumance of herds from lowland winter pastures to alpine rangelands. In summer, yaks move up to alpine pastures at altitudes of about 5,000m where they remain until late September or early October when they began to descend to lower altitudes as winter approaches. In winter, yaks graze in forest areas at altitudes of 2,500m. In the spring, as the climate becomes warmer, yaks move to higher altitudes once again.

Though most herders own grazing rights to one or several pastures (either individually or with other herders), most of the pastures are community- or government-owned. Herders pay a nominal fee to the government on an annual basis for access to grazing land. In some areas, grazing lands are owned by absentee landlords who sub-lease these areas to herders.

Traditional Management Practices

Seasonal Activities

Early spring activities include supplementary feeding programmes for weak and young stock, the supervision of calving, and the subdivision of herds. In summer, milk production and processing and the supervision of mating and hair production activities are carried out. Hay is made in September. Weak animals are given supplementary feed in winter.

Grazing Management

The following factors determine the type of grazing management practised by herders.

- The ownership of grazing areas
- The size and topography of grazing areas
- The vegetation and productivity of grazing areas
- The size and ownership of yak herds

Generally, grazing land consists of summer and winter pastures with small areas devoted to autumn and spring grazing; the latter are mostly located in the country's intermediate zone. Summer pastures are usually located at the top of mountain ridges, while winter pastures are found closer to permanent settlements and in more areas on south-facing slopes at lower elevation. Spring and autumn grazing lands are occupied for relatively short periods while herders are in transit between summer and winter pastures.

When herders own enough independent grazing areas, they use a grazing system that closely resembles rotational grazing management. The areas are in relatively healthy condition compared to those grazed all year round by an entire community.

In most of the yak-rearing areas, larger herds are divided into two or more sub-herds. Herders separate pack yaks and growing males from the main herd of females and young calves. These herders drive pack yaks to the uppermost reaches of ridges for the whole summer, only rounding them up when necessary. The dry females, young bulls, and heifers are herded on marginal pastures away from main camp sites. Milch animals and calves are allotted the best and most accessible pastures.

The daily grazing schedules generally followed in most yak-rearing areas are listed in Table 3.

Table 3: Milking and Grazing Schedule

Time	Daily milking
05.00-07.00	Yaks cows rounded up from night grazing to camp site
07.00-08.30	Milking, calves are released from overnight tethering or shelter.
08.30-17.30	Yak cows & calves released and allowed to graze together freely.
17.30-19.00	Yak calves rounded up for penning & tethering
20.00-05.00	Yak cows left to graze freely overnight.

Source: Gyamtsho 1996

Management of Individual Animals

Calf Rearing

Immediately after parturition, calves are encouraged to suckle and feed on the colostrum. No milking is carried out for several days to enable calves to mature well. Later, calves are allowed to suckle for a few minutes before milking to encourage milk flow and again after milking to drink the remains. Weaning takes place from six to 12 months, depending on the reproductive status of the dams. A locally-made nose ring is used to obstruct suckling when weaning calves persist.

Breeding Bull Selection and Management

Breeding bulls are selected from within the herd's growing male stock or purchased from other herds according to the following selection criteria.

Body Size: The breeding bull should be bigger than other bulls of the same age.

Body Confirmation: The breeding bull should have a proportionate body and not possess any deformities.

Colour: Black bulls with a white tail and a white spot on the face are preferred.

Horns: The bull's horns should be large and symmetric as they are highly correlated to fighting ability.

Temperament: The bull should be dominating and aggressive in order to be able to fend off challengers.

Castration of Males

Young males other than breeding bulls are castrated. This procedure is carried out when the bulls are about three to four years of age.

Harvesting Down and Coarse Hair

Yak hair is shorn in early summer. In the case of male yaks, the upper section of the breast is clear cut, while only the inside portion on the lower flank is cut. The tail is trimmed. Down, which comes off easily at that time, is pulled out by hand. Female yaks are clean shorn except for their leg hairs.

Opportunities for Improvement

The present herding system is dictated by land ownership and grazing rights. Grazing lands were registered in an *ad hoc* manner based on visual estimations. A cadastral survey of Bhutan's pastures should be carried out. Traditional herding systems are breaking down under increased pressure from new herders bartering for their share of limited resources. Traditional herders have little control over these changes, particularly when new herders are related to traditional herding families.

Any change in yak-rearing systems, however, must begin with systematic surveys which determine the exact locations of grazing lands and include a review of land ownership. Once information on area and ownership is established, institutions must be built into community organisations to oversee the proper use and maintenance of grazing lands. User group associations (UGA) should be formed to oversee timing and duration of grazing, management, and maintenance of pastures and control of stock numbers on different rangelands.

PRODUCTION, PROCESSING, AND MARKETING OF YAK PRODUCTS

The major constraints faced by yak herders is the time span required for marketing yak products.

Traditional Yak Product Production, Processing and Marketing

Milk Products

The primary milk products are butter and cheese. These products are sold or bartered for food grains. In larger herds, yak milk is churned every day using a wooden churner called a *shom*. In smaller herds, milk from successive milkings is accumulated in the churner until a sufficient quantity is collected for churning. The butter is collected and then pressed into a hard circular cake to remove liquid. It is then packed into skin and wooden containers for storage. In some places, butter is wrapped in broad, hard leaves. Well-prepared butter can be stored for long periods without turning rancid.

Buttermilk is poured into a large pan where it is slowly heated and stirred continuously until cheese is formed. The cheese is collected and pressed between two large, flat stones covered with a muslin cloth to remove fluid. The cheese is either used fresh or processed further into hard cheese for marketing.

Two types of dried cheese, *chuto* and *hapiruto*, are made, depending on the market for which they are intended. *Chuto* is made by slicing the circular cheese into small pieces and hanging them in strings of twenty pieces. After boiling them in milk, the strings are hung on a pole in the tent and allowed to dry until they become hard. *Hapiruto* is made in larger pieces and dried on 20-piece strings until it is rock hard. Whey is consumed by yak herders or fed to calves. The average annual production from a female yak is 25 kg of butter and 30 kg of cheese (Win 1992).

Meat Products

Yak meat is considered a delicacy and eaten as *masha* (red meat) by preserving a piece of leg wrapped in cloth, as dried meat, or as fresh meat cooked in curries. Yak meat is the most expensive kind of meat available in Bhutan. A yak sold for meat purposes costs Nu* 6,000-7,000, depending on size.

Yak Hide

The fresh skin of a yak is stretched on smooth, dry ground by fastening the ends into the ground with wooden pegs. When dried, the hide is processed into floor mats, leather (used for making bags for storing and transporting grain, shoes, and saddle straps), glue, and hide meat.

Yak Hair Products

The hair from the yak is a valuable item and essential for the daily life of herder households. The long hair is washed, dried, and spun into thick yarn which is used for weaving tents, bags, rags, slings, and ropes. Yak wool products are waterproof and very durable. The yarn is often dyed red, particularly when it is used for making rugs and bags. The soft hair is used for making garments and blankets.

Opportunities for Improvement

The great demand for yak meat suggests that there are opportunities to expand the yak meat production market. Improvement of butter- and cheese-making to increase the products' shelf lives as well as their marketability would greatly improve the earnings and nutrition of yak herders. The development of yak hair and leather products is also promising in terms of further economic benefits.

* There are 35.50 *Nu* to one $ U.S.

CHANGING ECONOMIC AND DEVELOPMENT FORCES: IMPLICATIONS FOR YAKS

Changes in Yak Production and Management

No major changes have taken place in yak production and management strategies in Bhutan's yak-rearing areas. Yak herders still follow age-old traditions handed down to them by their forefathers.

Impact of Tourism on Yak Production

Tourism in Bhutan started in the late 1970s and trekking operations commenced in the 1980s. Due to the government's conservative tourism policy and high tariff charges, the government has been able to keep the number of trekkers and tourists within manageable limits. The impact of tourism on yak production has been very minimal.

PRIORITIES FOR FUTURE ACTION

Research Programmes on Yaks

The following is a list of suggestions for future yak-related research projects.

- Carry out rangeland improvement and management initiatives to increase the productivity of alpine pastures.
- Improve genetic diversity and selection characteristics in local yak populations.
- Physiological and management factors influencing the reproductive performance of female yaks and breeding bulls should be studied.
- The production characteristics of yaks i.e., growth rate, body weight, milk yield and milk composition, meat yield and composition, fibre production, and draught performance should be studied.
- The economics of yak-rearing under traditional and improved management systems should be investigated.
- Studies of dairy production and processing techniques should be implemented.
- Studies of yak diseases should be carried out.

Development Programmes

The following is a list of possible yak-related development programmes.

- Interchange of yak bulls within Bhutan and from other countries
- Introducing rangeland management practices to help provide adequate fodder
- Creating marketing outlets for yak herders
- Introducing better health programmes

CONCLUSIONS

The multipurpose yak is the primary means of livelihood for inhabitants of Bhutan's high altitude areas where harsh environmental conditions limit crop production and other means of livelihood. Yak rearing will continue to be important, though it is not expected to grow significantly since yaks have to compete with protected wild herbivores like blue sheep and *takin* for already scarce grazing resources.

Feed shortages and decline in the quality of yak-breeding stock are the main obstacles hindering the development of sustainable yak production. The effects of widespread inbreeding also negatively impact yak production. Thus, yak populations need to be controlled according to available feed resources. Breeding programmes must be strengthened and the productivity of yaks should be improved to promote sustainable yak production in Bhutan.

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The Situation of Yaks in China

Guo Shijian and Chen Weisheng

INTRODUCTION

Tibetans, or the people of *Zang*, inhabit a region synonymous with native yak distribution areas. The yak is inextricably linked to the lifestyle, culture, and religion of Tibet. This animal is a fundamental element in the means of production in harsh areas like the Tibetan Plateau and is indispensable to Tibetan subsistence. Meat and milk produced by yaks are dietary staples for the Tibetans. Yak hair can be used for weaving tents, clothes, and other necessities. Yaks also provide Tibetans with transportation. Grazing patterns dictate the seasonal migration of entire communities. Even the yak manure is vital to Tibetan survival, as dung is burned for fuel throughout the pastoral areas of Tibet.

China's yaks are distributed mainly on the Qinghai-Tibet Plateau and in the immediately surrounding areas, from the Pamir Mountains in the west to the Minshan Mountains in the east, and from the southern slopes of the Himalayas to the Altai Mountains in the north. Yaks roam across an area which covers 2.7 million sq. km. of alpine and plateau environments at attitudes ranging from 2,000 to 4,500 metres. Alpine and semi-alpine meadows form the main body of grassland in this cold, semi-humid area. In 1995, it was estimated that there were about 14.5 million yaks in Chinese territories (including yak-cattle hybrids) and about 1.3 million head of yak produced annually for commercial purposes.

CHINA'S WILD YAK

China's wild yak are found throughout the upper reaches of the Yarlung Zangbo River, an area of approximately 1.4 million sq. km. surrounded by the Kunlun, Altun, and Qilian mountains, at a minimum altitude of 4,000 metres. The wild yak's natural habitat is harsh: the annual average temperature is -8°C; the growth of plentiful grasses lasts only 100 days of the year. In such rugged conditions, wild yaks must roam for food constantly. In winter, the wild yak has no fixed habitat, but wanders in search of fodder across a given range (usually 200-300 sq. km.). According to the 'Law for Protection of Wild Animals' issued by the Chinese Government, the protection and conservation of wild yaks are a top conservation priority. The number of wild yaks has been increasing in some areas; it is estimated that there are 40,000 head of wild yak in China at present.

YAK BREEDING AND CROSS-BREEDING PRACTICES

Although the yak is indispensable across the Qinghai-Tibet Plateau and neighbouring regions, this animal is a unique bovine with relatively low productivity. As a result, herdsmen have been adopting various means of improving yak productivity for years. Most significantly, herdsmen have developed methods of cross-breeding yaks and cattle to produce hybrids (*pienniu*). This practice is about three thousand years old in China. In the past few decades, several breeds of cattle with large bodies and high productivity have been introduced into China's yak population. These animals make excellent cross-breeding combinations with domestic yaks. Holstein-Friesian dairy cows, Hereford beef cattle, and Simmental dual-purpose cattle, when mated with female yaks, also produce exceptionally productive offspring. These crosses grow rapidly, and their weight is significantly heavier than yaks at parallel stages of development.

The meat and milk outputs of yak/cow hybrids are 40-70 per cent and 150-400 per cent higher than pure-bred yaks, respectively. Cross-breeds are also highly resistant to disease and can adapt well to diverse, harsh environments. As the number of cross-breeds continues to rise, the overall benefit to yak raisers also increases, partially due to the heterosis concentrated within the F1 generation.

The productivity and viability of F2 generations, however, are very poor: male animals produced by cross-breeds experience cross sterility; the new F1 generation is unable to withstand the harsh conditions over 3,000 metres. Therefore, interspecific crossing among species is obliged to be limited within a certain range of herds. Experts suggest using 25 per cent female adult yaks and crossing them with cattle to produce *pienniu*. The Fl generation should be primarily used for milk production; meat production should be concentrated within the F2 generation.

Improving yak productivity through the control and selection of mates (type selection, crossing among types, etc) is a method that has also been adopted in China. The effects of this method are not obvious. Presently, pure-breeding selection and mating is simply made according to an individual's phenotype; a nucleus herd is then formed and some herds enjoy high productivity. However, the results of such selection compared to a herd of yaks that breed naturally and have lived in relatively good conditions for some time are negligible.

As mentioned above, crossing wild yaks with domestic yaks can improve yak productivity. Wild yaks are used to living in cold areas at altitudes over 4,700 metres. These animals have strong constitutions and can live through much difficulty. Under the same feeding and treatment conditions, the birth weights, live weights at six months, and live weights at one year of wild/domestic hybrids increase by 30.77, 40, and 47 per cent, respectively, compared to those of domestic yaks. The production levels of offspring who are one-quarter 'wild' also increase. Their birth weights, live weights at six months, and live weights at one year rise by 18.6, 21, and 21.82 per cent, respectively. Moreover, the conception and reproductivity rates of hybrids produced by artificial insemination reach 99.4 and 80.4 per cent, respectively. These results indicate that crossing wild yaks with domestic yaks can improve growth rates, viability, and reproduction significantly.

FODDER AND PASTURE MANAGEMENT ISSUES

Both pure-bred yaks and hybrids have adapted to the grassland ecology of areas like the Tibetan Plateau. Yaks thrive on plentiful, free range grasses, becoming heavier in the summer and autumn and increasing in strength during lactation. Presently, certain areas of China's grasslands are being improperly utilised. Grassland improvement programmes have made slow progress thus far. In order to improve upon the productivity of a given yak population, supplementary feeding programmes and herd management programmes should be adopted.

Priority should be given to the implementation of the 'Law of [the] Grasslands', a statute which gives long-term land use rights to herdsmen so that they will invest in protecting and conserving this valuable resource. In winter, the grassland should be well treated to enable summer grasses to thrive. Artificial pastures, where grass can be cut seasonally and used for supplementary fodder, should also be established. Seasonal animal production and the adjustment of duration and locations of grazing should be followed to help maintain and improve China's grasslands.

Establishing artificial pastures in alpine grasslands located near cultivated fields requires special attention. Inadequate heat can hinder growth, particularly during winter when the hours of sunlight per day wane and shadows grow longer. In addition, once original vegetation is damaged, it has difficulty recovering. Consequently, artificial pastures should be established in areas in which annual precipitation exceeds 350 mm, the annual accumulated temperature exceeds 1,000°C (i.e., at least 5°C per day), and the soil is at least 40 cm thick. A suitable variety of grass should also be selected and the areas should be monitored according to scientific management methods.

In order to improve the quality and productivity of yaks, the rearing of calves should take more precedence than in current practice. In pastoral areas, herdsmen wean their calves at a young age; this practice seriously affects growth rates. Calves are kept hungry and the excess milk is collected and used for human consumption. According to one source, if a male calf is given enough milk to drink, the animal's live weight can exceed 117 kg at six months. The calf is large enough to be slaughtered at that time. Herdsmen can reap twice the economic benefits by selling calves for meat at six months rather than by milking cows while offspring are still nursing. This shift from milk to meat production would also help mitigate the pressure placed on grasslands in winter and increase the number of females per herd. However, considering that yak milk is one of the primary foods of pastoral people, some compromise between these two systems should be reached.

Many reports about yak productivity and calf development maintain that calves can gain 360-400 grammes of body weight per day by maintaining a medium growth rate. Their body weights should reach 76-80 kg at six months. Reproduction rates level off at 75 per cent. Likewise, 75-100 kg of milk can be produced during a 150-170-day lactation cycle if females are milked once a day. Practical benefits can be achieved from such a system, aiding development of sustainable and healthy yak industries.

The structure of yak herds should also be adjusted to improve productivity. As some reports indicate, the best herd structure includes 43 per cent adult females, 18 per cent heifers, 23 per cent calves, and 16 per cent bulls and steers in meadows situated at over 3,500 metres. A series of measures should be applied to achieve this advantageous herd structure. Outstanding bulls should be selected; the number of bulls in a given herd should be restricted; the use of yaks as draught animals should be limited; and bulls should be taken to market every two years.

PROCESSING AND MARKETING YAK PRODUCTS

Many of the herdsmen engaged in yak production rely on outmoded methods of animal husbandry. Their closed economic system does not encourage innovation. Herdsmen raise yaks to meet their family's needs. As yaks are also a symbol of status and wealth, the quantity of yaks is often considered more important than the quality of individual animals. These nomadic and semi-nomadic families settle for a lower quality of life (i.e., less productive livestock) in exchange for larger herds.

With the introduction of a market economy in China and the subsequent rise in consumerism, however, the economy of pastoral communities is also changing. Yet the commercial production of yak products remains low: 40 per cent of slaughtered yaks, 60 per cent of milk and milk products, and 80 per cent of wool and underwool are used by herdsmen and their families; surpluses are rarely sold in the market and most yak products that are sold are not processed.

Changes in the structure of local economies should encourage economic growth. A strategy for gradually increasing the value of yak products has been introduced; processing methods for special products (such as beef, butter, cheese, whey juice, and whey powder) are also being introduced. Blood powder and high quality chemical products can also be made from yak blood. Once carded and cleaned, wool and underwool can be used to make sweaters and other clothes. All of these activities aim to generate local income on an incremental basis. Only when strategic measures are employed to combine production, processing, and marketing — keeping the needs of local communities and the realities of local economies in mind — will the standard of living of China's herdsmen be improved.

RECOMMENDATIONS FOR PROMOTING YAK PRODUCTION

- Establish a yak AI station for AI technology extension. Benefits can be increased by using wild yaks and outstanding cattle to cross with domestic yaks.
- Set up a yak production pilot area in alpine grasslands.
- Breed new yak species and improve the growth rate of yaks.
- Develop yak meat production and produce 'green' (non-polluted) food.
- Continue to develop yak-related resources. One example of such an activity is the China National Commission for Animal Genetic Resources. Founded this year, the Commission will be implementing policies and programmes on Chinese domestic animal breeding, as well as other development programmes.
- Improve the education of technicians and local people in pastoral areas about yak production. Give more attention to herdsmen; provide them with practical, technical improvements. Ranchers with particularly large herds should be targeted in this education campaign. Only when herdsmen become increasingly well-educated can opportunities for yak production increase.

Yak Production in India

Rathindra Narayan Pal and Moti Lal Madan

BACKGROUND

Importance and Role of Yaks in India

Yaks are said to have been domesticated about 4,500 years ago in China. Since then, yaks have become vital components of pastoral lifestyles from Central Asia to India's high Himalayan regions. Yaks are first mentioned in Indian literature in the works of Kalidasa, the legendary fourth century Sanskrit scholar. He eulogised yaks as *Kamara*, animals who move in a rhythmic style in the pine forests of the hills.

Yaks inhabit over 3,000 km of Himalayan rangelands, stretching from the bend of the Brahmaputra river in the east to the bend of the Indus river in the west. The entire length of this yak habitat is divided into four physiographic zones: the Eastern Himalayas, the Central (Nepal) Himalayas, the Western or Kumaon-Garhwal Himalayas, and the North West or Kashmir and Punjab Himalayas. This habitat confluences with the Hindu Kush, Trans-Karakoram, Tien Shan, Kunlun Shan, and the Trans Altai mountains in the northwest—an area known as the 'Pamir Knot'. The Tibetan Plateau lies to the northeast of the Pamir Knot. Incidentally, the Tibetan Plateau and the Kunlun Shan, Tien Shan, and Altai regions harbour more than 94 per cent of the world's yak population.

The Indian Himalayas have been divided into three parallel zones: the outer Himalayas (900-1,000m), the middle Himalayas (4,000-5,000m), and the inner Himalayas (average: 6,100m). Great numbers of yaks live in the mid-Himalayan zone. The eastern Himalayan zone is characterised by a wet, temperate climate, whereas the western Himalayan zone is dry, arid, and cold.

The vegetation below the tree line varies in composition throughout the Himalayas, though many species of flora are common to all regions. The major tree species in the Himalayas are *Acer* sp, *Juglans* sp, *Rhododendron* sp, *Quercus* sp, *Betula* sp, *Magnolia* sp, *Michela* sp, *Arundinaria* and other bamboo species, *Lithocarpus* sp, *Prunus nepalensis*, *Abies densa*, and *Tsuga dumosa*. Beyond the tree line, climatic pockets are characterised as moorlands. *Rheum, Arenaria, Urtica hyperforea, Festuca, Dreuzia, Anthistiria, Hierochloa, Stipa, Agrostis, Calamoegrostis, Avna, Danthonia, Tripogon, Poa, Glyceria, Miscanthus, Cryzosis, Phleum, Agropyron*, and *Cata brosa* are all found in these areas, as well as other species of flora not yet identified.

Agricultural production in the Himalayas above 2,500m is very limited due to area, climate, and altitude; yet sizeable populations of Tibeto-Mongolian peoples live in these areas. These highlanders grow millet, rye, and mustard during the short crop season (120-180 days). Yields are not adequate to sustain these communities throughout the year; they must rely on a combination of agriculture, animal husbandry, and trade to meet their basic needs.

Yaks and sheep are the most common animals raised in the mid-high Himalayas. Other species of animals, such as the *Pashmina* goat and the double hump camel (*Bactrian* sp), are also raised in limited numbers in Ladakh. The herders of Arunachal Pradesh and Sikkim do not like to rear sheep with yaks. Sheep herders move all year round, travelling down from the high hills to foothills in the winter and then back up to high altitudes in the summer. Yak herders, on the other hand, restrict their movements to pastures between 3,000 and 5,500m. In the winter, yaks graze around villages at about 3,000m. Though snowfall is frequent in these areas, it is usually not heavy enough to cover grasses for long.

Yaks provide India's highlanders with milk, meat, wool (undercoat), and coarse hair. The income earned from yak husbandry, though not spectacular, is sufficient to provide poor herders with a simple living. Wealthier herders might own a great number of yaks and entrust them to an outsider or a less fortunate villager to rear. Yaks reared through this tenant system generate additional income for the owner. This tenant system also distributes wealth within a given community, providing poorer families with access to vital yak products (meat, milk, cheese, etc), but allowing wealthier community members to maintain large yak herds while simultaneously engaging in other business ventures.

Yak-raising Areas

The yak-rearing states in India are Arunachal Pradesh, Sikkim, and the high hills of Uttar Pradesh, Jammu, Kashmir, and Himachal Pradesh (Figure 1). Arunachal Pradesh, India's eastern-most yak-rearing area, shares international borders with China to the north and Bhutan to the west. Although the region is vast, covering 83,743 sq. km., yaks are only found in a small portion of the West Kameng and Tawang districts (Table 1). Incidentally, these are the two districts which are inhabited by the *Monpa*, a Tibeto-Mongolian Buddhist tribe.

Table 1: Distribution of Yak and Yak Crosses in Arunachal Pradesh

District	Pockets	Pure Yaks			Crossbreed (*Dzo* & *Dzomo*)		
		Male	Female	Total	Male	Female	Total
West Kameng	Sange Mandalaphudung Chander Lubrang Nyukamadung Lagam	580	799	1379			
Tawang	Mukto Jung Mago Thimbo Luguthang Zimithang Lumla	2645	4205	6853			
Upper Subansiri	Taliha Mechuka	117	131	248			
		3345	5135	8480	2448	3833	6281

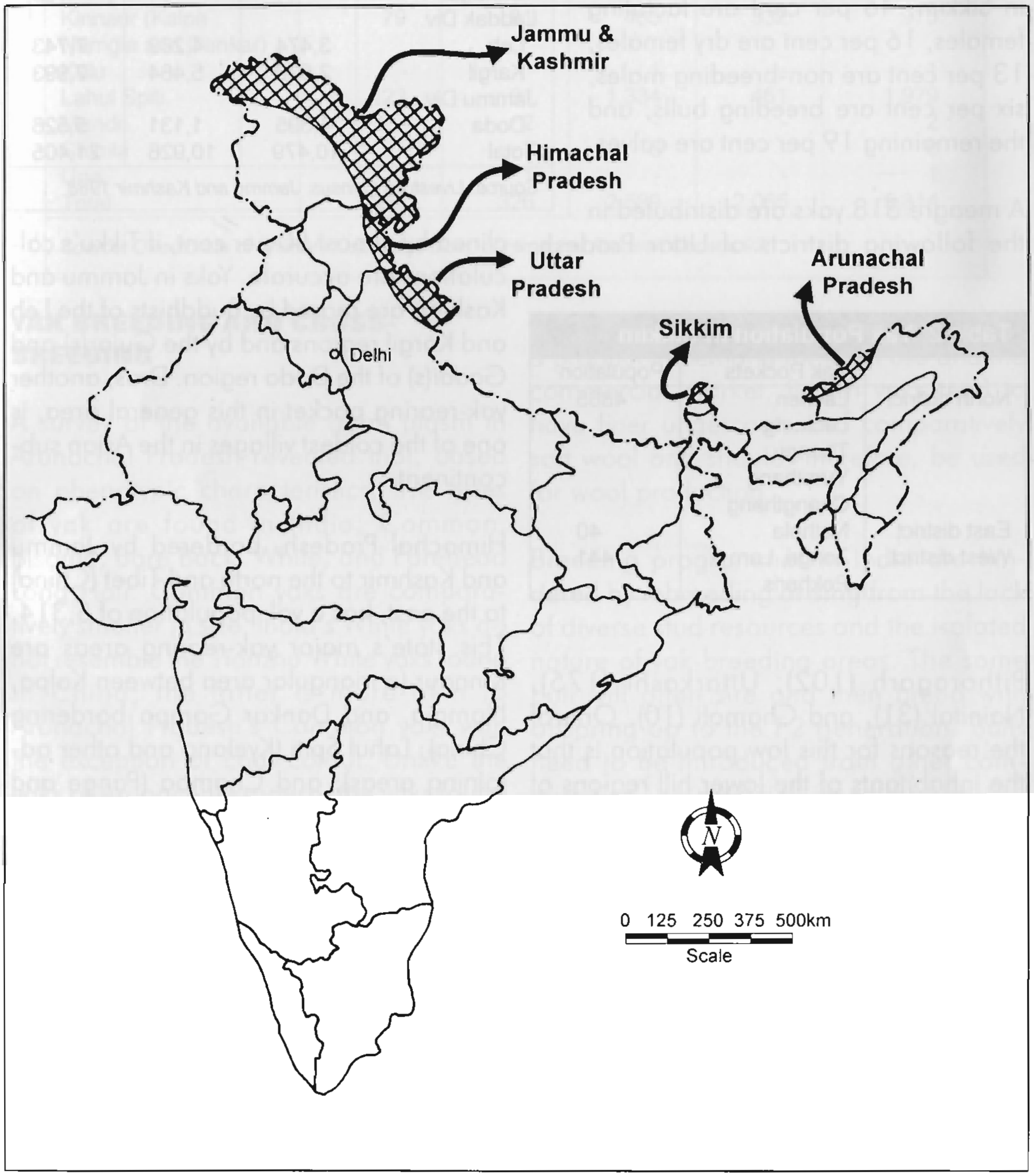

Figure 1: *Indian States Rearing Yaks*

Sikkim, a small northeastern Indian state sandwiched between Nepal to the west and Bhutan to the east, has yaks in its northern, eastern, and western districts (Table 2). Of all the yaks in Sikkim, 46 per cent are lactating females, 16 per cent are dry females, 13 per cent are non-breeding males, six per cent are breeding bulls, and the remaining 19 per cent are calves.

A meagre 318 yaks are distributed in the following districts of Uttar Pradesh:

Table 2: Yak Population in Sikkim

	Yak Pockets	Population
North district	Lachen Lachung Thongu Yumthang Changthang	4865
East district	Nathula	40
West district	Zongri, Lam Pokharis	441

Pithoragarh (102), Uttarkashi (175), Nainital (31), and Chamoli (10). One of the reasons for this low population is that the inhabitants of the lower hill regions of this state are ethnic Hindus who do not know about — or care to know about— yak husbandry techniques, as this animal does not fit into their social structure. Otherwise, the highlanders of Uttar Pradesh are as willing as other highland populations to accept the hardships a life of yak-rearing implies.

Jammu and Kashmir, the 'crown' of India, is home to the greatest number of yaks. Approximately 21,405 head are found in these areas. Details of distribution and sex are listed in Table 3. According to Tikku (1967), yak populations in these areas totalled 44, 292 at the end of the 1960s. Within two decades, the population declined by almost 50 per cent, if Tikku's calculations are accurate. Yaks in Jammu and Kashmir are reared by Buddhists of the Leh and Kargil regions and by the *Gujar*(s) and *Gaddi*(s) of the Doda region. Dras, another yak-rearing pocket in this general area, is one of the coldest villages in the Asian subcontinent.

Table 3: Yak Populations in Jammu and Kashmir

Districts	Male	Female	Total
Kashmir Div			
Baramula	4	1	5
Srinagar	44	61	138
Laddak Div.			
Leh	3,474	4,269	7,743
Kargil	2,529	5,464	7,993
Jammu Div.			
Doda	4,395	1,131	5,526
Total	10,479	10,926	21,405

Source: Livestock Census, Jammu and Kashmir 1988

Himachal Pradesh, bordered by Jammu and Kashmir to the north and Tibet (China) to the east, has a yak population of 5,314. This state's major yak-rearing areas are Kinnaur (a triangular area between Kalpa, Namgia, and Dankar Gompa bordering China); Lahul Spiti (Kyelang and other adjoining areas); and Chamba (Pange and adjoining areas contiguous with Doda in Jammu and Kashmir). The yak habitats of Pangi, Lahul Spiti, and Kinnaur are the most prominent, though a few other yak populations are found in the Pir Panjab range. These two regions run parallel to each other from north to south. Population and distribution statistics are presented in Table 4.

STATUS OF THE WILD YAK

No reports of the wild yak (*Poephagus mutus* L) have been received from the domestic yak-rearing areas of India. Some of India's highlanders were amazed to look at a picture of wild yaks taken in China.

Table 4: Distribution of the Yak Population in Himachal Pradesh					
Districts	Up to 3 years		Above 3 years		Total
	Male	Female	Male	Female	
Bilaspur		3	-	-	3
Chamba (Pangi)	132	178	783	1,272	2,365
Bilaspur	-	3	-	-	3
Kinnaur (Kalpa Namgia and Dankar)	79	81	465	332	975
Kulu		-	1	-	1
Lahul Spiti	123	61	1,334	461	1,979
Mandi	-	2	-	-	2
Shimla	-	-	6	-	6
Una	-	1	-	-	1
Total	334	326	2,589	2,065	5,314

Source: Directorate of Animal Husbandry, Govt. of Himachal Pradesh Census 92.

YAK BREEDING AND CROSS-BREEDING

A survey of the available germ plasm in Arunachal Pradesh revealed that, based on phenotypic characteristics, five types of yak are found in India: Common, Bisonia, Bare Back, White, and Forehead Long Hair. Common yaks are comparatively smaller in size. India's White yaks do not resemble the Tianzhu White yaks found in China; the latter is more akin to Arunachal Pradesh's Common yak, with the exception of coat colour. Unlike the yaks of Arunachal Pradesh, the yaks found in Sikkim have been categorised into two groups: *Bho*, or 'large' varieties and *Aho* meaning 'small'. The *Aho* are similar to the Bisonia and Common yak.

Issues

Yak breeding and cross-breeding programmes should aim to produce animals with high milk yields, quality meat, draught power strength, and high wool productivity. All four of these traits are of major importance to yak herdsman. In India specifically, Common yaks are most suitable for milk production, while Bare Back varieties should be raised for meat and Bisonian yaks should fulfill draught needs. Young calves yield the most fine undercoat wool, a product in demand for local use and the commercial market. Brown yaks tend to have finer undercoats and comparatively soft wool and should, therefore, be used for wool production.

Breeding programmes in India are hindered by inbreeding arising from the lack of diverse stud resources and the isolated nature of yak-breeding areas. The same bull will often sire and then breed with offspring up to the F2 generation. Bulls need to be introduced from other communities, or artificial insemination (AI) techniques should be employed to quell inbreeding.

Traditional Breeding Strategies

Cross-breeding of domestic yaks and cattle has been practised for centuries. The male hybrids (*dzo*) produced from this cross are sterile but are very productive draught animals. Female hybrids' (*dzomo*) milk yields greatly exceed those of pure-bred female yaks. Despite these advantages, dzo(s) and *dzomo*(s) are unable to thrive at extremely high altitudes and are more susceptible to cold weather than pure-bred yaks. Since the F1 males are infertile, back-crossing is not possible.

Traditional breeding strategies among the highlanders of India are haphazard. Herders breed *dzomo*(s) with local cattle to produce new types of hybrids which are mostly small in size and less productive than their parents. Yak raisers should be advised not to breed F1 females with cattle, but rather to back-cross *dzomo*(s) with yaks to increase productivity.

Presently, there are no breed improvement projects in India's yak-rearing areas. Although the National Research Centre on Yak (NRC) has obtained frozen wild yak semen from Lanzhou, PR China, this resource is only being used for AI on yak farms. Improved males obtained from the farm will be made available to farmers for breeding purposes in the future.

Opportunities for Improving Yak Breeding and Cross-breeding

Although efforts to improve yaks and yak cross-breeds should have begun some time ago, such opportunities do exist today. Breeding policies should be organised according to traits. Breeding should also be geared towards market demands, be those demands for pack animals for tourism or for beef animals bred for slaughter. In areas where alpine pastures are abundant, yaks should be bred for milk production. Cross-breeding should be confined to F1 generations; this will improve herd quality and decrease pressures on pasture land. Well-bred yaks should meet their owners' subsistence needs and also provide herders with surplus products they can sell for profit.

YAK NUTRITION AND HEALTH

Issues

Optimum production can only be reached in any husbandry system if nutrition and health care are sound. Yak husbandry in India and other yak-raising areas must be cognizant of these issues and strive to improve health and nutrition standards. Much research remains to be done on yak health and nutrition as well.

Traditional Feeding and Veterinary Care Practices

Traditionally, pastoralists feed their yaks by taking them to alpine pastures. From May to October, yaks graze on high altitude grasslands, shifting to lower altitude pastures in the winter. No feed supplements are given to yaks, with the exception of salt. Sometimes herdsmen save dry leaves and grasses and use these as supplementary fodder in winter; though such efforts help slightly, the fodder gathered and dried in this manner is not sufficient to stop seasonal weight losses.

Existing Nutrition-Related Improvement and Health Care Programmes

According to traditional feeding systems, yaks spend the summer and fall regaining weight lost the previous winter. Without this winter weight loss, growth and production levels would not be interrupted. Supplementary feeding, if carried out in sufficient quantities, can help achieve this goal, as testified by yak production centres in China and information supplied by India's National Research Centre on Yak. A pilot trail to conserve green maize by making silage and conserving summer grasses has proved useful. Though yaks initially refused to eat these supplements, they accepted this fodder within a two-week period. As maize is a major agricultural product in India's hills, sufficient quantities of maize residue are available and can be supplied to yak herders as supplementary fodder.

Feed concentrates, on the other hand, are often expensive to produce and transport to yak-rearing areas. Primary emphasis should be placed on conserving, cultivating, and preserving natural grass for winter feeding. Mineral and salt supplements should also be administered. Between nine and ten thousand feet, fodder tree species, such as, *salix,* also grow well. Farmers should be encouraged to plant these trees for fodder and alternate income generation.

Due to the inaccessibility of most yak-rearing areas, administering prophylactics and other routine health care measures have proven difficult, particularly in emergencies. However, establishing such health care routines is essential for maintaining animal health and improving productivity. One such measure adopted in a particular village by a scientist at the National Research Centre on Yak has produced encouraging results on monitoring calf mortality.

Opportunities for Improvement

Another option for the improvement of health and nutrition issues in yak-herding areas would be for the State Veterinary Department and the NRC-Yak to hire and train extension workers, who will then be stationed in key pastoral communities. These workers should be skilled in dealing with emergency measures and could serve as a link between herding communities and urban centres.

YAK MANAGEMENT SYSTEMS

Issues

Traditional yak management systems have been practised and refined for centuries. Although pastoralists throughout the Himalayas and the Tibetan Plateau possess great knowledge about yak management, their indigenous systems can be improved. Innovative measures can be introduced without drastically altering traditional methods. Yak herders in India tend to be conservative about altering their management systems; local socioeconomic realities must be understood and acknowledged if alterations in these systems are to occur with community consent. For example, traditional breeding systems tend to produce unproductive calves; local methods are not economical but rather historically accepted.

Yaks are traditionally kept outside, even in the winter. Although this system works most of the time, yak health could be improved if these animals were given shelter in extreme weather. The tenant system of yak rearing also adversely affects husbandry practices. Fights over grasslands also occur within and among neighbouring pastoral communities. These are just some examples of management practices which could be improved upon.

Traditional Management Practices

Yak management systems are essentially transhumant; these animals spend their lives moving from one pasture to another depending on season. Yaks are driven to high altitude pastures in the summer; herders sometimes pay small fees for access to this land. With the onset of winter, yaks are brought back down to pastures closer to villages at altitudes of about 3,000 m.

Designated yak shepherds exist within a given community. These people not only herd their own yaks, but also watch yaks belonging to other villagers, particularly affluent ones. A yak herdsman may herd 50 to 100 yaks at one time. Although the shepherds are paid (often in kind) for their work, most of the profit generated from this tenant system of management is relayed back to the actual owners.

Existing Programmes to Improve Management Practices

Many of India's high altitude pastures are denuded because of improper use over many years. Regenerating denuded pastures poses the biggest problem for yak husbandry. Pastures should be weeded and new, nutritious grasses should be introduced to these areas to increase productivity. The National Research Centre on Yak has classified 53 varieties of grass for pasture regeneration. However, only *Dactylis glomerata* has been introduced successfully.

Traditional management systems condone irrational herd structures. Yak herdsmen do not follow any set procedure for male to female ratios; replacement of stock is also not standardised. Yet these are two primary factors determining herd economy.

Opportunities for Improvement

Presently, the Indian Government has not introduced any management improvement programmes in yak-rearing areas. The NRC-Yak is attempting to improve management, though resources are limited.

Although yak herders are basically conservative, they are receptive to ideas that may revitalize their economy by improving yak husbandry. Improving feeding methods, veterinary care, natural pasture land, and herd structure are all possible.

PRODUCTION, PROCESSING AND MARKETING OF YAK PRODUCTS

Issues

Yak Product Production, Processing, and Marketing

Milk products, primarily *churpi* (hard, dried cheese) and butter, predominate among the herders of the Indian highlands. Yaks are milked once a day in the morning, often under unhygienic conditions. The pan in which milk is collected is rarely washed; collected milk is stored in a cylindrical churner in which it is made into butter. The residual whey is then processed into *churpi*; this cheese is kept in untanned bags. As such, these products have no market value outside herding communities.

In order to optimise the yak's production potential, many factors must be considered. Female yak lactation periods range from 120 to 300 days. If this level could be standardised at 300 days, as it is with cattle, milk and dairy production levels would greatly improve. Similarly, yaks usually calve once every two years. Under hospitable conditions, however, they calve each year. If feeding and management practices were improved to encourage annual calving, yak productivity would increase. The introduction of trace elements into yak diets could also improve yak production.

Traditional processing of yak products such as milk, meat, skin, hair and wool, and meat should be improved upon. Currently, the substandard items produced locally do not have any market value and are traded between villagers according to barter and exchange systems. Until production methods for products such as butter and cheese are standardised and improved, it is not possible to market these products. However, great potential exists for such improvements. In Sikkim, for instance, herders have begun to market small cubes of hard cheese.

Existing Programmes to Improve Production, Processing, and Marketing

There are no programmes for the improvement of yak products, processing, and marketing in the highland communities of India.

Opportunities for Improvement

A vast opportunity to commercialise yak products exists in India, provided that proper technology is developed and made available to yak herdsmen. The simple introduction of cream separators with slight modifications will yield better cream and butter than traditional methods. Cheese and *paneer* could be sold outside pastoral communities. If yak butter were clarified, ghee could be processed and sold. Ghee made from clarified butter has a longer shelf life and smells better. Yak tails, if aesthetically prepared, would have a profitable market. Fine yak wool is considered to be one of the eleven luxury fibres in the world; yet such wool produced in India is not exported. Interactions with established textile factories would facilitate economic use of this valuable product. The processing and marketing of yak meat could provide additional economic benefits to herders.

CHANGING ECONOMIC AND DEVELOPMENT FORCES AND IMPLICATIONS FOR YAKS

Changes in Yak Production and Management

Before the NRC-Yak was established, the State Animal Husbandry Department and the Veterinary Departments in the five major yak-rearing states of India were responsible for overseeing yak production. However, due to the inaccessibility of these regions, officials have never taken the problems of high altitude husbandry seriously. Meanwhile, herders, who are dependent to a great extent on yaks for their livelihood, have been forced to abandon this profession for several reasons. Attitudes have adversely affected the profession as a whole. Recent census statistics reveal a progressive decline in population and overall production.

Since the establishment of the NRC-Yak, scientists have developed rapport with yak herdsmen. Unlike the absent government officials, these scientists are requested to visit herding communities; their help is welcomed and their opinions are valued. This increase in local trust may help herding communities to retain and improve upon their traditional management systems in the future. Their attitudes have changed. Given proper direction, the economic conditions of yak-herding communities can improve. Suitable projects for improvement of rangelands, veterinary care, disease prevention, and simple technology should be introduced in yak-rearing areas. These efforts will help herders envision their age-old profession as a viable one for generations to come. Without such efforts, India will ultimately lose an important animal species and leave vast amounts of high altitude pasture land unutilised.

Impacts of Tourism on Yak Production

Recently a few yaks have been kept in Shimla, Himachal Pradesh, for 'yak riding' purposes — a new tourist attraction which provides substantial economic benefits to yak owners. No such ventures have been introduced in other yak-rearing areas of India, though some yaks are exhibited in zoos.

If organised properly, yaks could be used as pack animals for tourist treks and large-scale climbing expeditions. Yaks could also be used as pack animals for government expeditions to remote areas. This industry has not even begun to realise its potential. If used as pack animals, yaks could benefit herding economies significantly.

PRIORITIES FOR FUTURE ACTION

Research and Development Requirements

Research must be carried out to evaluate yak breeds and improve management practices. Specific programmes should aim to carry out the following work.

- Evaluate different breeds/types/strains
- Conserve yak genetic resources
- Conduct breeding and genetics' research
- Develop suitable management practices
- Study heterosis in yak/cattle hybrids

The physiological aspects of yak production, such as their work potential and adaptation mechanisms, should also be better understood.

Physiological studies of yaks at different stage of growth, production and reproduction should be carried out, as should research on work, adaptation, and lactation physiology.

Yak nutrition and feed resource development should also be studied. Pastures and other feed resources should be evaluated. Estimates should be made about the digestibility and nutritive value of available fodder. In conjunction, a rumen fermentation study should be carried out and fodder resources should be augmented.

Yak health must be a research and development priority. Disease surveillance and monitoring must be carried out to determine the major diseases and causes of death, and factors affecting animal productivity must be studied.

In order to improve yak reproduction, studies on reproductive behaviour, including hormonal and biochemical studies, are required. Semen collection and preservation are also necessary, as are studies on delayed maturity, seasonality of breeding, long post-partum periods, and infections as causes of infertility.

Technologies for the production of yak products and by-products, such as meat, milk, wool and hide, should be evaluated, improved, and made available to herders. Similarly, extension work (training, socio-economic studies, etc.) should be introduced.

Presently, the Government of India has launched no major development programmes related to yak husbandry, apart from the National Research Centre for Yak. Additional facilities and support are needed to realise the above research and development goals.

CONCLUSION

The declining population of yaks in India's Himalayan states has prompted the Indian Council of Agricultural Research, the Department of Agricultural Research and Education, and the Government of India to establish the National Research Centre on Yak. The scientists employed at this Centre are creating a yak-related infrastructure and carrying out research on different aspects of yak husbandry. This work has impacted India's herders in certain locations; yak research will continue to expand, reaching different yak-rearing states in the near future. The efforts of the Centre will help improve and support yak production and highland herders throughout India.

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Conservation and Management of Domestic Yak Genetic Diversity in Mongolia

Myadag Davaa

BACKGROUND

The Role of Yaks in Mongolia

The domestic yak (*Bos grunniens*) is one of the most important resources in the overall economy of Mongolia. The highland pastures of Mongolia are a perfect habitat for yaks. The raising of yaks provides the majority of Mongolians with a large portion of their annual income. Meat, dairy, and wool products derived from the yaks are indispensable elements of life in Mongolia. These animals are the wealth of many nomadic and semi-nomadic Mongolians and their numbers are among the largest of all livestock populations.

Yak-raising Areas

Mongolia is divided into three zones — Mountain/Khangai, Forest Steppe, and Gobi Desert — according to the country's physical geography, vegetation patterns, and livestock management systems. Most of Mongolia's yaks live in the Hangay Mountains of the western portion of the country and in the high altitude areas of the Altai; the rest are found in the mountains of mid-north Mongolia. In the Khangai/Mountain region, yaks are primarily distributed in areas ranging from 3,000 to 5,000 metres. Annual precipitation in these yak-rearing areas ranges from 350 to 500mm.

Population and Distribution of Yaks

At present, the world's yak population is thought to number around 14 million. (This figure includes some yak-domestic cow cross-breeds.) Thirteen million of these yaks are located in Chinese territories; approximately 0.7 million yaks are found in Mongolia; the remaining 0.3 million yaks live in other countries that have part or all of their territories in the Himalayas (Nepal, India, Bhutan, etc.) and countries within the Russian Federation.

Yaks are well adapted to high altitudes and thrive in high mountain grasslands. In fact, their physiology requires that they live above 2,000-3,000m. About 40 per cent of Mongolia's yaks are found in the mountain provinces of Arkhangai, Zavkhan, and Khuvsgul. In 1995, the total number of yaks in Mongolia was estimated at 708,700; *khainags* (F1 hybrids) numbered 53,039. Yaks are currently raised in more than 130 *sum* (county) of 13 *aimag* (county) , most of which are situated in mountain areas.

YAK BREEDING

Traditional Breeding and Cross-breeding Strategies

Mongolian herders have been crossing yaks with native Mongolian cattle to produce hybrids for thousands of years. These hybrids, commonly called *khainag*, are hardier and more productive than their parents; however, appearance varies according to the sex of the cattle used for cross-breeding. First generation (F1) crosses of female cattle and male yaks are called *sunny khainag*; reciprocal crosses are called *moonny khainag*. The F2 back-crosses are called *ortoom* and F3 back-crosses are called *baliam*.

The production of *khainag* in Mongolia is still governed by natural mating practices. Although this system is less costly than artificial insemination (AI) methods, the number of offspring per 100 breeding females does not exceed 20 to 30 per cent. This phenomenon is explained in part by the specific biological and ecological features of yaks as well as differences in the parent species' patterns of sexual activity.

Existing Breeding and Breed Improvement Programmes

Yak herders in Mongolia select breeding stock according to traditional colour preferences, size and body conformation, horn shape, milking characteristics, and behavioural patterns.

Although no specific improvement programmes, aside from traditional selection, have been introduced, yak production in the Hangay region has experienced a marked increase: from 570,800 in 1994 to 708,768 in 1995.

Major Problems and Challenges

Ecological shifts, altercations in the natural environment caused by human disturbance, a rising human population, and environmental changes resulting from economic development have had a detrimental impact on yak populations in Mongolia. The distribution of yaks is now restricted to relatively few areas. From 1940 to 1994, Mongolia's yak population decreased from 725,800 to 570,800. Presently, the total population of yaks and their hydrids in Mongolia is 761,800.

Nevertheless, most Mongolians depend on these animals to a large extent for their livelihood. As such, improving the productivity of Mongolia's yaks through increased selection, better management practices, and the active protection of yak habitats should be a top priority.

Opportunities for Improvement

In order to improve upon current yak-breeding and cross-breeding methods in Mongolia, artificial breeding methods should be introduced. An embryo bank used for *in vivo* fertilization of oocytes collected from superovulated female yaks or yak/cow hybrids should be established. Semen should be obtained from highly productive yak bulls. Such initiatives would expand the gene pool among different yak populations which, in turn, will help avoid problems arising from inbreeding.

YAK NUTRITION AND HEALTH

Land Use and Feeding Methods

Mongolia covers a land mass of about 120 million hectares of grassland, tundra, desert, and forests. The country boasts almost 2,000 different plant species, of which over 600 are used for animal fodder. The annual growth of new grasses in Mongolia's pastures begins in April, usually reaching its maximum height in August.

Pasture land is presently considered a common resource in Mongolia. The population density in rural areas is very low. Herders can move their animals freely from one location to the other throughout the year in search of quality pastures. In fact, the nomads and herdsmen of Mongolia depend on such transhumance patterns for survival, particularly during Mongolia's harsh winters. Given these seasonal migration patterns, different herds of yaks may graze together throughout the year.

Major Problems and Challenges

Mongolian yaks are primarily free range animals; over 90 per cent of the fodder they consume annually comes from open pastures. During the winter, however, this free range dries up, becomes poor in quality, and is often covered with snow. Consequently, yaks only consume an average of 40-60 per cent of their daily fodder requirements in the winter; an individual animal can lose as much as 25-30 per cent of its total body weight from late fall through early spring. The number of yaks that are infertile or do not produce milk is considerable, particularly when they are undernourished.

In order to maintain healthy, productive herds and quell seasonal weight losses, it is necessary to develop supplementary feeding strategies. The efficient utilisation of locally available grassland resources, including the production and storage of fodder, should be a priority. Similarly, educating herders about yak physiology and reproduction, as well as biotechnology, should be considered.

YAK MANAGEMENT SYSTEMS

Migration Patterns and Traditional Pasture Management Practices

Land-use patterns and pasture management are essentially seasonal in Mongolia. Mongolia's nomads must be able to travel in an organised fashion with ease and relative speed from one distant location to the next in search of fodder for their herds. The Mongolian phrase *otort yakakh* literally translates as "to go a long way from one's home territory, looking for better pasture land in bad seasons."

Management practices themselves are intricate systems in which herdsmen balance the level of abundance of grasses, the availability of water and soda/salt, changes in weather, and the distances between pastures to determine when and where they move their herds. Other forms of pasture management include penning animals in on a section of pasture, shifting base camp locations as a means of moving herds without travelling to an entirely new pasture, or engaging in long-distance or winter camping.

In general, Mongolian herdsmen spend from late spring through summer letting their yaks recuperate from the previous winter. Grass is plentiful during this time and yak herds are kept on high altitude mountain pastures, accumulating fat on which they will rely to sustain themselves during the fall and winter months.

Major Problem and Challenges

At this point, most management practices follow the above-mentioned traditional patterns of movement. Although these patterns of transhumance provide an effective base for management strategies, they could be improved. Climatic and seasonal changes, Mongolia's topography, and some cultural factors contribute to problems faced by herders who depend on Mongolia's pastures to survive.

Opportunities for Improvement

Mongolia's traditional seasonal migration patterns and the periodic movement of herds to new sites mirrors some of the elements of modern rotational grazing systems. As such, Mongolia might benefit greatly from retaining the present management practices, building upon these practices as per the suggestions of relevant experts in fields such as grassland ecology and natural resource management. Ancient strategies can form the basis for modern improvements.

PRODUCTION, PROCESSING, AND MARKETING OF YAKS AND YAK PRODUCTS

Traditional Processing and Marketing of Yak Products

Yaks and yak products provide Mongolians with a primary economic base. Yaks and yak hybrids provide herders with milk and other dairy products, meat, draught power, and manure. Yak wool is essential to life on the Mongolian plains; spun wool is woven into clothing, tents, bags, etc. Yak tails, bones, and other products are used to produce national costumes, including jewellery and wigs. The animals themselves are well adapted to the country's harsh environment and high altitude.

The most important products derived from yaks and hybrids, in terms of both their commercial value and the fundamental place they occupy within the Mongolian diet, are milk and meat. Milk production is highly variable, depending on the availability of fodder, the age of milk-producing animals, and fluctuations within gestation, calving, nursing, and weaning cycles. Milk production usually peaks between March and June. Normally, a female yak or hybrid produces from 500 to 700 kilogrammes of milk in one lactation. Yak milk is famous for its high fat content (about 7.5 per cent) and is an essential component of the Mongolian diet. Yaks kept for slaughter are a principal source of meat for Mongolia's herdsmen, as well as ethnic minorities who populate the country's highland regions. In recent years, some yak beef has even been exported to international markets.

Opportunities for Improving the Production, Processing, and Marketing of Yak Products

In the last few decades, yak production in Mongolia has increased significantly through the introduction of technology that helps improve production and processing. By monitoring variables such as productivity characteristics, growth rate, and survival rate, meat and milk yields have been improving constantly. Similarly, meat processing for commercial use has been aided by the development and improvement of slaughterhouses. Meat production and distribution could be further improved, however, if more slaughterhouses were established throughout the country; at present, these facilities are rather centralized.

Other yak-producing countries have also set examples of innovative production techniques, some of which could benefit Mongolian yak production activities. For instance, foreign examples show that two different types of hybrid can be produced through the reciprocal crossing of yaks. This practice is thought to have a positive effect on increasing milk and meat production.

With the end of communism and the introduction of a market economy in Mongolia in 1990-91, yak raising and yak products have been privatised. As a result, Mongolians are increasing the number of yaks they keep. New labour organisations concerned with yak production issues have also been formed.

Other Significant Changes in Yak Production

One of the most significant changes in yak production in Mongolia has been the introduction of genes from Chinese wild yaks into Mongolia's domestic yak population to help maintain and improve genetic diversity. It is thought that such cross-breeds are particularly healthy, robust, and active. This initiative aims to improve the production and productivity levels of Mongolian yaks.

CONCLUSIONS AND PRIORITIES FOR FUTURE ACTION

In order to use and explore Mongolia's yak resources most effectively, the yak industry must focus on increasing the quantity of products the country is able to produce and process. As such, it is necessary to increase the overall population of yaks. Similarly, yak genetic diversity should be safeguarded and, where possible, improved. In particular, the introduction of Chinese wild yak strains into the Mongolian domestic yak gene pool is a worthwhile initiative.

Need for Further Research

The National Yak Research Centre (NYRC) is located at Mongolia's Agricultural University. The NYRC has been responsible for organising and conducting national yak research. During the Second Meeting of Yak held in Arakhangai *Aimag* on 22 August, 1996, the organising committee unanimously accepted a resolution to form the Mongolian Yak Association (MYA).

The primary objectives of the NYRC and MYA are to continue research into the various environmental and genetic factors significant to yak raising and producing yak products. These organisations also aim to successfully implement a cross-breeding programme between Chinese wild yaks and Mongolian domestic yaks. (Levels of abortion and *dystocia* should also be studied.)

Development Programmes

As the primary objectives of yak breeding should be to produce quality animals, development programmes should take into account such factors as survival of the young and performance characteristics, as well as the number of elite and first-grade yaks produced in a given herd. Top quality yaks selected from native strains should be used as the nucleus of pedigree herds. Concomitantly, selective mating, based on such features as hardiness, viability and performance of offspring, should be a priority. Increasing the number of elite and first-grade yaks will also lead to an increase in overall meat and milk production.

ACKNOWLEDGEMENTS

This workshop on the Conservation and Management of Yak Genetic Diversity being held at the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, represents an opportunity for yak scientists from all over the world to discuss recent research

findings, exchange information, and compare experiences related to the conservation, production, and management of yaks from the Hindu Kush-Himalayas to the Central Asian Steppes. This meeting offers us a rare opportunity and marks the beginning of what I hope is a continued commitment to yak-related issues. I look forward to attending other such events in future.

I would like to thank Mr. Daniel Miller, other ICIMOD representatives, and all fellow participants for their presence and contributions to this Workshop.

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Conservation and Management of Yak Genetic Diversity in Nepal

Laxman Sherchand and Neel Prakash Singh Karki

BACKGROUND

The Yak, *Bos grunniens,* is a multipurpose animal raised by the high altitude peoples of Nepal. Yaks are raised at altitudes of from 3,000m to 5,000 masl. No other domestic animal thrives in such extreme environmental conditions. The yak's genetic capabilities to survive harsh winters with minimum feed are unmatched. The yak provides milk, butter, cheese, meat, leather, hair, wool, and transport to the people of the Himalayas and of the plateaus of Central Asia.

Yak herding is transhumant and seasonal. When winter snowfall begins, yaks are brought down to pastures at about 3,000 metres. As the weather grows warmer, yak herds return to higher grasslands. Many high altitude pastoralists and agro-pastoralists raise yaks for cross-breeding purposes. Yaks are bred with *Bos indicus* and *Bos taurus* to produce cross-breeds (*chauri*) for milk production, draught power, and the transportation of goods. Many of Nepal's people depend on yak and *chauri* husbandry for their livelihoods.

Table 1: Composition of Yak Herds

District	Total Pop	Pack yak	Breeding adult		Heifer (<5 yr & >1yr)		Calf	
			Yak	*Nak*	Male	Female	Male	Female
	100%	12.7%	3.3%	33.9%	10.6%	10.4%	14.6%	14.5%
Humla	2,815	358	93	954	298	293	411	408
Mugu	1,000	127	33	339	106	104	146	145
Jumla	50	6	2	17	5	5	7	7
Dolpa	1,743	221	58	591	185	181	254	253
Mustang	191	24	6	65	20	20	28	28
Manang	200	25	7	68	21	21	29	29
Gorkha	100	13	3	34	11	10	15	15
Dhading	100	13	3	34	11	10	15	15
Rasuwa	130	17	4	44	14	14	19	19
Sindhupalchok	145	18	5	49	15	15	21	21
Dolakha	103	13	3	35	11	11	15	15
Ramechhap	40	5	1	14	4	4	6	6
Solukhumbu	1,505	191	50	510	160	157	220	218
Sankhuwasabha	50	6	2	17	5	5	7	7
Taplejung	720	91	24	244	76	75	105	104
Nepal	8,892	1,129	293	3,014	943	925	1,298	1,289

Source: Joshi (1982)

YAK POPULATIONS IN NEPAL

Yaks are found in 15 of Nepal's northern districts (see Table 1 and Fig. 1). Approximately 9,000 yaks and 17,000 *chauri* populate these areas (Joshi 1982). Brower (1991) conducted a study based on comparative yak and *chauri* populations in 1957 and 1984 in six locations in Sagarmatha National Park. Her results revealed that the area's yak population is declining at the rate of 1.21 per cent annually, while the *chauri* and cattle populations are increasing at the rate of 1.50 and 0.84 per cent each year respectively. Yet, the cattle population across the Himalayan belt is declining by 0.35 per cent annually. If Brower's calculations are accurate, Nepal's current yak and *chauri* populations should be approximately 7,800 and 20,800 head, respectively. According to the Central Bureau of Statistics (CBS 1991-92), however, yak and *chauri* populations are declining at the rate of 1.1 per cent annually (Table 2). Families raising yaks and *chauri*, however, are increasing by 1.4 per cent each year.

STATUS OF WILD YAK IN NEPAL

At one time, wild yaks were believed to be found in Humla, Dolpa, Mustang, Manang, Solukhumbu, and Taplejung districts (Joshi 1982). However, there is no strong evidence to support the statement that wild yaks were found in Nepal at that time.

YAK BREEDING AND CROSS-BREEDING

Yaks usually breed from mid-July to early November (Shrestha 1990). Their breeding patterns reflect seasonal shifts in the availability of forage. Although yaks are pure-bred in Nepal, cross-breeding is more popular. Yaks are crossed with hump cattle *(Bos indicus)* and humpless cattle (*Bos taurus*) to produce *chauri*. Hump cattle, or *aule*, are raised from 1,500 to 3,000masl (Kharel 1996), while humpless cattle (called *kirko* in the east and *lulu* in the mid-western belt) are raised at slightly higher elevations. Farmers usually cross yaks for the first three to four generations with *aule*

Table 2: **Yak and *Chauri* Population of Nepal in 1981 and 1991 (CBS)**

District	1981			1991		
	Total No of households	Yak & *chauri* raising households	No of yaks and *chauri*	Total No of households	Yak and *chauri* raising households	No of yaks and *chauri*
Taplejung	18,293	339	1,382	20,241	138	572
Sankhuwasabha	22,442	250	934	25,382	90	1,733
Solu	14,200	1,054	8,515	18,043	3,623	20,988
Dolakha	27,452	1,410	17,628	34,154	413	3,847
Sindhupalchowk	34,251	250	934	25,382	382	3,119
Rasuwa	5,043	431	4,442	6,448	379	2,826
Gorkha*		NA*	NA		1,580*	10,798*
Manang	719	134	1,043	902	163	1,970
Mustang	2,139	275	1,667	2,487	91	1,363
Dolpa	2,207	493	7,730	4,607	799	5,307
Kalikot	NA	NA	NA*		39	*52
Mugu	6,042	453	4,794	6,670	350	1,216
Humla	3,672	522	2,160	5,890	631	3,781
Bajura	10,565	317	820	16,827	86	242
Bajhang	19,204	232	891	24,069	69	207
Darchula	10,335	329	716	16,806	216	564
Total	1,76,563	6,492	53,656	2,93,784	7,430	47,735

* excluded for comparison in total figure

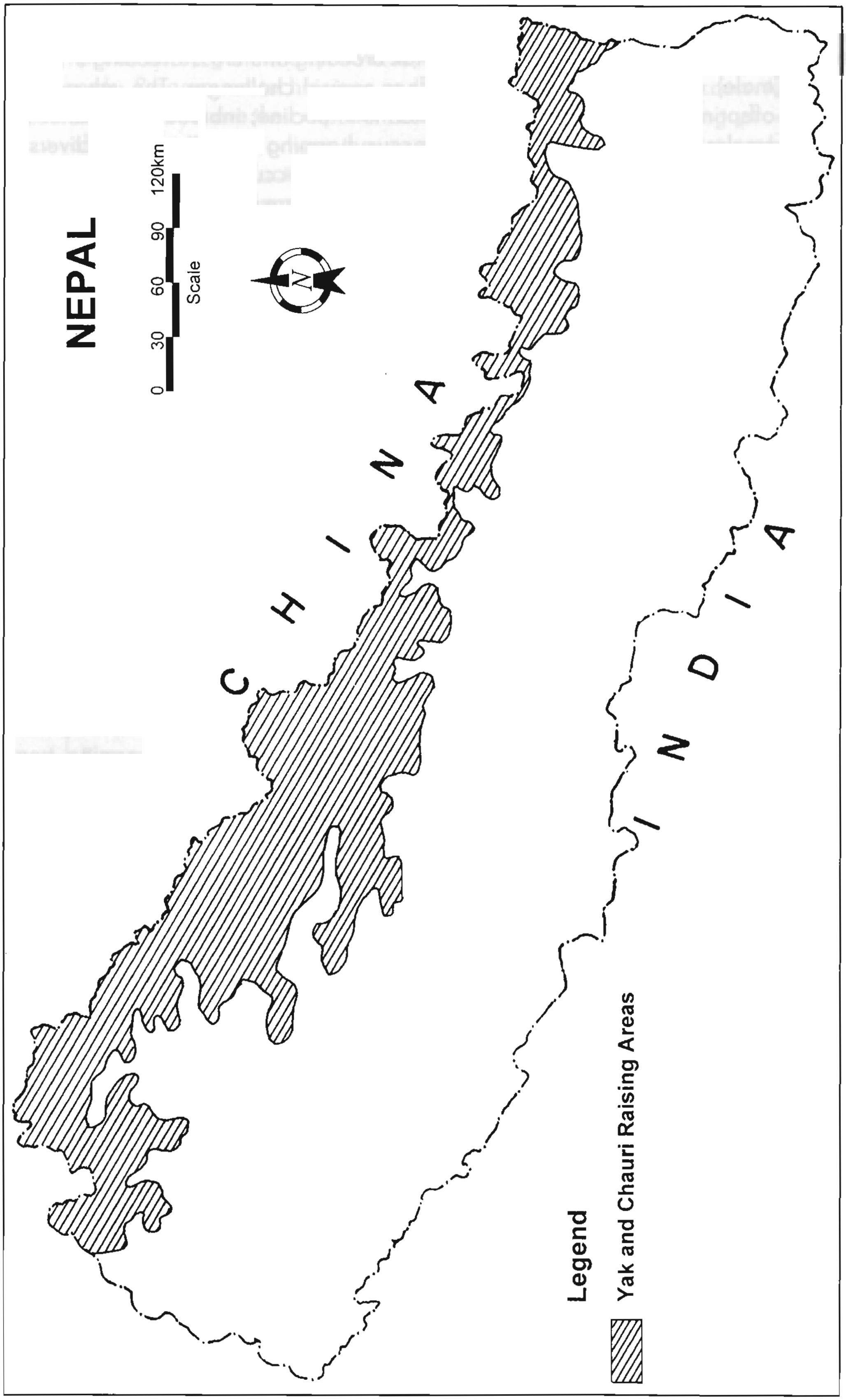

Figure 1: *Distribution of Yaks + Yak-hybrids in Nepal*

cows to produce cross-breeds called *urang jhopkyo* (male) and *urang jom* (female). The male offspring of these crosses are sterile, while females can reproduce. *Urang jom* are then back-crossed with pure-bred yaks. When female pure-bred yaks (*nak*) mate with *kirko* bulls, the offspring are called *lang dimzo jhopkyo* (male) and *dimzo jom* (female). As in the previous cross, the male hybrid is sterile, while the female is fertile.

Chauri(s) are considered more versatile than pure-bred yaks in many places throughout Nepal. They tolerate slightly lower altitudes than yaks and are more manageable draught and pack animals. *Jhopkyo* are used as pack animals and can carry between 60 and 80 kg, depending on the season. Milk production levels from *chauri*(s) also exceed those of pure-bred *nak*. *Jom*(s), in particular, are milk producers. They can produce from 1.5 to 3 litres of milk daily, whereas the *nak* and *aule* cattle only produce between 0.9 and 1.8 and 0.5 to 1 litres of milk per day, respectively. The milk yielded from female hybrids produced when *nak*(s) are artificially inseminated by Brown Swiss (BS) cattle is even higher; three to four litres of milk a day were recorded (Table 3).

Yak breeding and cross-breeding in Nepal face several challenges. The yak population is in decline; inbreeding continues to occur, harming overall genetic diversity; and calving occurs during the dry season. These issues are genuine hindrances to the improvement of yak production in Nepal and should be addressed.

Group Breeding Scheme

In order to protect the yak's unique genetic resources and improve overall production, the following 'group breeding scheme' should be introduced.

First, farmers' groups comprised of at least seven farmers who each own a minimum of five yaks should be formed throughout yak distribution areas. Group members must be literate enough to maintain simple breeding and production records and should be provided with monetary incentives to do so. Their animals should receive free vaccinations and de-worming treatment for the first few years of the progamme.

Members of the breeders' groups should receive a variety of training. They should become aware of the importance of main-

Table 3: Traits of Yak and Yak Cross-breeds

Traits	*Nak*	*Dimzo Jom*	*Urang Jom*[1]	BS *Jom*[2]	*Aule* cattle
Milk Yield (MY), lt					
MY/lactation	220	300-540	300-540	1045	300
Milk days	167	120-180	120-180	305	300
MY/day	1.3	1.5-3.0	1.5-3.0	3.4	1.0
Milk fat (%)	6.6	5.7	5.7	NA	3.8
SNF (%)	11.5	11.1%	11.1%	NA	NA
Age at first calving (yr)	4.3	3	3.7	4	4
Herd calving rate	55.4%	NA	NA	NA	NA
Calf mortality	22.5%	NA	NA	NA	NA
Herd mortality	9.3%	NA	NA	NA	NA
Calving interval (days)	689	425	425	NA	NA
Gestation period (days)	254	270	270	270	280

Source: Shrestha (1990); Kharel (1996); Joshi et al. (1994); Robinson (1993) taining productive, genetically diverse, strong herds. Programme technicians and farmers should also share their experiences about yak rearing, particularly as they relate to improving the productivity of indigenous animals through simple breeding, feeding, and animal health practices (Table 4).

Breeding males should be selected on the basis of their ancestors' performance levels — knowledge to which the farmers would presumably have access. Males not selected for this breeding programme should be castrated. Breeding males should be assigned in a ratio of 1:20 within a single herd. These males should be exchanged or replaced every five years to curb inbreeding. Dams should be selected according to reproduction rates and performance levels.

Table 4: Logistic Breeding Plan for Yaks including Financial Estimate of Costs and Benefits

Yak Locations	Solukhumbu and Mustang Districts
No of farmers' groups	12
No of farmers in each group	7-10
No of yaks kept by each farmer	5 (minimum)
Incentives given to the farmers (for the record)	Rs 500 /yak/year
Breeding plan used	Group breeding scheme
Duration of breeding plan	10 years
No of technical staff involved	4
No of supervisors	2 (4 visits per year)
Implementing agency	DLSO, Mustang; Yak Farm, Solukhumbu
Technical supervising agencies	Animal Breeding Division (NARC); Animal Breeding and AI Section (DLS)
Supporting technical agencies	Pasture and Fodder Research Division (NARC); Pasture, Fodder and Nutrition Section (DLS)
Overall responsible agency	Conservation and Use of Indigenous Animal Genetic Resources' Committee
Cost estimate (per year)	
Total incentive given to farmers	Rs 10*5*12*500 = Rs 300,000
Pasture improvement	Rs 600,000
Recording expenses (stationary)	Rs 2,000
Tags for identification	Rs 10,000
Technical staff (4)	4*12*7000 = Rs 336,000
TADA for technical supervisors (2)	2*4*10,000 = Rs 80,000
Data collection and analysis	Rs 50,000
Miscellaneous	Rs 22,000
- Total cost estimate/year	Rs 1,400,000
- Total cost estimate for 10 yr	Rs 14,000,000
Expected benefits	
Inbreeding effects	Controlled through out-crossing
Superior animals (bulls)	Selected - at least 20 in every 3 years
Feed and feeding system	Improved - new pasture seeds introduced, rotational grazing applied , removal of unwanted weeds from the grazing land, hay-making techniques
Productivity	Increased - at least 50% productivity (milk)
Number of improved animals	Increased - minimum of 300 per year
Farmers' income	Increased by 25%
Environment	Improved - 500 ha per year

The yak improvement programme should be incorporated into the District Livestock Services' Office (DLSO)/Livestock Farm Programme for sustainable *in situ* conservation of indigenous animal genetic resources.

YAK NUTRITION AND HEALTH

Yaks lose about 25 per cent of their body weight in the winter due to insufficient access to fodder. Although yaks are occasionally given a few kilogrammes of hay and about 200 grammes of supplementary feed per day, they continue to lose weight through spring. During the long, dry winter and spring (Nov-Dec. to May-June), yaks grow weak and susceptible to diarrhea, dysentery, fever, coughs, and pneumonia. When the ambient temperature is comparatively warm, lice, warble flies, and other pests infest yaks for a short period in the late spring (Shrestha 1990). Animals often die from minor health problems during this period.

Fifty-five yak herders from the Rasuwa, Dolakha, Ramechhap, and Solukhumbu districts were interviewed about disease prevalence in these areas. The results of this survey indicated that the following diseases most frequently affect local yak populations (Joshi 1996).

- *Bacterial*: Anthrax, Black quarter, Brucellosis, HS, John's disease, Mastitis, Tuberculosis
- *Viral*: FMD, Rinderpest
- *Parasitic*: lice, ticks, mites, parasites, and worms in the alimentary tract and lungs, and protozoan parasites in blood
- *Anomalous*: Bloating, Ketosis, Milk fever, Poisoning

When yaks become sick, 17.3 per cent are treated by traditional healers, 45 per cent are taken to a *Dhami Jhakri*, and 43.3 per cent do not receive any treatment (Joshi 1996).

Although yaks do get sick, particularly in winter, the clean environment in which they live keeps them quite healthy most of the time. Farmers are cautious about the quality of water they allow yaks to drink. For example, herders consider water drunk by buffaloes poisonous to yaks and so avoid these areas.

As mentioned above, yaks rely almost exclusively on free-range fodder to meet their nutritional requirements. *Festuca* (*Furcha*) is the most palatable of the grass species available in Nepal's sub-alpine rangeland. This grass grows well above 4,000 metres during monsoon. *Furcha* yields about 3,600 kg hay per hectare compared to the 2,800 kg of hay yielded from mixed grass that grows between 3,500 and 3,800 metres. Although the hay yield is expected to be higher above 4,000 metres, these harvest levels are not consistent and vary depending on available fertilizers.

In addition to sickness and fodder availability, yak health and mortality rates are affected by the presence of predators. Wolves *(Canus lupus)*, leopards *(Panthera pardus), and* tigers *(Panthera tigris)* all prey on yaks. Wolf attacks are particularly fatal. These predators first urinate in the yak's eye, temporarily blinding the bovine. Once blinded, the yak is easily attacked and killed (Kharel 1996).

Many opportunities for improving yak nutrition and health exist. Optimal stocking rates should be maintained, according to pasture availability and grass density and height. Rotational grazing systems should be introduced. Weeds should be removed from grasslands. Portions of community pasture should be allocated for hay-making and locals should be trained in quality hay production.

The breeding scheme described above may improve the genetic potentialities of endangered breeds by increasing disease resistance, reducing feeding stress, and controlling inbreeding. In order to increase animal productivity, however, feed programmes and fodder availability must be improved. Technical support should be provided by the Pasture and Fodder Improvement Division of Nepal Agricultural Research Council (NARC) and the Department of Livestock Services (DLS). The systematic control of grazing and the introduction of stall feeding may improve natural fodder resources and, subsequently, improve animal health.

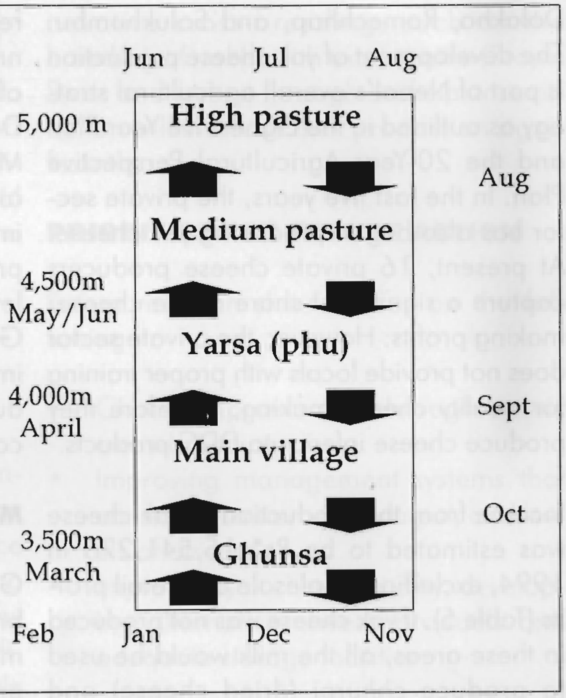

Figure 2: *Transhumance Patterns*

YAK MANAGEMENT SYSTEMS

During the cold winter, a yak's nutrient intake is minimal. However, the physiological stress of pregnancy demands that yaks, particularly pregnant females, be fed more. Without increasing fodder availability and improving management systems, yak productivity levels will remain low.

Both overgrazing and undergrazing hinder yak development in Nepal. Sometimes herders are lazy and do not want to take their herds to new locations because this transhumance is difficult and means travelling great distances. The herders' historical lack of record keeping also bears on grazing and other management strategies, as do their superstitious feeding, care, and breeding systems.

Figure 2 is one illustration of transhumance patterns as practised in the Solukhumbu area of Nepal.

The movement of yaks from 3,000 to 5,000 m and back again depends on the availability of forage and area temperatures. Yaks thrive at temperatures ranging from 0 to 10°C, although they can withstand temperatures far below freezing. Yaks are extremely sensitive to high temperatures. They either refuse to return to shelters or move to higher ground to avoid the heat.

Although no concrete programmes to improve management practices have been introduced in Nepal, plenty of opportunities exist for such improvement. *In situ* training on pastoral and land management, hay-making, and breeding could be given to yak and *chauri* herdsmen.

PRODUCTION, PROCESSING, AND MARKETING OF YAK PRODUCTS

The Dairy Development Corporation (DDC) began producing cheese in Nepal in 1964. The DDC operates nine cheese factories in five districts: Rasuwa, Sindhupalchok, Dolakha, Ramechhap, and Solukhumbu. The development of yak cheese production is part of Nepal's overall agricultural strategy as outlined in the Eighth Five Year Plan and the 20-Year Agricultural Perspective Plan. In the last five years, the private sector has also begun producing yak cheese. At present, 16 private cheese producers capture a significant share of the cheese-making profits. However, the private sector does not provide locals with proper training for quality cheese-making, therefore they produce cheese inferior to DDC products.

Income from the production of yak cheese was estimated to be Rs* 15,541,276 in 1994, excluding wholesale and retail profits (Table 5). If yak cheese was not produced in these areas, all the milk would be used to produce *chhurpi* (dried cheese) and ghee, thereby incurring an estimated loss of Rs 5,593,553.

Presently, Nepal's yak cheese is made above the treeline, in places where firewood is scarce; yet, large amounts of fuel are required to produce cheese. These environmental conditions constrain the growth of Nepal's yak cheese industry. The 10-Year Dairy Development Plan, approved by His Majesty's Government of Nepal in 1991, aims to satisfy urban cheese demands, improve production efficiency, and reduce production costs in order to increase profit levels and boost local herders' incomes. Given these objectives, opportunities for improving milk production, cheese production, and marketing strategies must be considered.

Table 5: Economic Importance of Yak Cheese Production for 1994

DDC yak cheese production	76,000 kg
Private yak cheese production	46,800 kg
Individuals dependent on yak cheese production for their livelihood (excluding Kathmandu wholesalers and retailers)	3,900
No of *chauri/nak* associated with yak cheese production	4,750
Earnings of industry participants (milk producers, cheese producers, and hired villagers)	Rs 15,541,276
Annual retail value of yak cheese	Rs 28,858,000
Annual foreign exchange earnings from yak cheese	$ 525,000
Revenue for Kathmandu-based yak cheese markets (costs of marketing have not been deducted)	Rs 6,198,000
Source: Calavito 1994	

Milk Production for Cheese-making

Genetic improvement through group breeding schemes will help raise overall milk production levels. Fodder production programmes oriented towards increasing the availability of winter and spring feed should be undertaken. Interested farmers should be trained to make cheese. Pasture management in the vicinity of cheese production sites should aim to revive indigenous management systems and improve these systems, where necessary, to reduce overall environmental impact.

Cheese Production

Simple training in quality cheese-making could both improve management strategies and increase local income. Producers should be given proper cheese-making training. Imported goods needed for cheese production should be readily supplied to cheese factories. A Cheese Producer's Association should be formed and a corresponding revolving fund should be established for local producers.

* There are 56.75 Nepalese rupees to the U.S. dollar

Marketing

Cheese production should be viewed as a commercial enterprise. Proper storage areas should be built. Advertising and distribution of yak cheese throughout Nepal should be initiated on a wide scale and a marketing chain should be established.

CHANGING ECONOMIC AND DEVELOPMENT FORCES: IMPLICATIONS FOR YAKS

Tourism, and the economic benefits it implies, have led Nepal's younger generation to depart from their forefathers' subsistence lifestyles; yak herding, for instance, is no longer a primary occupation for many young Nepalese. They recognise the difficulties farmers and herders face, with little economic rewards.

Similarly, yak breeding is becoming less geared towards milk production. Instead, yaks and *chauri*(s) are used as pack animals to carry tourists' loads. The closure of the Nepal/Tibet border has further changed Nepal's yak production systems. Nepalese herders used to winter their yaks on the Tibetan plains; this is no longer possible, at least on a wide scale, and has thus reduced the overall number of yaks and yak crossbreeds herded throughout Nepal. Unless alternative income-generating programmes and fodder development initiatives are launched in yak production areas, this trend will continue.

In order to offset the impacts of these changes, practical breeding, feeding, management, and animal health training should be given to herders. Locals should also be trained as cheese producers. Low-interest credit systems should be established in yak production areas to provide economic incentives for raising yaks. Innovative cross-breeding, such as the breeding of *nak*(s) with exotic cattle (Brown Swiss and Jersey) through artificial insemination will increase milk production significantly.

PRIORITIES FOR FUTURE ACTION

Future research should focus on the following.

- *Chauri* improvement through exotic cross-breeding.
- Improving management systems that consider nutrition, milk output, and levels of disease.
- Improving yak cheese quality; developing alternative cheese products and adequate storage facilities.

Development programmes should be initiated based on research findings and available technology. Such programmes should aim to implement group breeding schemes to increase yak production. *In situ* training programmes for farmers and cheese producers will further maximise local income generation possibilities. Pasture and fodder improvement programmes that place special emphasis on supplementary feed will further benefit yak production in Nepal.

CONCLUSION

At present, yak production is not too economically beneficial for local herders. Overall herd productivity and individual animal productivity need to be improved. Scarcity of fodder limits yak and *chauri* populations, as well as production levels. The need for pack animals throughout Nepal's yak distribution areas is also in decline — with the exception of those animals used for tourism. Attempts to increase milk production in response have been introduced through cross-breeding; yet the full genetic potential of cross-breeds is stifled by the lack of winter feed. Malnutrition results in poor breeding performance. In order to increase production levels, solutions to fodder shortages must be found. As such, the conservation of area biomass is imperative if yak production is to flourish in Nepal.

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Yak Production and Genetic Diversity in Pakistan

Rash Khan

INTRODUCTION

Yaks are only found in cold, mountainous regions of Pakistan's Hindu-Kush Himalayas, particularly in areas that border Ladakh, Tajkistan, and China. These large, domesticated bovines produce milk, meat, and wool for local herders. Yaks also play a vital role in transportation throughout Pakistan's snow-bound, mountainous regions. Yaks subsist primarily by free grazing in forests and grasslands. Approximately 6,000 yaks are being raised in Pakistan today. The number of yaks and their productivity levels remain low due to fodder scarcity, management practices, disease, and outmoded breeding systems.

YAK PRODUCTION AREAS IN PAKISTAN

Despite environmental limitations, the high altitude, mountainous, and seasonally snow-bound areas of the Northwest Frontier Province (NWFP) and Skardu, as well as the Ganche, Ghizer, Chitral, and upper Hunza districts remain potential areas for increasing local yak production. As mentioned above, these areas border China, Tibet, Ladakh, and Pamir. The yaks found in Pakistan were most likely imported from these neighbouring countries.

Of Pakistan's 6,000 yaks, one-third are found in the Chitral hills, while the rest are raised in Pakistan's Northern Areas. Other areas may also be suitable for yak production and rearing. Yaks should be introduced into these potential areas on an experimental basis.

YAK FEEDING AND GRAZING SYSTEMS

Unlike domestic cattle, yaks need very little daily care. They survive almost exclusively on free-range grasses. For the most part, domestic yaks mirror the grazing patterns of their wild counterparts. In winter, yaks eat grasses, branches, and leaves of various trees and shrubs. Although the winter grasses are scare and their quality poor, yaks are rarely fed straw or other feed supplements during the cold months. As a result, they are often sick, weak, and more prone to disease than other animals during the winter; mortality rates rise correspondingly.

As winter passes into spring, yaks move from winter grazing lands to mid-alpine pastures near forests in search of better fodder. In summer, yaks travel to even higher alpine pastures — areas in which fodder is plentiful from May to October. Due to the severely arid climate in the Hindu Kush-Himalayas, summer is the only season in which grass is abundant at altitudes of up to 5,000 metres. In winter, autumn, and spring, yaks face acute shortages of fodder. Since local land holdings are often small and are in short supply, fodder can be planted only on lands not suitable for maize, wheat, or barley. Fodder cultivation to provide yaks with supplementary feed is rarely practised.

Although Pakistan's yak herders recognise the economic value of these animals, they have done very little to improve upon yak and pasture management systems, or to ensure that their animals receive proper veterinary care. Owners simply mark their animals as their own (often by cutting the ears) and release herds to graze.

YAK BREEDING

Traditional breeding systems exist throughout yak-raising areas in Pakistan, including the Skardu area and the Astore Valley. According to this breeding method, a given yak bull is isolated from other male yaks and kept with cows. During the breeding season, male yak are also crossed with cows to produce hybrids. Male hybrids are called *dzo* and female hybrids are called *dzomo*. These crosses supply local herders with transportation and are also used for ploughing fields. Female hybrids produce more milk and butter fat than both local cows and pure-bred yaks.

When a *dzomo* is crossed with a yak (F2), the male hybrid offspring (*gar*) is sterile, while the female (*garmo*) remains fertile. When *garmo* are crossed with male yaks (F3), the male is called *gir* and the female is called *girmo*; the males are infertile while the female is fertile. The female *girmo* can be crossed with a male yak; such crossbreeding can continue through the F6 generation, at which point the hybrids become real male and female yaks. This traditional system of yak breeding and crossbreeding has met most of Pakistan's needs in terms of milk, transportation, and beef.

Notwithstanding, Pakistan would benefit from the introduction of new, scientific breeding systems. Such innovations would help improve the overall productivity and genetic diversity of the country's yaks. Since Pakistan's limited yak population exists in cold, isolated high-altitude regions, researchers and development agencies have neglected to extend scientific breeding methods to these areas to such an extent that livestock census reports contain no mention of such activities. According to these reports, only one person in all of the Northern Areas has received training in yak breeding. This lack of expertise is compounded by the lack of training facilities, new breeding technologies, and other resources.

Traditional breeding systems also hinder productivity and should be improved upon. Artificial Insemination (AI) and other such methods may improve production. The difficult climatic conditions under which yaks survive further hinder production levels.

YAK PRODUCTION AND MANAGEMENT

Pakistan's domesticated yaks live and graze widely throughout the high hills and alpine grasslands of Pakistan. Aside from marking given animals as their own and overseeing the movement of herds from one season's pasture to the next, herders do little to manage their herds. During parturition, female yaks are sometimes brought down from the pastures to the villages for a couple of days and are given supplementary fodder as well as access to village area grasslands. Yaks are also brought down from pastures to be sold and butchered, when and as necessary.

The proper management of Pakistan's yaks could help improve the national economy. At present, buffaloes and cattle are raised in the Punjab and NWFP for slaughter in order to meet the human population's daily nutritional requirements. Yaks could help do the same across a wider area than the one currently covered.

In order for this to occur, however, yak production needs to be improved and the number of yaks must increase. Current production levels remain quite low for several reasons. Yaks, like all animals, require adequate food to thrive. Unfortunately, Pakistan's yaks must depend on very limited fodder resources. (Yaks are also subject to accidental death by avalanche while searching for fodder.) This lack of proper food precipitates weakness, disease, and a high mortality rate. Pakistan's yaks also lack winter shelter and adequate veterinary care, which further contributes to low productivity levels.

YAK PRODUCTION AND MARKETING

Yaks produce milk, meat, and wool — products on which herders depend to meet their subsistence needs and, at times, to sell or trade. Yak milk is often made into butter and a variety of cheese products which provide herders with a large percentage of their caloric intake. Yak are normally slaughtered for beef in winter and the beef is then dried; once preserved, this meat is consumed from December to April. A yak raised for slaughter usually costs between Rs* 10,000 and Rs 15,000, depending upon weight and size. Yak wool is used for making carpets. These carpets, known locally as *sharma*, are sold for between Rs 700 and Rs 1,200 per piece.

Despite the marketability of yak products and by-products, production levels are limited by the number of yaks raised in Pakistan. The fact that yaks live at high altitudes in rugged climates creates additional problems for the transport and subsequent marketing of yak products.

IMPROVING YAK RAISING IN PAKISTAN

In order to improve the quality of Pakistan's yak populations and increase animal productivity, the following recommendations should be carefully considered. Supplementary fodder programmes, or other means of ensuring that yaks maintain proper nutrition levels, should be implemented. Winter shelters should be built and maintained for local yaks, particularly for use during heavy snows. Overall access to veterinary care and specific measures to guard against disease must be a priority.

In addition, traditional breeding methods should be augmented with scientific breeding systems and innovative crossbreeding. Such measures, along with the introduction of yaks to prospective regions suitable for yak raising, will help increase overall yak productivity levels in Pakistan. More research on the possibilities for improving yak breeding and production methods must be conducted. Paramedical staff and local herders should also be educated about ways in which to improve the quality and production levels of Pakistan's yaks.

** There are 40.00 Pakistani rupees to the U.S. dollar*

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Status of the Wild Yak in the Qinghai - Tibetan Plateau

Cai Guiquan

INTRODUCTION

This paper presents information on the status of wild yaks in the Qinghai-Tibetan Plateau of the People's Republic of China. The wildlife survey work presented in this paper was gathered as part of a collaborative programme between the Northwest Plateau Institute of Biology, Xining, Qinghai Province, and the University of Montana, Missoula, Montana, USA. From 1990 to 1992 survey work on wild yaks was conducted in the Wild Yak Valley, located in the Haixi Mongolian People's Autonomous Prefecture, Qinghai Province (approx. 34°-39°N by 90°-98°E). Surveys were conducted by vehicle, on horseback, and on foot. Researchers observed wild yaks during this time (with the aid of spotting scopes and binoculars), recording census information such as herd numbers and composition. Estimations of the wild yaks' summer and fall diet compositions were determined by conducting micro-histological analysis of faecal samples.

SIZE AND DISTRIBUTION OF WILD YAKS

The wild yak *(Bos grunniens)* is larger than the domestic yak, reaching a body length of up to 260cm (see Tables 1 and 2). Wild yaks are found throughout the Qinghai-Tibetan Plateau area. These large bovines range across parts of Gansu and Qinghai Provinces as well as the Autonomous Regions of Tibet and Xinjiang (Figure 1). Schaller and Liu (1996) recently mapped the distribution of wild yaks in this region. However, based on the survey work carried out by this author in 1992 and 1993, the range of wild yaks in Qinghai Province should be extended beyond the boundaries set forth by the above-mentioned scientists.

Table 1: Measurements of Male Wild Yaks in Wild Yak Valley, 1991

Length	52.2 cm
Length of right horn	98.5
Distance from horn tip to tip	59.5
Right horn circumference	48.4
Length of nasal section	23.3
Width of nasal section	10.1
Width across orbit on dorsal section	23.4
Zygomatic width	31.8
Orbit to tip of rostrum	33.4
Upper cheek teeth	13.4

Table 2: Measurements of Female Wild Yaks

Total length	230 cm
Tail	46
Hind foot	56
Ear	21
Greatest spread of horns	63
Height at shoulder	146
Height at hindquarters	145

During fall 1992, the author surveyed two herds of wild yaks comprised of 176 animals. In summer 1993, the author

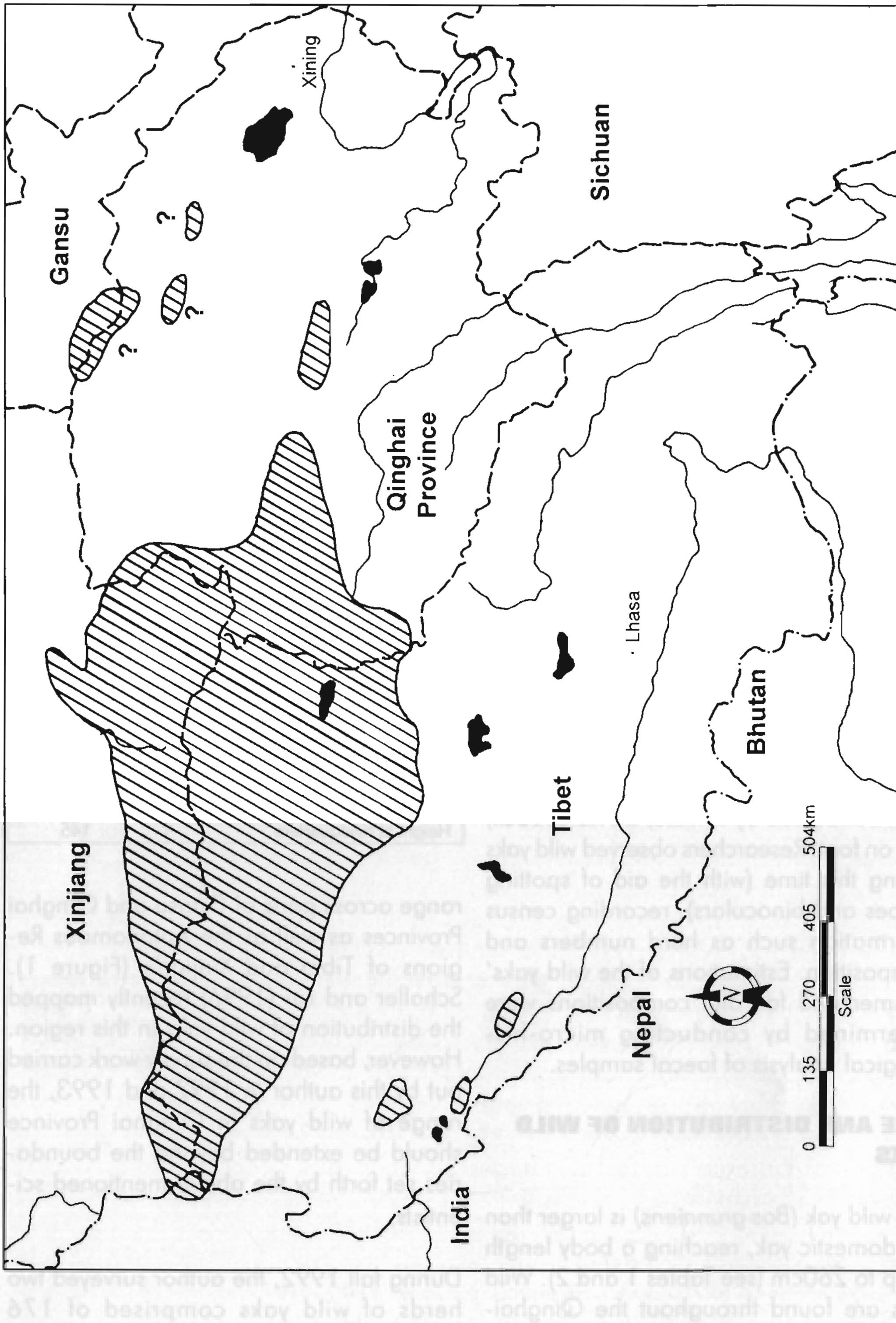

Figure 1: *Distribution of Wild Yaks*

observed another herd of 126 wild yaks. These yaks were situated to the east of the Golmud-Lhasa highway, beyond the eastern limits set by Schaller and Liu. As such, the recorded range and distribution of wild yaks should extend east to include populations found in the southern Burhan Budai Mountains. Although the number of wild yaks found in this area is threatened by continual illegal poaching, research indicates that wild yaks are still found to the east of the Golmud-Lhasa highway.

The southern range of wild yaks rests at approximately 32° N, near the Yarlung Tsangpo River watershed. The western border of wild yak distribution is Ladakh, India (Fox *et al.* 1991). Until recently, some wild yaks were found in Nepal (Miller et *al.* 1994). The Qilin and the Arjin mountains represent the northern borders of wild yak distribution.

HABITAT CHARACTERISTICS OF THE WILD YAK

Although wild yaks now inhabit the mountains and valleys from Qinghai across the Tibetan Plateau, their former range extended from southeastern Tibet to central Qinghai Province and southwest Gansu Province and the Arjin Mountains in Xinjiang.

In the summer, wild yaks divide themselves into large nursery herds of females and juveniles and smaller bachelor herds of adult males. Old wild yak bulls often graze alone. Herds range in size from ten to almost 350 animals, with an average of 107 animals.

Nursery herds consist of females with young (calves and yearlings), juveniles of one or more years of age, barren females, and sometimes a few males. Yearlings found within these nursery herds were routinely seen nursing; this indicates that most of the wild yak found in Wild Yak Valley calve in alternate years.

These nursery herds generally locate themselves in high elevation mesic sedge meadows to feed, moving to nearby glacial moraines to rest. The mean elevation of these summer nursery herds was 4,763 m.

Exclusively male bachelor herds and single, old bulls occupy these sedge meadows as well, but they were also found grazing in lower elevation xeric, *Stipa* grasslands.

From late August to early September, wild yak nursery herds abandon high elevation mesic, sedge meadows and move to lower elevation *Stipa* grasslands. This movement seems to coincide with the maturation of *Kobresia* in sedge meadows. Following this movement to *Stipa* grassland habitats in the autumn, yak diets mirrored these shifts in location; *stipa* grasses became more prevalent than sedges in faecal samples (Table 3). Wild yaks begin their rutting period in late September. Large nursery herds and smaller bachelor herds unite to form large mating herds.

Table 3: Relative Density of Plant Fragments Found in Wild Yak Faecal Matter Determined in Summer and Autumn after a Major Range Shift

Plant Genus	Summer	Autumn
Sedges		
Cares	5.3	2.1
Kobresia	67.1	23.2
Grasses		
Stipa	2.8	66.2
Poa	5.6	2.6
Forbs	10.3	3.8

Lu et al. (1993) described two ecological types of wild yak, the Qilin Mountain type and the Kulun Mountain type. Given the similarities the author observed among and between the herds which formed the basis of his research, however, it is believed that all wild yaks should be classified as just one type.

CONCLUSION: WILD YAK CONSERVATION ISSUES

Populations of wild yak have declined considerably in recent decades. It is now impossible to find wild yaks in areas of Qinghai Province that once boasted flourishing herds. The construction of roads in remote areas has allowed hunters to access previously remote wild yak herds. Although wild yaks are officially protected under China's wildlife legislation, these animals are still being hunted and killed at an alarming rate. Aside from the growing network of roads throughout rural China, poachers have increased access to trucks and other off-road vehicles, as well as modern weapons. Wildlife authorities are poorly trained and are not equipped to control illegal hunting.

The number of wild yaks in the Qinghai-Tibetan Plateau probably totals no more than about 14,000 animals. There are about 300 wild yaks in Gansu Province, 2,500 wild yaks in Xinjiang (Arjin Mountain Reserve), 1,500 wild yaks in the Wild Yak Valley of Qinghai, 400 in the east Burhan Budai Mountains of Qinghai, perhaps 150 animals in Tian Jun County of northern Qinghai, 2,000 head in the Kokoshili region of western Qinghai, and about 7,000 in the Chang Tang Reserve in the Tibetan Autonomous Region.

It is urgent that the widespread protection of the remaining wild yaks be undertaken. Continued surveys of existing herds should be conducted. Funds should be provided to wildlife organisations for establishing and enforcing anti-poaching measures. Concomitantly, the Wild Yak Valley in Qinghai Province should be declared a national nature reserve. This stretch of plateau is not only home to viable populations of wild yak, but it is also an ideal habitat for other wild animals such as the argali, blue sheep, Tibetan gazelle, and Tibetan antelope.

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Use of and Research on Wild Yaks in China

Han Jianlin and Lu Zhonglin

INTRODUCTION

The wild yak *(Bos grunniens)* is the ancestor of the domestic yak *(Bos grunniens)*. Both animals belong to the species *Bos grunniens*. The distribution and ecological variation found among wild yak populations have been discussed by Zhonglin (1993) and Zhonglin and Kongliang (1994). These scientists assert that wild yaks inhabit alpine meadows in the western Qilian mountain region and the eastern Aerjin Mountains; these animals are classified as the 'Qilian type'. Wild yaks found in the Kunlun mountain area and across northern Tibet are labelled the 'Kunlun type'. From 1990 to 1992, surveys on general habitat types and herd composition of wild yaks were conducted by D. J. Miller and his colleagues in the Wild Yak Valley, Qinghai Province, China.

The first report that compares differences in growth and development between wild and domestic yaks was published by Xu Guiling in 1995; data for this report were gathered in Yushu Prefecture, Qinghai. Guiling (1995) found that wild yak calves were 86 per cent and 63 per cent heavier than the domestic yak calves at three and 16 months of age, respectively. It was thus concluded that wild yaks may be used to improve domestic yak breeds. This paper provides information regarding the use of wild yaks for such purposes.

DOMESTICATION OF WILD YAKS FOR BREEDING PURPOSES

In 1980, a pair of (male and female) wild yaks (Qilian type) were caught by hunters from the Subai Yugur Autonomous County of Gansu Province. Two offspring (bull calves) were produced in June 1981 and July 1983. In 1990, two wild yak bulls (Kunlun type) were obtained from the Yushu and Haixi Prefectures of Qinghai Province. Subsequently, these four bulls were tamed in order to collect their semen; this semen was then used for artificial insemination (AI) cross-breeding purposes. This work, which requires intensive management and training, was carried out at the Datong Yak Farm in Qinghai in cooperation with the Lanzhou Institute of Animal Science of the Chinese Academy of Agricultural Sciences (CAAS). This marked the establishment of the first wild yak bull station.

Since 1983, F1 crossbreeds of the wild yak bulls mated with domestic yak cows were produced through AI at Datong Yak Farm. Nine semi-wild yak bulls selected from the F1 offspring of the two Qilian type wild yak bulls were also tamed to facilitate semen collection.

USE OF THE FROZEN SEMEN OF WILD OR SEMI-WILD YAK BULLS

Since 1991, the annual yield of frozen yak semen collected at Datong Yak Farm has been about 50,000 pellets. These pellets have been used for artificially inseminating domestic yak cows in the Tibetan, Qinghai, Gansu, Yunnan, and Xingjiang Provinces of China. The results of this hybridisation revealed that conception and live birth rates were 40-50 per cent higher than those of domestic yak herds that mate naturally (see Table 1). Despite these significant improvements, it remains difficult to extend the use of the frozen semen of wild yaks to general production areas including to most private herds, because of the poor organisation of breeding facilities and the unreliable control of the temperatures required for the artificial insemination process.

Table 1: Conception Rate and Reproductive Alive Rate in AI

Location	Cows mated	Con. rate	Repro. live rate	Duration
Datong Yak Farm	1537	88.90	85.97	1984-1989
Shandan Horse Farm	268	76.12	67.77	1987-1989
Gannan	1222	78.64	58.30	1987-1989

GROWTH AND DEVELOPMENT OF F1 GENERATION

The growth and development of the F1 generation and local yaks in Gannan and Datong Yak Farms are shown in Table 2

Table 2: Body Measurements and Live Weight of F1 and Local Yaks in Gannan at Different Development Stages (unit:cm, kg)

Month	Group	Sex	No	Height	Length	Heart Girth	CCB ***	Weight
New borns	SWY*	m	4	59.20	54.75	63.50	9.75	16.00
		f	5	56.50	48.60	60.20	8.70	13.84
	LY**	m	10	51.90	45.40	58.60	8.25	13.17
		f	7	53.92	46.77	58.00	8.16	13.21
3	SWY*	m	12	71.54	72.42	86.67	11.13	39.09
		f	11	70.64	75.91	89.82	11.00	43.25
	LY**	m	7	69.00	69.50	84.71	10.36	35.19
		f	6	69.25	67.25	84.82	10.67	33.71
6	SWY*	m	13	71.12	70.69	92.96	10.70	42.80
		f	12	70.14	71.17	89.13	10.63	39.58
	LY**	m	12	67.42	67.46	83.00	10.33	32.54
		f	14	68.93	68.86	86.86	10.04	36.74
12	SWY*	m	17	80.71	83.68	106.06	12.91	66.10
		f	10	80.80	83.25	107.70	11.80	67.48
	LY**	m	11	72.27	72.41	92.09	11.45	43.09
		f	14	72.12	72.24	96.57	11.64	47.52
18	SWY*	m	9	97.00	100.70	125.22	14.98	108.16
		f	5	89.50	89.50	113.80	13.90	81.08
	LY**	m	10	83.75	91.60	113.10	13.35	82.41
		f	11	84.57	88.50	112.09	13.77	78.60
24	SWY*	m	6	97.33	98.83	125.17	14.50	114.04
		f	5	94.70	98.70	121.80	14.10	99.45
	LY**	m	10	82.50	85.75	108.60	12.81	70.90
		f	10	81.65	84.15	107.80	12.75	69.20

**SWY = semi-wild yak, **LY = Local yak; ***CCB = Circumference of cannon bone* and Table 3 respectively. As the figures reveal, the F1 generation had a faster growth rate than that of local yaks. The body weights of F1 animals at six months at Datong Farm were higher than those of the F1 generation in Gannan; this discrepancy can be explained by the fact that the cows in Gannan are milked, whereas in Datong they are not, even though the average weight of newborns in Gannan was slightly higher than that of Datong newborns.

Table 3: Body Measurements and Body Weight of F1, F2 and Local Yaks at Age Six Months, Datong Yak Farm (unit: cm, kg)

Items	F1	F2	Local Yaks
No	7	7	7
Height	82.42	84.43	79.36
Length	87.71	87.07	82.00
Heart Girth	106.17	106.79	96.36
CCB	12.43	12.00	11.29
Weight of new born	12.78 (49)*	12.40 (46)	10.21 (40)
Weight at 6 months	70.70	74.71	59.83

*(): number of animals tested

Consequently, management changes should be implemented in Gannan. Milking procedures should be altered. Measurements for controlling the total yak population and avoiding overgrazing should also be introduced. (One possible solution to the latter problem is to process calves for beef once they reach six months of age.)

Table 4: Comparison of Average Body Measurements and Live Weights of F1 and Local Yaks Aged 18 Months, Datong Yak Farm (unit: cm, kg)

Group	Sex	No	Height	Length	Heart Girth	CCB	Weight
Local Yak	m	3	101.83	103.67	132.00	13.90	126.97
	f	3	99.17	102.50	130.50	13.50	108.50
F2	m	3	104.67	109.30	144.17	15.17	153.17
	f	3	101.67	107.67	139.00	14.00	147.83

Similar data were also obtained about the cross-breeding of wild and domestic yaks through AI in Sichuan, Xingjiang, Tibet, and Yunnan.

CHARACTERISTICS OF THE F2 GENERATION (FIxF1)

Beginning in 1990, F2 generation herds were produced at the Datong Yak Farm, the National Shandan Horse Farm, and Liqiaru Farm. A total of 491 animals were produced from the F2 generation. No obvious segregation in terms of body colour, measurement, or weight were found between the F1 and F2 generations (see Tables 3 and 4).

PRODUCTION OF BACK-CROSSES OF F1 BULLS WITH DOMESTIC YAK COWS

Due to the stable growth and development of the F1 and F2 generations, the selection of F1 (semi-wild) bulls for the production of back crosses attempted to take advantage of as many of the wild bull's genetic strengths as possible. Since 1990, 124,000 pellets of frozen semen of F1 bulls were gathered. Two hundred and ten F1 breeding bulls were extended to Qinghai, Gansu, Tibet, Yunnan, and Xingjiang. This dissemination of F1 bulls helped alleviate some of the problems faced by remote provinces in successfully carrying out AI.

Breeding results indicate that the body weights of newborns and six-month-old back-crosses were lower than those of the F1 generation but significantly higher than those of local yaks in Datong (see Table 5). It can be concluded that crossing F1 bulls with local yaks is a beneficial and productive venture that can be practised on most private farms.

Table 5: Weight of Newborn and Six Month Old Back-cross (F1 bulls X local cows), F1 Generations, and Local Yaks (unit: kg)

	Weight of Newborns		Weight at 6 months	
	Male	Female	Male	Female
Back-cross	15.81 (35)	14.84 (41)	88.25 (8)	84.77 (13)
F1	17.74 (45)	16.84 (32)	102.3 9 (22)	99.09 (11)
Local yaks	13.23 (13)	13.21 (12)	66.74 (33)	63.74 (31)

USE OF WILD YAKS FOR GENETIC IMPROVEMENT OF DOMESTIC YAKS

By August 1993, a system which included the Breeding Bull Station at Datong Yak Farm; the nucleus F2 herds in Datong, Shandan, and Gannan; the reproductive herds of F1 bulls; and extension areas in Qinghai and Gansu had been established. These efforts will help secure the future production of frozen wild yak semen and F1 bulls for cross-breeding purposes. Due to the wild yak's genetic superiority, efforts of this kind aim to select and breed a new strain of domestic yak that contains 50 per cent of the wild yak's genetic makeup.

NEED FOR FURTHER RESEARCH: GENETIC CHARACTERISTICS OF THE WILD YAK

The protein polymorphisms of the F1 generation wild yaks were studied by Zhang Caijun (1994) and Tu Zhenchang (1996). Little is known, however, about the genetic background of wild yaks. It is important to distinguish the genetic differences which exist between wild and domestic yaks. Molecular biological methods should be employed to detect *"the relative importance of the role of heterosis and of the additive genetic contribution from the wild yak to its cross with the domestic yak."* (Cai and Wiener 1995).

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SECTION

Two

The Yak
A Photo Essay

Daniel J. Miller

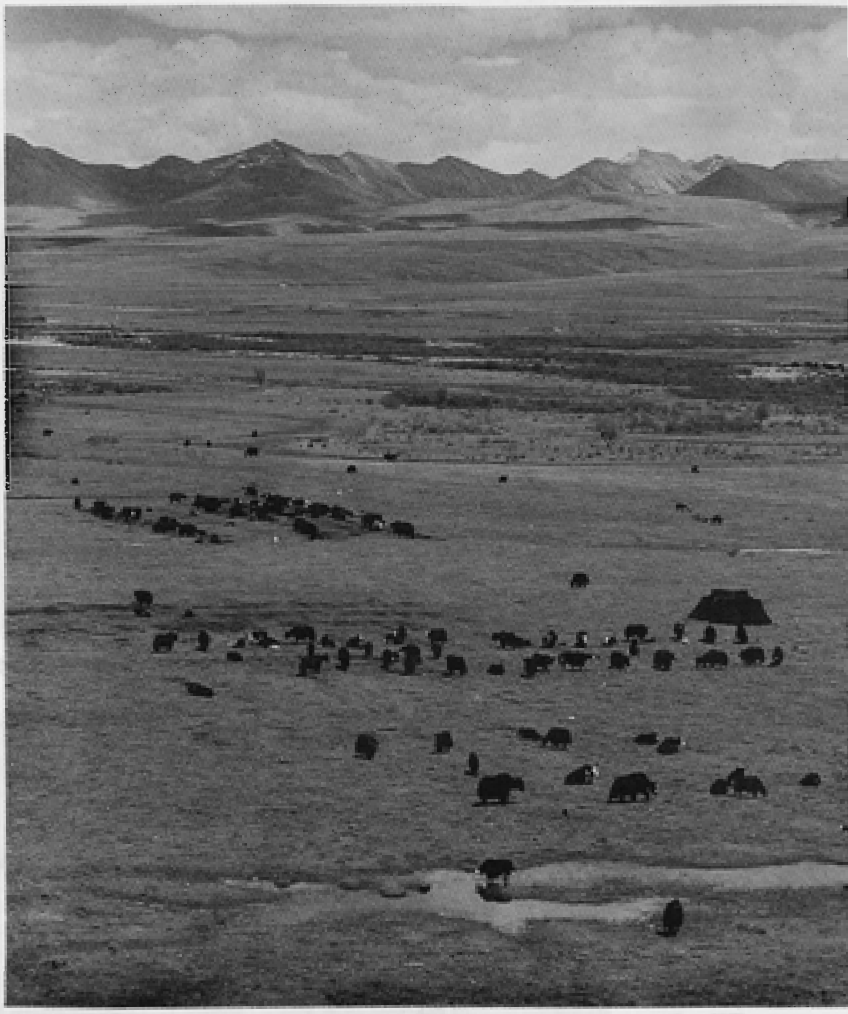
Yaks tied up for milking, Hongyuan, Sichuan Province, China

Yak herder, Zhongdian,
Yunnan Province, China

The yak as transport, Maiwa, Sichuan Province, China

Yak pastoralism is perhaps 4,000 years old. The fact that prosperous pastoral groups remain to this day bears witness to the extraordinary animal husbandry skills of the herders and the productivity of the Tibetan rangelands.

Yak productivity is often constrained by inadequate forage, especially in the winter. This leads to poor nutrition, disease, and reduced fertility. These problems are sometimes exacerbated by increasing livestock numbers which places more pressure on rangelands, often leading to overgrazing and declining rangeland productivity. Improving yak productivity and maintaining yak genetic diversity will require that the rangelands, upon which yak production systems depend, be well managed.



Nomads at a spring pasture, Hongyuan, Sichuan Province, China

In much of northern Sichuan Province, China, an average nomad family maintains a herd of 100-150 yaks with about 50 milking females. This number of animals is about the optimum number of yaks a typical nomad family, with five members, can manage with the available labour.

Pure-bred yaks are also trained to the saddle and used both as pack animals and as mounts. Yaks, once trained, are easily handled, even by women and children. Yak races are held in some parts of Tibet. These events, like their equestrian equivalents, are popular community events wherever and whenever they occur.

Nomad camp, Hongyuan, Sichuan Province, China

Tibetan nomads near the headwaters of the Yangtze River, Qinghai Province, China

Since yak-raising areas are often remote, at high elevations, and sparsely settled, they have largely been neglected in the past by most research and development agencies. In many areas on the Tibetan Plateau, nomads are now being 'settled', rangelands are being divided into individual family units, and the rangelands are being fenced. Monitoring the condition of rangeland , as these new yak husbandry practices are being implemented, will be an important activity.

Yak crosses as riding animals, Zoige, Sichuan Province, China

Yak hybrid cross being milked, Dolpo, Nepal

Yak hybrid crosses give more milk than pure-bred yaks and can calve every year. Intricate cross-breeding programmes have been developed by herders and the various offspring of these crosses and back-crosses have separate terminology. The female hybrids are fertile and can be bred to either yaks or cattle bulls, but males are sterile.

Yaks and yak crosses are often ridden in the winter instead of horses since horses tend to be weak at this time. Yaks are sure-footed and travel easily across rough terrain. They can also withstand colder temperatures than horses.

Migrating to summer grazing land, Aba, Sichuan Province, China

Tibetan yak herder, Aba, Sichuan Province, China

Herders inside a yak hair tent, Qinghai Province, China

The unique structure of Tibetan yak hair tents allows light to enter, yet rain is repelled. Tents can easily be packed up and moved to new camps on the backs of yaks.

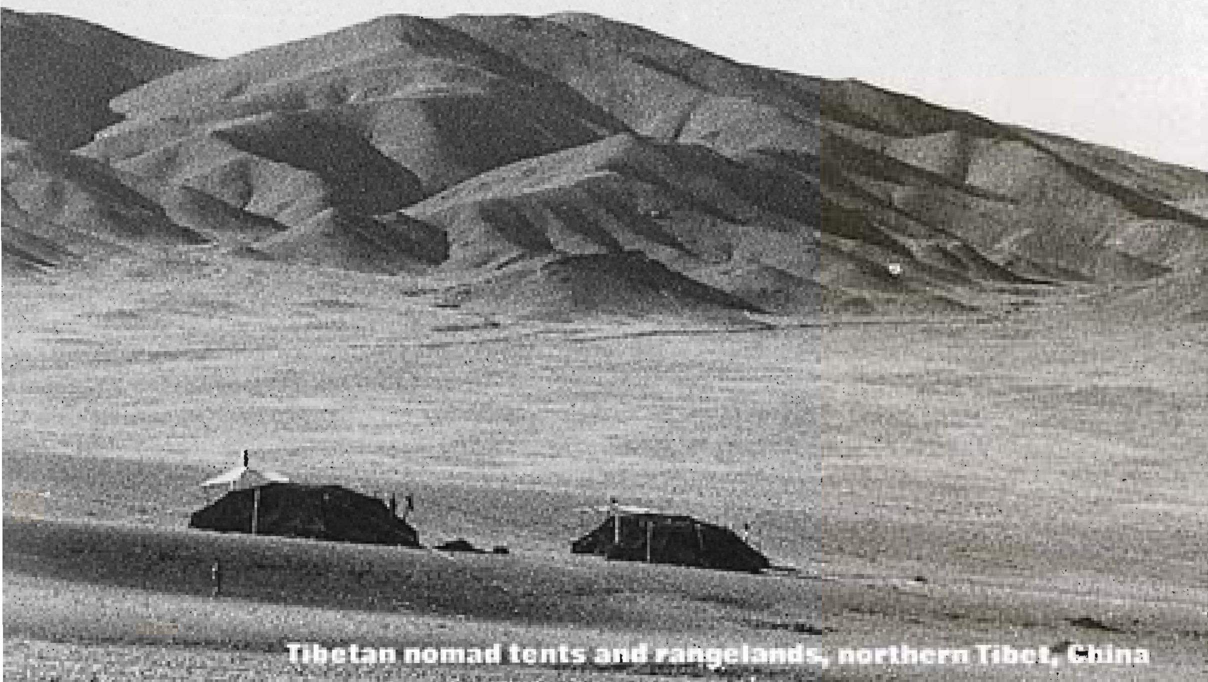
Traditional yak pastoral management systems were designed around mobility and the tracking of favourable forage conditions. Women manage livestock alongside men and are valuable sources of knowledge about pastoral systems.

Existing indigenous pastoral systems need to be better understood to ensure that the goals and needs of pastoralists are incorporated into new development programmes. Herders should be active participants in the development process. Analysis of the ecolgical and social processes at work in pastoral areas is a key challenge for researchers working with yak production systems.

Yak herder, Sakten, Bhutan [also cover page]

Yak herders have acquired intricate ecological knowledge and understanding of the landscape in which they live and upon which their lives depend. Local climatic patterns and key grazing areas are determined, allowing herders to select favourable winter ranges that provide protection from storms. Yak development planners need to access this vast indigenous knowledge and incorporate such knowledge in livestock development programmes.

In many areas on the Tibetan Plateau, herders raise both sheep and yaks. In western Tibet, goats are an important animal. Such a mix of livestock is often the most efficient way to use rangeland vegetation since different species of livestock graze on different plants. Maintaining a mix of animals is also a strategy pursued by herders to ensure livestock survival in the event of diseases affecting certain species.



Tibetan nomad tents and rangelands, northern Tibet, China

Tibetan nomads' tents are made from strips of woven yak hair. This material is durable and water-resistant. It also insulates heat well. Without yak wool tents, pastoralists from throughout the Himalayas and the Tibetan Plateau would not be able to thrive in the high, harsh environments.

Yak hair is woven on simple looms and the belts of yak cloth are then sewn together to make tents. Weaving is done by women, but much of the spinning of yak hair is done by men. Yak hair and wool are also made into clothes, blankets, bags, and ropes.

Tibetan yak hair tent, Luqu, Gansu Province, China

Weaving yak hair for a tent, Hongyuan, Sichuan Province, China

Man spinning yak hair, Dolpo, Nepal

Moving to greener pastures, Zamtang, Sichuan Province, China

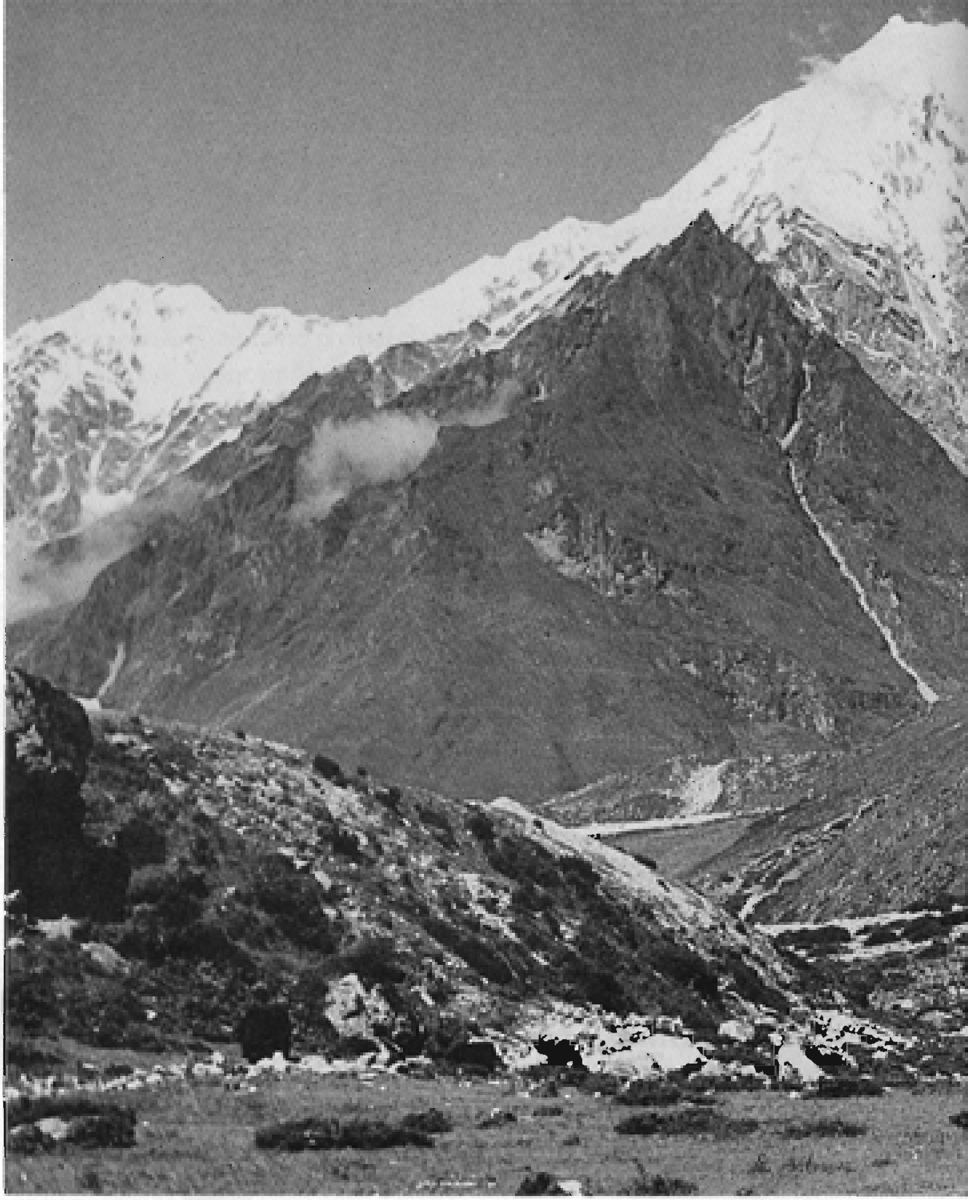
Adjusting loads on a yak, Aba, Sichuan Province, China

Yak herders do not move randomly across the rangelands; their movements are often well prescribed by complex social organisations. Pasture management, like irrigation in agricultural and agro-pastoralist communities, is highly regulated among nomadic herders.

Yak herders are adept at handling animals. Theirs is a lifestyle on the move. Herders' wealth and property must fit on the backs of their animals — aside from being the animals themselves.

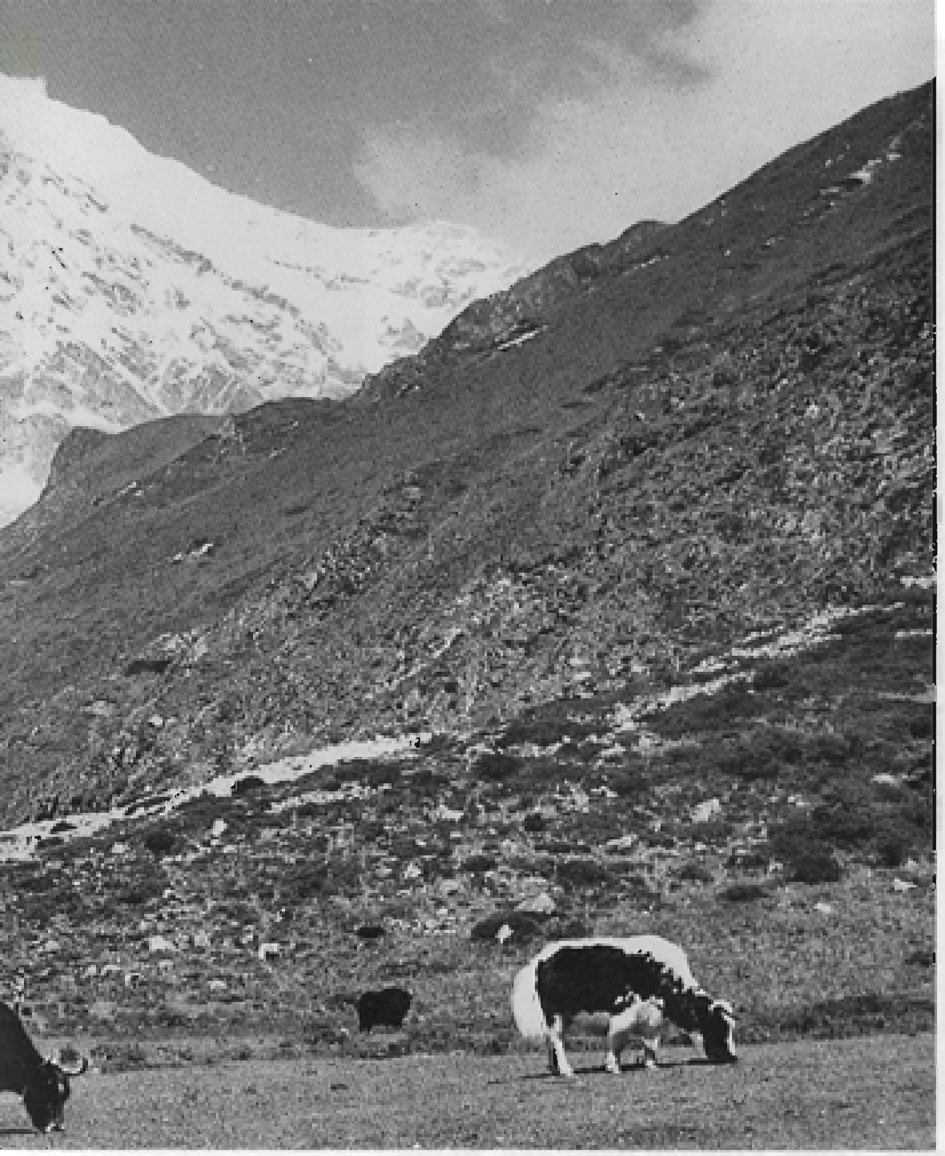
Pastoral development policies often maintain that yak herders are 'backward' and that their traditional practices need to be improved. Increasingly, however, traditional pastoral production systems are viewed as highly efficient exploitation strategies for living in a harsh environment.

Travelling on the hoof, Hongyuan, Sichuan Province, China



The world's first yak cheese factory was established in the Langtang Valley of Nepal in 1951. The factory now produces about six tonnes of yak cheese annually. There is considerable potential for expanding yak cheese-making technologies to other yak-raising areas.

Rangeland degradation is of growing concern in many yak-raising areas. Improving yak productivity depends on maintaining rangeland conditions. Those involved with managing rangelands, and they include herders, researchers, extension workers, and policy-makers, need to make the best use of the information available and the new ideas emerging about rangeland ecosystems.



Yaks in Langtang, Nepal

Yaks in sand dunes, Hongyuan, Sichuan Province, China

Nomad camp, Zoige, Sichuan Province, China

Yak herders in Nepal often maintain native grass fields. Hay is harvested from these fields and used as supplementary fodder during the winter. Hay fields in the Mount Everest region, at 4,700m, are some of the highest elevation hay fields in the world.

White yak tails were once an important export item for Tibet; they were shipped to the USA and used for making Santa Claus beards. Developing markets for high-value yak products should be a priority activity in yak development programmes.

The wide appreciation for the complexity and ecological and economic efficacy of traditional yak pastoral systems is encouraging. It provides hope that the wealth of indigenous knowledge that herders possess will be better understood and used in designing new interventions.

Summer grazing lands and hay fields, Khumbu region, Nepal

White yak, Tianzhu, Gansu Province, China

Summer grazing lands and hay fields, Khumbu region, Nepal

White yak, Tianzhu, Gansu Province, China

Conservation and Management of Yak Genetic Diversity in The Tibetan Autonomous Region

Huang Wenxiu

BACKGROUND

Importance and Number of Yaks

More yaks live in China than any in other country in the world. Approximately 13 million of these large, high altitude bovines occupy China's rangelands, comprising 92.8 per cent of the gross number of yaks on this planet. Yaks provide milk, meat, wool and transportation to herders across China's highlands. The yak's unique genetic makeup is also a valuable resource.

The wild yak, the animal from which the domestic yak originated, can still be found throughout the Tibetan Autonomous Region, on the northern Tibetan Plateau, around the Kandgese Mountains, and at the foot of the Himalayas. Herders often see groups of wild yaks while grazing their domestic flocks. Domestic and wild Tibetan yaks sometimes share habitats, as both usually graze on pastures above 3,500 metres. Consequently, wild male and tamed female yaks often mate. Little information exists about the history of the domestication of the wild yak; however, it cannot be disputed that this interbreeding remains a vital means of maintaining quality domestic yak herds.

Four million yaks live in Xizang, the Tibetan Autonomous Region — almost one third of the total number of yaks in China. Yaks are the most important domestic animals for Tibetan herders. Without the yak, people across the Tibetan Plateau could not survive. As such, Tibetan yak protection and development, and the efficient use of yak by-products, is fundamental to improving the lives and livelihoods throughout the Tibetan Autonomous Region.

Domestic yaks are widely distributed throughout the Tibetan Autonomous Region. Although sheep and goats outnumber yaks, the latter remain the most important of all livestock. Without yak products — milk, beef, and wool — the nomadic and semi-nomadic Tibetan peoples could not survive. Butter and cheese, primary milk by-products, are two of the major sources of nutrition for Tibetans. Yak wool is used to weave tents and ropes, as well as to make textile materials. Pack yaks provide transportation power and are indispensable for locals who must travel vast distances to market or from one settlement to another. Yaks are indespensable to local and national economies.

Collectivisation across the Tibetan Autonomous Region has created many opportunities for yak development. As agricultural

Table 1: The Yak's Quantitative Distribution in the Tibetan Autonomous Region and Percentages in Local Livestock Populations(%)

Area	Tibet	Nagqu Pref.	Qambo Pref.	Xigaze Pref.	Lhasa City	Shannan Pref.	Ngari Pref.
Percentage in local livestock population	18.50	22.55	31.47	11.85	27.14	9.63	5.03
Quantitative distribution	100.00	38.09	26.46	14.92	11.78	5.85	2.90

modernisation continues throughout China, the Tibetan Autonomous Region is sure to become one of China's chief yak-raising and production centres.

Geographical Distribution of Yaks across the Tibetan Plateau

China's yaks are primarily distributed over the Qinghai-Tibetan Plateau and along its borders by the Himalayan, Hengduan, Qilian, Aerjing, and Kunlun mountains. More than one-third of China's yaks are found within the boundaries of the Tibetan Plateau.

Tibetan yaks are specifically adapted to the Plateau environment. Domestic yaks are mainly distributed throughout the grasslands from 4,000 to 4,700 metres. These distribution areas are inhabited by either agro-pastoralists or purely nomadic herding communities. Yaks range from pastures as high as 5,300—5,500 metres in summer and autumn, to grasslands between 2,500 and 3,000 metres in winter and spring, relying on high-altitude alpine grasslands for survival.

The yaks of Nagqu and Qamdo Prefectures account for 38.09 per cent and 26.46 per cent of the regional yak population, respectively. The percentage of yaks within the overall livestock numbers is quite high throughout the Tibetan Autonomous Region. The yaks in Nagqu account for 22.55 per cent of the local livestock population; those in Qamdo comprise 31.47 per cent. The Ngari and Shannan Prefectures have fewer yaks, accounting for 2.09 per cent and 5.85 per cent of the Regional yak population (5.03% and 9.63% of the local livestock population), respectively. Yak populations in Lhasa and the Xigaze Prefectures remain in between these two extremes. For details of yak distribution across Tibet, see Table 1. This table analyses the administrative distribution of Tibetan yaks.

In order to get a better understanding of the relationship between yak distribution and environmental factors, the author has conducted a comparison of the proportion of yaks to overall livestock populations in several of the region's stock-raising counties from east to west (31°—33° north latitude). Meterological factors were also considered and distribution densities per unit area were also determined (see Table 2). The results of this enquiry reveal that the percentage of yaks within the local livestock population, as well as their distribution density, remain lower in the west than other areas of the Region. Gradual reduction of rainfall and increasing aridity in climate from east to west also contribute to these results. In the Riwoge and Nagqu counties of eastern Tibet — areas in which yak populations are more dense and more predominant — the annual average temperature ranges from -19°C to 3. 2°C; annual rainfall ranges between 400 and 650 mm; and the humidity coefficient ranges from 0.7 to 1.0. Nutgrass, flat sedge, and weeds predominate.

Table 2: Relationship of the Proportion and Distribution Density of Yaks to Meteorological Factors in Several Stock—raising Counties in the Tibetan Autonomous Region

County Names	Meteorological Factors: Annual average temperature (°c)	Annual rainfall (mm)	Coefficient of humidity	The proportion of yaks in the local livestock population %	The Yak's distributive density per unit area (h/km)	Grassland zone
Riwaoqe (3920 m)	3.2	649.4	1.05	39.41	16.59	Timber-pasture
Nagqu (4507 m)	-1.9	400.1	0.65	25.80	17.05	Timber-Pasture
Bangion (4700m)	-1.2	301.2	0.40	12.16	1.29	Prairie grassland
Coqen (4668m)	0.1	166.2	0.18	6.64	1.39	Prairie grassland
Gar (4278m)	0.2	60.4	0.09	5.14	0.61	Desert grassland

Given these environmental parameters, these areas are classified as timber-pasture grasslands. As such, yaks not only thrive in cold, arid plateau habitats but can also adapt to semi-humid climates; yet yaks prefer high, grassy marshlands. Since western Tibet is quite arid, this part of the region can support fewer yaks.

YAK PRODUCTION

Milk Performance

The milk performance of yaks varies among individuals and in accordance with feeding and management systems, particularly with the quality of grasslands and the change of seasons. The milk yield and butterfat content of the yak are the two basic elements by which milk performance is measured.

Milk Yield

The overall milk yield of a female yak depends on the duration of lactation. Most female yaks in Tibet begin producing milk in April or May, immediately after calving. Annual lactation periods last from five to seven months per year (range: 3-8 months). A lacating female yak who does not conceive in consecutive years can be expected to produce milk until the end of the autumn the year after she gives birth. Dams who give birth every two years will lactate for about 14-15 months.

No systematic record of Tibetan yak milk production exists. During the author's investigation, some milk yield measurements were taken (see Table 3). Table 4 is included for comparative purposes and includes statistics regarding milk production of yaks in Nugqu County made in 1965 by the Animal and Veterinary Scientific Research Institute of the Tibetan Autonomous Region.

As is indicated in Table 3, milk yields of lactating female yaks are low before June, average daily yields not exceeding one kilogramme. This low output is due to grass shortages after the calving period and the effects of winter and spring weight losses.

Table 3: Daily Milk Yield of a Lactating Females which Calved the Same Year

Time	Number	Daily Milk Yield: Average	Range	Place
Middle ten days of June	12	0.65	0.30-1.05	Zhongba county
Middle ten days of July	5	2.10	1.60-2.40	Jomba county
Last ten days of August	10	2.10	1.75-2.50	Lhunze county
First ten days of January	120	0.26	0.22-0.32	Jiali county

Table 4: **Average Daily Milk Yield of a Lactating Yak in Nagqu County**

Time	Number	The milk yield of a lactating yak which calved in the previous year (kg)	Number	The milk yield of a lactating yak which calved in the previous year (kg)
Middle ten days of July	55	0.60	14	1.18
First ten days of August	38	0.79	16	1.30
Middle ten days of August	16	0.81	11	1.44
Last ten days of August	13	0.78	11	1.52
First ten days of September	13	0.70	11	1.38

After July, daily yields gradually rise, paralleling grass growth and peaking in late August. When grasses begin to yellow in September, yields drop. Milk production peaks between July and September, during which time the average daily milk yield is about 1.5-2 kg (Range: 1-2.5 kg). After December, pregnant, lactating female yaks will go dry; those female yaks that are not pregnant, but which are lactating, may continue to produce 0.2-0.3 kg of milk per day. As grasslands grow throughout the summer and fall, the daily milk yield of these females will reach another small peak (see Table 4). The milk production of female yaks which calve every two years will peak twice in a given lactation period, while females which calve each year only peak once. A female's overall milk yield per lactation period is about 200-300 kg, after calves have suckled. According to Academia Sinica's Integrated Survey Work Team, which was sent to Tibet in 1961, the average yearly milk yield of yaks on the Heihe Farm in Nagqu Prefecture was 280.77 kg, with maximum and minimum yields of 439.67 kg and 245 kg, respectively. Including the milk suckled by calves, the total yield per lactation period did not exceed 500 kg, a little lower than that (450-600 kg) of the Tian Zhu yak found in Gansu Province.

Butter-Fat Percentage

Butter-fat percentage is one indicator of milk quality. The author has calculated this percentage as the ratio of butter yielded by local herders to overall milk yield. The butter-fat content of milk from Bangoin County was 7.0 per cent in August, compared to 7.3 per cent measured at the same time of year in 1961 in Pagri, Tibet. Fluctuations in butter-fat content occur due to shifts in milking season, feed management, individuality, and milk yield. In summer and autumn, when yaks feed only on grasses, they can produce more milk; but butter-fat is comparatively low. Herdsmen believe that milk produced from lactating female yaks which have recently calved will have a lower butter-fat content than milk from females who gave birth the previous year. Data gathered in Tibet in summer and autumn indicate that butter-fat percentages in different geographical areas range from six to eight per cent. Milk from Tibetan yaks has a high butter-fat content, twice as high as that from average dairy cattle (3.5-4%) and slightly lower than buffalo milk (8-10%).

Beef Yield

Compared to yaks in other parts of China, Tibetans yaks mature later and are lighter, therefore decreasing the overall beef yield. Female yaks in Nagqu Prefecture average 199 kg. Castrated yaks from Damxung County average 267. 80 kg after reaching maturity (4-5 years). The average dressing percentage of Tibetan yak is 42.8 per cent for mature females (more than nine years old) and 45.5 per cent for castrated yaks (7-11 years old). These measurements were taken in Damxung County in October, 1974, by the Animal and Veterinary Scientific Research Institute, Tibetan Autonomous Region. Elderly, culled yaks are slaughtered for meat in October or November after being fattened up in summer and autumn. These yaks have less fat distribution and their muscle fibres are thicker than those of other animals; protein and ash percentages are also higher. According to some sources, yak muscle fibre has a diameter of 60.29 microns, thicker than Mongolian cattle (45.90 microns). Coarse protein accounts for 22.7 per cent; fat, ash, and dry materials account for 0.31, 1.15, and 24.73 per cent, respectively.

Draught Performance

Called the 'ship of the Plateau', yaks have provided for Tibetans' transportation needs for centuries. In Tibet, only castrated yaks ('pack yaks') are uses for draught purposes; female yaks and studs never work as draught animals. Pack yaks are chiefly employed for transportation and ploughing. Two yaks can plough two *mu** of land each day. Yaks have much more endurance and strength than horses, the other logical alternative for fulfilling transportation needs.

Pack yaks are broken into the saddle between four and six years of age. In general, each yak can carry 50-60 kg; a single herdsman can manage more than twenty head of pack animals. Yak caravans begin moving at dawn, eat grass along the way, stopping only at dusk. These caravans can cover 20-30 km daily. In autumn, when yaks are plump and sturdy, caravans may cover even more ground per day.

Hair and Other Products

Although yaks do not produce very large amounts of milk and beef, they possess a variety of other economic benefits. Yak hair and fur are two important livestock products. Across Tibet, yaks are sheared every June-August. Yak hair is used to weave tents, ropes, and sacks; yak fur is mixed with sheep wool to produce high quality woollen goods. The fur-hair yield of yaks varies with the sex and individuality. The fur-hair yield of adult female yaks in Somda County is 0.25 kg; this same yield among adult pack yaks in Lhunze County is one kg. The average annual fur-hair yield of one female yak is between 0.3 and one kg, whereas the pack yak produce 0.5-1.5 kg. According to the 1961 Academia Sinica survey, the average fur-hair yield of non-pregnant, lactating female yaks which calved that year is 0.35 kg (range: 0.2—0.5 kg).

Castrated males produce the maximum fur-hair yield. Although breeding male yaks are entirely covered with long, thick hair, they are either selectively sheared or not sheared at all. This not only preserves their 'majestic' appearance, but also provides the animals with some protection. Yaks less than one year old are not sheared. Yak tails — particularly white ones — are exported and processed into ornaments. Yak manure is used for fuel throughout pastoral areas. Yak skin provides raw materials for the leather industry, though cattle skin is of better quality.

YAK BREEDING AND NUTRITION

Yak Reproduction

Selection of Male Yaks for Breeding

Only superior bulls are used for breeding. Experienced herdsmen pay close attention to bull selection, which occurs by the time a bull is four, at which time those not selected are culled and castrated. Usually, herdsmen select male calves born from fe-

* *A mu = 1/6 of an acre or 1/15 of a hectare*

male yaks with large, strong bodies and high milk performances. Breeding bulls should be well-developed with long, thick hair, straight limbs, and sturdy hooves. The colours preferred for breeding bulls are brown and black; white facial markings are also desirable.

Sexual Maturity and Age at First Breeding

Individuals who have adequate access to good pasture will develop and breed well. Under these conditions, male yaks reach sexual maturity at two years, while females mature at two and a half years. However, this only marks the beginning of their sexual maturity. In practice, they will not be bred until the female yak is about a year older and the male is four or five years old.

Mating Season and Gestation Period

Yaks usually breed between July and September and mating occurs naturally. The ratio of males to females in a given mating herd depends on the male's covering capacity. In general, this ratio is 1:10-30. (Some experienced herdsmen think this ratio should be maintained at 1:15.) No precise records are available on gestation periods, but most local herdsmen believe it to be nine months. The average gestation for the ten female yaks at the Datong yak farm in Qinghai Province (producing a hybridized calf) is 269 days, with a range from 254 to 285.

Lifespan and Reproductive Efficiency

According to the author's investigations, yaks live about 20 years. A male yak only breeds for 10 years, after which time it is culled and used for other purposes. In some areas, intense service prompts early aging and male yaks are castrated at eight years to ensure offspring quality. Female yaks may be used for mating until they are 12 or 13 years old, at which time they are culled. Female breeding yaks usually calve every two years. Those that are fed on richer grasslands are known to give birth each year, though such yaks only account for five-10 per cent of all female breeding yaks, according to locals. Some farms and communes — including the Gyorxung Stud farm in Qamdo Prefecture and farms in Nangarze County — boast animals who routinely calve once a year or three times in two years. This increased production is directly proportional to quality and quantity of fodder and feeding management.

Yaks rarely produce twins; when they do, the offspring are weak and rarely survive. A female breeding yak can only produce five or six calves in her lifetime. Reproductive rates are low due to the cold plateau environment. According to the Animal and Veterinary Scientific Research Institute of the Tibetan Autonomous Region, the 1,910 adult female yaks at the Mongdoi Commune in Nagqu County produced 919 calves in the six years from 1959 to 1965, a reproductive efficiency of 48.11 per cent.

Feeding and Management of Yaks

Feeding

Yaks are only able to reach optimum performance and production levels when they are adequately fed. These animals live on natural pasture grasses all year round and are seldom given supplementary forage. During the grassless winter and spring, only old, weak, sick, and young yaks are given extra food such as crop straw, dried grass, concentrate, waste tea, and bone soup.

In recent years, supplementary feeding programmes have been systematically introduced, along with the steady growth of collective production. A few communes are beginning to supply all their yaks with supplementary feed. Even so, yaks still primarily depend on natural pastures. Shifts in grassland quality and quantity affect yak weights. The saying that yaks are *"alive in summer, strong in autumn, thin in winter, and tired in spring"* is an accurate description of yaks across China. Tibetans are now trying to improve on feeding methods to increase production and advance animal husbandry techniques.

Local herders feed yak salt and soda in the summer. In pastoral areas of northern Tibet, for instance, yak herds are driven every ten days to graze on grasslands containing salt and soda. Freely licking this saline-alkaline soil replenishes the yak's lost salt and other essential minerals. Salt is hand fed in southern and eastern Tibet. Yaks are given about 50 grammes of salt or are given a salt lick every two weeks.

As Tibet is rich in water resources, yaks can drink water from rivers or melted snow water at any time. In one or two places the locals even feed yaks hot spring water, which both quenches their thirst and provides them with essential minerals.

Calf Nutrition

The first year of a calf's life is critical in terms of feeding and nutrition. Just like human offspring, feeding during this time will greatly influence the growth and development of calves; healthy calves, in turn, ensure that herders will be able to survive as animal husbanders. The calving season ranges from April to June, when the climate is warm enough for calves to survive. Newborns are usually able to stand and suck on their mothers' teats. Artificial nursing is practised for weak newborns. Mother yaks are not milked for the first month after giving birth. Calves do not graze with their mothers for the first few days after birth but are suckled in the morning and evening when mother yaks are milked. At night, calves sleep together with mothers and may nurse at any time.

Calves are then weaned. Generally, the actual nursing period lasts about four months; but, from the second month on, calves begin to graze on area pastureland and dams are regularly milked. Young calves are organised into small groups and are then left to free graze near the camping ground during the day, returning to sleep with their mothers at night. In order to help calves survive their first winter and spring, the locals cook barley flour and dried flax into gruel and give this mixture to calves as supplementary feed.

GRAZING MANAGEMENT

Grazing management is the most important element of yak production, as these animals depend on free ranges to survive. Collectivisation, which includes grazing management strategies, throughout Tibet has created favourable conditions for the organisation of large-scale animal production. Tibet's yak are now divided according to their sex and age into different grazing groups: the adult female yak herd, the calf herd, the young yak herd, and the pack yak herd. For grazing management convenience, some communes group young and pack yaks into one herd. Mothers and calves form a second, combined herd. Breeding male yaks are left alone on alpine pastures when they are not mating, joining female herds when mating season begins.

Yak herds vary in size depending on grassland conditions. Adult female yak herds normally include 100-125 animals. Youth and pack herds total 150-200 head and calves number about 50 animals per herd. Winter and spring herds are smaller than summer and autumn groups due to poor grassland conditions. Similarly, there are fewer yaks in each herd in farming and mountainous areas than in pastoral and gently-sloping areas.

Local herdsmen are knowledgeable about grassland management. Their years of experience as pastoralists have led them to divide grasslands into distinct pastures and to use these resources in turn. Usually, productive grassland is classified according to terrain and condition. These pastures are then used on either a two or three-season rotational basis.

Grazing Management in Summer and Autumn

Summer and autumn grazing lasts from June through September in the pastoral areas of northern Tibet. In the south, this grazing period begins two weeks earlier and lasts until the end of October. Grass is most abundant during these seasons. Milk production reaches its peak, and mating occurs at this time. Locals graze their herds on dry, highland pastures where water is abundant and the climate is cool. Some communes graze milch females on marshy meadows along dams and lakes, which proves beneficial for both milk production and grassland management.

The weight yaks gain during the summer and fall sustains them through the difficult winter; inducing this weight gain is the herder's central goal during the warm weather seasons. Grazing time is prolonged. Herds are driven out to pasture early in the morning and are not brought back to camp until late afternoon or evening. Some females might graze from 8 a.m. until 9 p.m., returning to tent settlements only at night. Some communes even allow yaks to free graze through the night. Since pack yaks and young herds are not milked, herders allow them to graze day and night on alpine grasslands. As it is hot in summer, yaks are bothered during the day by mosquitos and gadflies; allowing them access to grass in the morning and evening assures that they will meet nutritional requirements and gain weight.

Management of Grazing in Winter and Spring

In most of Tibet's pastoral areas, the winter-spring grazing season lasts from October to May. (Climatic differences in the various areas of Tibet might alter this schedule by two weeks.) During this time, herders try to provide yaks with the best grass possible, given Tibet's frigid winter climate. Foetuses can miscarry during the cold months; pregnant dams should be cared for accordingly.

During calving time in spring, grasslands that are low, flat, sunny, and provide shelter from wind are chosen by herders. Grasses in such areas must be tall enough so that they are not covered by snow. In early winter, yaks that are still strong can be grazed on high pastures. As the weather becomes colder, yaks may be gradually driven down to lower grasslands. This migration pattern helps reduce the pressure placed on spring grazing land. Some communes have specifically set aside areas of pasture on which female yaks graze during the winter and spring.

Throughout winter and spring, yaks are taken out to area pastures at about nine in the morning, driven back to camp at six in the evening, and then placed in open pens.

These simple enclosures, about 1.5 metres high and built of adobe and stone, are rather simple and do not retain much heat. Snow often covers the ground, withering grasses and decreasing the quantity of fodder. Yaks never have much to eat during the cold season and rely on fat stored from the previous summer and fall to sustain themselves.

Some communes have tried to offset this winter weight loss by introducing supplementary feed. If conditions permit, communes give yaks extra hay once a day from about December through March. Supplements vary in kind and amounts and include highland barley straw, hay, highland barley grain, barley flour, etc and range in allowance from one to several kilogrammes per day.

By spring, pregnant female yaks have entered the later stage of gestation. Their feeding and management programmes must be strengthened accordingly. Pregnant dams are slowly driven to flat grasslands. Efforts are made not to frighten the animals and they are given water at midday. If dams crowd up and push against each other when being let in or out of night pens, they run the risk of abortion; care is taken to avoid such crowding. Before yaks give birth, they are watched with much scrutiny and separated from other animals.

PRIORITIES FOR FUTURE ACTION

Direction of Development Programmes

Development programmes should be cognizant of a given district's place within the overall development direction of the national economy and the needs of local people. As socialism continues to advance throughout China, the standards of living of its residents will improve; milk and meat requirements will rise accordingly, particularly in places like Tibet where butter, cheese, and beef have always been essential foodstuffs. In order to meet such needs, the yak industry across the Plateau must be developed. This goal is both sustainable and feasible, as yaks are highly adapted to Tibet's harsh environment.

Major efforts should be devoted to increasing the quantity and quality of Tibetan yaks, thereby affecting milk and beef production. Such efforts are of tremendous significance to local people. Not only would living standards improve, but the collective economy of the people's commune would also improve, thereby promoting economic growth throughout the Region and its border areas. Yaks should be selectively bred to produce sturdy yaks for both milk and meat production. Such yaks should thrive in the grazing conditions of the Plateau and maintain medium production levels.

Breeding and Selection

"In-and-in" selection should be adopted. This method basically involves the systematic selection of original breeds to be crossed with each other. Livestock breeds are fairly abundant in Tibet and, therefore, lend themselves to this kind of selection. In-and-in breeding not only improves the overall quality of domestic stock but also helps maintain yak genetic diversity and raise production levels.

An organisation focussed on breeding techniques should be established to help manage this breeding and selection programme. The chief responsibilities of the organisation would include determining breeding strategies and selection classifications. Research should also be carried out on the causes of problems arising from selection and advice should be given about improvement possibilities; this should include technical assistance.

In order to make yak breeding in Tibet more efficient, several farms of finely bred yaks should be established as key breeding resources. Ecologically speaking, all areas of Tibet are suitable for yaks. Yet, the northeast of the Tibetan Autonomous Region is the most suitable for such farms. These yak farms should apply scientific theories of animal husbandry to feeding, management, and breeding programmes so as to maximise the yak's potential. These farms should also supply communes with high-quality breeding yaks. More generally, such farms should continue to execute scientific research on the yak, thereby advancing overall yak development in Tibet.

Increasing Productivity through Cross-breeding

Some farming and agro-pastoral areas cross-breed yaks with cattle to produce *pien niu*, hybrids with high milk yields and strong draught power which raise overall production levels. However, such cross-breeding practices are not as popular in Tibet as they are in other yak distribution areas. Cross-breeding should be encouraged in Tibet through the introduction of a large-scale breeding project. The introduction of exotic dairy cows with high performance levels for cross-breeding purposes would further increase the productivity of the *pien niu*.

Improving Grazing Strategies

Natural, free-range fodder is the principal source of nutrition for grazing livestock across the Tibetan Plateau. The Tibetan Autonomous Region covers a vast area of natural pasture and maintains rather superior grazing conditions. However, some improvements in grazing strategies can be made. Herds should be organised according to species, sex, age, and health; different feeding and management systems should be developed accordingly. Grazing grounds for various animal herds should be selected in relation to seasonal climatic changes, grass availibility, and production season. For example, winter-spring pastures must not cause an unnecessary drain on animals' strength and must not be too far away from shelter and sun. Herds of dams and young animals must be grazed in areas that protect developing foetuses, curb seasonal weight loss, and encourage production and development of young livestock. Grass compositions should vary to include fairly rich fodder grass of fine quality. With the increasing specialisation in livestock types, grassland management strategies need to consider the different physiological characteristics and nutritional demands of these domestic animals.

Herd organisation and management should aim to make full and responsible use of an area's natural resources. Presently, most herders across the Tibetan Autonomous Region graze their livestock without control. Once led to pastures, livestock scatter, eat freely, or, if they so desire, stay in one place and graze pastures to the nub. Local grazing management systems are seldom studied. Grazing practices should be improved according to overall prairie construction and the scientific improvement of animal husbandry. Tibetan Autonomous Region's high elevation, complicated terrain, and dramatic climate, give rise to a variety of grasslands; grazing techniques must suit the ecology of a given region. Since the types of grassland across Tibet are distinct, it is necessary to investigate the grazing techniques practised throughout these different regions and to welcome the introduction of progressive animal husbandry.

Improving Feeding Management

Nutritional needs vary depending on an animal's age, sex, and type. Scientific feeding methods are scarcely practised throughout Tibet. Even during winter and spring, when grasslands are limited and of poor quality, both the percentage of the livestock fed supplementary fodder and the quantity of supplement feed given remain low. Without improved management of feeding, the overall quality and productivity of Tibet's livestock will not improve as it should. Standard feeding methods should be developed to increase livestock productivity and health. Peas and leguminous fodder grasses should be introduced to raise nutritional standards and help realise a consistent, modernised, and high quality animal husbandry industry.

Increasing forage relies on the protection, rational utilisation, and capital construction of natural pasture. Grass-cutting farms should be established and green grass should be stored as hay. Artificial forage bases should also be developed. Fine fodder grass and forage crops should be planted. In order to heighten the use ratio and nutritional value of forage, large quantities of agricultural and sideline products, natural grass, forage grass, and artificially cultivated feed must be maintained, and sources of forage devevelopment must expand. Mixed feeds and feed additives should also be developed. These products help improve livestock nutrition. If distributed to remote areas, such supplements will further improve the overall quality of the Region's livestock.

Preserving Genetic Diversity and Other Resources

The Tibetan Autonomous Region hosts a number of breeds of yak. These animals are uniquely adapted to the environment of the Tibetan Plateau and are also invaluable to the local subsistence economy. Maintaining large and viable gene pools is fundamental to the future of yaks in Tibet. It is necessary to guard against inbreeding and continue to introduce new genes into a given community. Such steps will help improve livestock quality and establish new strains of yak and yak cross-breeds.

As such, yak genetic diversity should be protected. Their gene pool has developed over thousands of years, producing animals that are some of the most resilient on earth. If breeding disregards an animal's genetic makeup, or if careless hybridisation damages the yak's gene pool, the future success of yak husbandry could be endangered. Selection and breeding programmes would be rendered useless. Such a prospect should serve as a warning. Breeding must be carried out with adequate awareness of the animal's genetic resources.

CONCLUSION

Yaks are widely distributed throughout the Tibetan Autonomous Region. They account for about two thirds of the total bovine population of this area. Yaks possess many distinctive virtues. They thrive at altitudes above 4,000 metres and can live in some of the most harsh climates on earth. They are strong, highly resistant to disease, and can survive on the coarse fodder of the Plateau, often without receiving any supplementary food. These animals rely almost exclusively on grasslands and high pastures to meet their fodder needs. Yaks serve a number of economic purposes, producing milk, beef, draught power, fur and hair. The fat content of their milk exceeds that of cattle and provides herders across the Tibetan plateau with much of their caloric intake. Despite their importance to local livelihoods, yaks are less productive (in terms of milk and meat outputs) and mature more slowly than cattle or hybrids. Lack of careful breeding selection has produced yaks with dented backs and unsubstantial rear ends. Mortality rates are high in winter and spring due to fodder shortages. The production of adequate supplementary feeds remains minimal. Reproductive rates are also low. Female yaks calve every two years in most places, averaging a reproductive rate of about 44 per cent.

To this date, no definite feeding programmes and selection criteria for the improvement of yak breeds have been determined. The care of calves has been similarly disregarded by development work. No system of selective mating has been introduced on a wide scale. All of these factors greatly influence the quality and quantity of the Tibetan yak. Initiatives such as those mentioned as **priorities for future action** should be undertaken if yak production is to contribute to improving living standards and extending modernisation throughout Tibet.

Qinghai's Yak Production Systems

Long Ruijun and Ma Yushou

BACKGROUND

Qinghai Province is located between 31° 39' and 39° 21'N and between 89° 35' and 103° 04'E. The Province straddles the northeastern Qinghai- Tibetan Plateau and northwestern China (Figure 1). Qinghai covers 1,200km from east to west and 800km from north to south. Its area has 29.54 per cent in the Plateau and 7.5 per cent in Chinese territory. Eighty per cent of Qinghai's land mass lies between 3,000 and 6,800masl. As such, the high altitude yak thrives in Qinghai and is the Province's predominant and most valued livestock. The yak provides herders with meat, milk, hair, and transportation.

Table 1: Yak Population and Natural Pasture Areas in Qinghai, 1995

Item	Yak Population ($\times 10^4$)		Natural Pasture Areas ($\times 10^6$ ha)		
	Number	Per cent	Total area	Used by yaks	Per cent
Total	495.07	100.00	36.45	31.61	86.72
Yushu	146.13	29.52	10.85	9.56	88.11
Guole	123.83	25.01	6.75	6.24	92.44
Hainan	66.61	13.42	3.61	3.37	93.35
Huangnan	58.67	11.84	1.65	1.56	95.55
Haibei	45.11	9.11	2.57	2.37	92.22
Haidong	34.83	7.03	1.52	1.26	82.89
Haixi	19.89	4.07	9.45	7.25	76.72

China's yak and yak-cow hybrid populations total 13.3 million animals, accounting for 90 per cent of the world's yak population. Most of China's yaks live in Qinghai, Tibet, Sichuan, Gansu, Xinjiang, Inner Mongolia, and Yunnan provinces. Qinghai's yak population is the highest in China. There are 4,786,900 yaks living in Qinghai's seven prefectures, accounting for 40 per cent of China's yak population and 95.3 per cent of the entire bovine population of Qinghai. The largest yak population in Qinghai is found in Yushu prefecture (1,461,300), followed by Guole (1,238,300), Hainan (666,100), Huangnan (586,700), Haibei (451,100), Haidong (348,300), and Haixi (198,900). Yak numbers and distribution patterns, as well as their relation to rangeland areas throughout Qinghai, are illustrated in Table 1.

During the Eighth five-year plan (1991-1996), the yak population in Qinghai ranged between 4.7 and 5.0 million head. The number of yaks in each prefecture remained stable, with the exception of Haidong where the yak population doubled between 1993 and 1995. Yak populations in each of Qinghai's prefectures from 1991 to 1996 are illustrated in Table 2 and Figure 1.

Table 2: Yak Populations in Different Prefectures, 1991-1996

Prefecture	Annual yak population ($x10^4$)					
	1991	1992	1993	1994	1995	1996
Yushu	150.20	154.44	158.57	149.47	146.13	139.65
Guole	118.35	122.43	124.36	120.03	123.83	122.45
Hainan	69.95	72.09	70.75	64.19	66.61	60.96
Huangnan	53.69	65.33	66.55	62.39	68.67	60.09
Haibei	49.9	49.81	49.03	45.18	45.11	44.66
Haixi	20.77	20.55	20.55	20.04	19.89	18.16
Haidong	15.37	15.47	16.60	15.44	34.83	35.82
Total	478.23	500.13	506.41	476.74	495.07	481.79

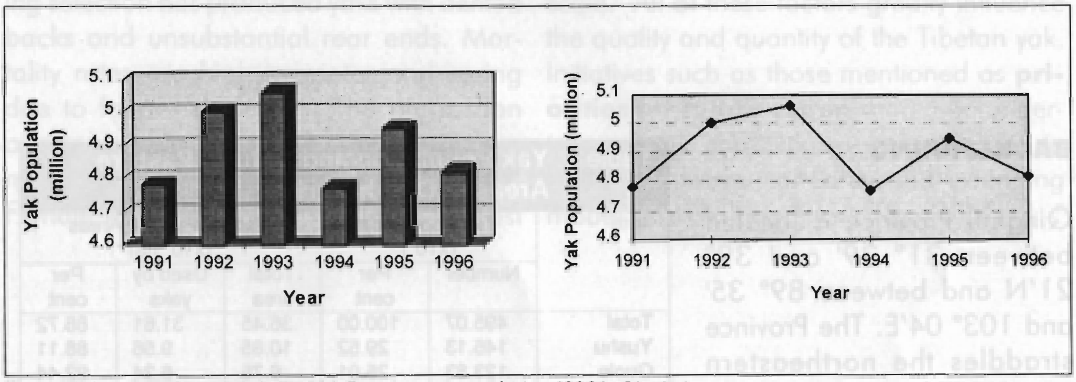


Figure 1: *The Developments in the Yak Population from 1991 to 1996 in Qinghai*

THE STATUS OF WILD YAKS IN QINGHAI PROVINCE

An accurate estimate of the wild yak population in Qinghai is not available; but based on some reports (Miller *et. al.* 1994, Lu *et. al.* 1994) approximately 6,000-10,000 wild yaks live in Qinghai's mountain areas above 4,000m.

YAK BREEDING AND CROSS-BREEDING

Three natural breeds of yak are found in Qinghai: the Qinghai Plateau yak, the Huanhu yak, and the White yak. The distribution of these breeds throughout the Province is illustrated in Figure 2. The Qinghai yak is found in northern Qinghai, including Yushu and Guole prefectures, as well as in some counties of other prefectures. In 1981, there were 3.46 million Qinghai yaks in the Province, accounting for 69.06 per cent of the yaks in Qinghai. This yak is produced from the native mating of wild yak bulls with domestic dams; its aspect and body size are similar to those of the wild yak.

The Huanhu yak is mainly found in some counties of Haibei, Hainan, and Haixi prefectures. These yaks totalled 1.42 million in 1981, comprising 28.34 per cent of Qinghai's total yak population. These yaks are produced from cross-breeding Mongolian cattle with local yaks. The Huanhu yak is similar in body size and aspect to the latter, apart from having longer wool on the head and back and heavy down hair. The Changmao yak is a strain of the Huanhu yak.

The White yak is only found in Menyuan and Huzhu counties, and in the adjoining county of Tianzhu, Gansu Province — areas that are ecologically similar. The Qinghai White yak totalled 7,684 head in 1980. Some information on these breeds is given in Table 3.

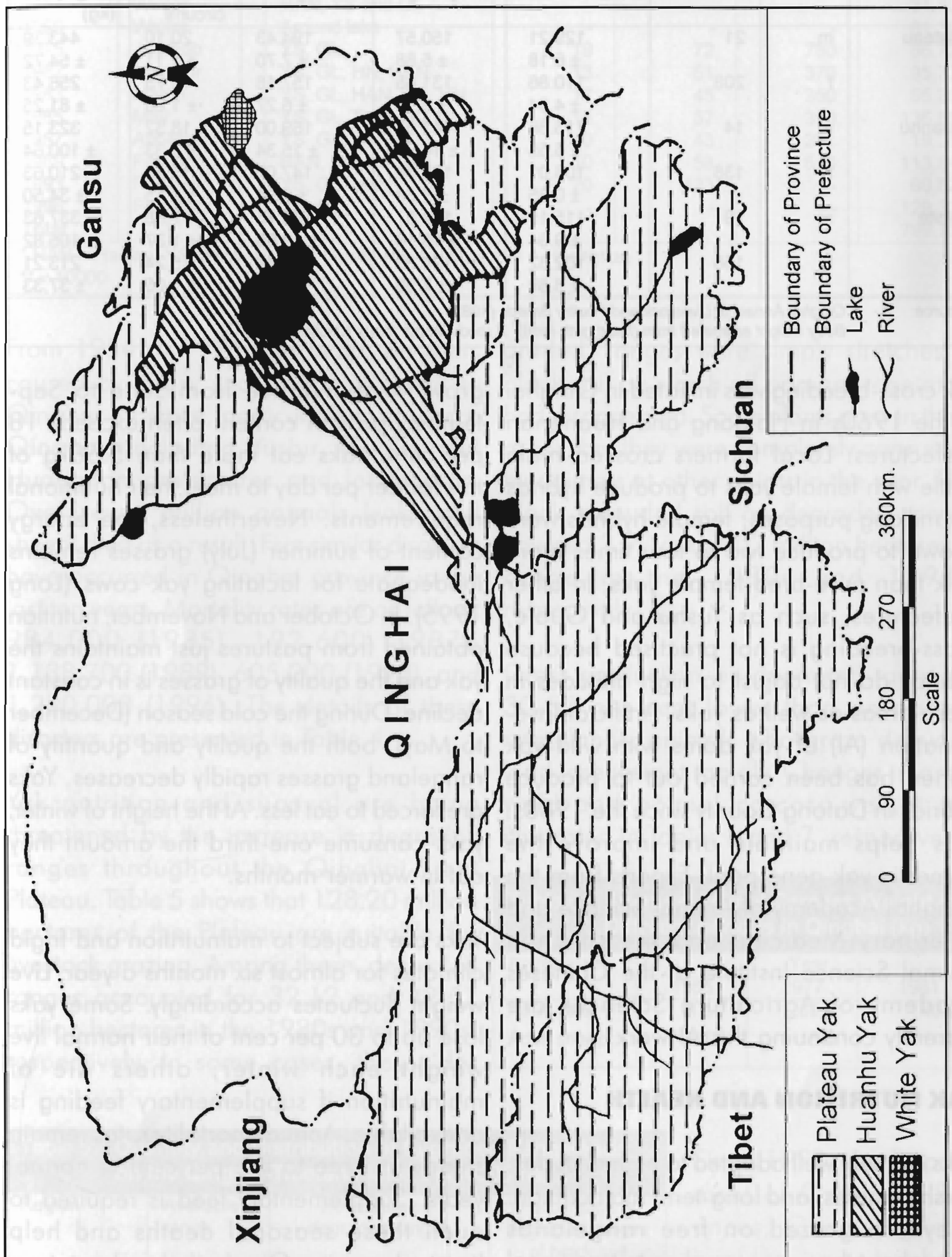


Figure 2: *Distribution of Yaks in Qinghai Province*

Table 3: **Body Measurements and Body Weights of the Main Yak Breeds in Qinghai**

Breed*	Sex	No	Body measurements (cm)				Body weight ** (kg)
			Ht at withers	Body length	Heart girth	Cannon circumf.	
Plateau	m	21	129.21 ± 6.18	150.57 ± 5.88	194.43 ± 7.70	20.10 ± 1.11	443.39 ± 54.72
	f	208	110.86 ± 4.94	131.88 ± 5.11	157.18 ± 6.27	15.75 ± 1.06	256.43 ± 81.25
Huanhu	m	14	113.86 ± 6.55	143.67 ± 14.94	169.00 ± 15.34	18.32 ± 2.33	323.15 ± 100.64
	f	138	103.01 ± 0.25	123.78 ± 7.58	147.07 ± 6.94	15.35 ± 1.15	210.63 ± 34.50
White	m	19	115.15 ± 9.64	138.87 ± 10.16	175.76 ± 18.68	17.66 ± 1.37	337.63 ± 105.82
	f	150	102.32 ± 3.89	124.56 ± 7.59	147.49 ± 7.73	15.24 ± 1.05	213.21 ± 37.33

Source: * *Qinghai Annals of Livestock and Poultry Breeds (1983)*
** *Body weight estimated from (heart girth (cm))^2 X (body length (cm))/10800x0.85*

Yak cross-breeding was initiated in Qinghai in the 1960s in Haidong and Huangnan prefectures. Local farmers crossed male cattle with female yaks to produce hybrids for milking purposes; female hybrids were known to produce two to four times more milk than pure-bred female yaks. In other prefectures, such as Yushu and Guole, cross-breeding is not practised because hybrids do not adjust to high altitudes in these areas as well as yaks. Artificial Insemination (AI) of yak dams with wild yak semen has been carried out to produce hybrids in Datong County since the 1980s. This helps maintain and improve the domestic yak gene pool. Experts from the Qinghai Academy of Animal Science and Veterinary Medicine and the Lanzhou Animal Science Institute of the Chineses Academy of Agriculture Sciences are currently continuing this AI work.

YAK NUTRITION AND HEALTH

Yaks are very well adapted to high altitudes, harsh climates, and long-term malnutrition. They are grazed on free rangelands throughout the year according to traditional management systems. As such, these animals' nutritional needs are greatly affected by the quality and quantity of grasses found in native pastures. Grasses grow in abundance from June to September; protein content often exceeds 18 per cent. Yaks eat more than 5.58kg of this fodder per day to meet their nutritional requirements. Nevertheless, the energy content of summer (July) grasses remains inadequate for lactating yak cows (Long 1995). In October and November, nutrition obtained from pastures just maintains the yak and the quality of grasses is in constant decline. During the cold season (December to May), both the quality and quantity of rangeland grasses rapidly decreases. Yaks are forced to eat less. At the height of winter, yaks consume one-third the amount they eat in warmer months.

Yaks are subject to malnutrition and frigid climates for almost six months a year. Live weight fluctuates accordingly. Some yaks lose up to 30 per cent of their normal live weight each winter; others die of malnutrition if supplementary feeding is unavailable. Annual mortality rates remain steady at three to five per cent in normal years. Supplementary feed is required to quell these seasonal deaths and help livestock survive Qinghai's harsh winters. However, supplementary feed resources are limited in prefectures like Yushu and Guole. If pastures are covered by heavy snow, many yaks are sure to die.

Table 4: Areas Covered and Animals Killed by Heavy Snow in Qinghai

Year	Time	Prefecture	No. of counties	No. of townships	Animals** involved	Animals lost**
1954	Winter	HAN, YS and GL	-	-	-	31.30
1960	Winter	Around lake	-	-	-	61.30
1975	Jan-Fab	YS, GL	19	72	730	86.72
1982	Mar-Apr	YS, GL, HN, HAN	13	51	370	95.73
1983	March	YS, GL, HAN, HB, HN	17	45	350	65.20
1985	May	YS, GL, Tanggula Mt.	16	37	390	136.80
1987	Apr-May	YS. GL, HN, HAN	10	43	201	19.26
1989	Feb-Apr	HAN, HB, GL, HN	10	58	616	113.84
1993	Feb-Apr	YS, GL, HAN	20	123	-	60.52
1996	Feb-Apr	YS, GL	-	-	-	129.33
Total						799.70

* HAN = Hainan, YS = Yushu, GL = Guole, HB = Haibei, HN = Huangnan
** x 10000

From 1954 to 1996, ten major disasters caused by heavy snow were recorded in Qinghai province, particularly in southern Qinghai, including Yushu, Guole, and Huangnan prefectures and lake areas. Over seven million animals (yaks and sheep) died as a result. Five similar disasters have occurred in Qinghai province in the last ten years. Mortality rates are as follow: 984,000 (1985), 192,600 (1987), 1,138,700 (1989), 605,200 (1993), and 1,290,000 (1996). The details of these disasters are presented in Table 4.

Yak nutrition and survival are being threatened by the increase in degraded ranges throughout the Qinghai-Tibet Plateau. Table 5 shows that 128.20 million hectares of the Plateau are suitable for livestock grazing. Among these, degraded ranges accounted for 32.12 and 42.51 million hectares in the 1980s and 1990s, respectively. In some cases, these 'degraded' ranges were simply stretches of black soil on which all primary vegetation had disappeared. Some plants grew in these areas, but they were completely consumed by animals at other points in the year. This black, denuded soil on degraded ranges covered 3.97 and 7.03 million hectares of range in the 1980s and 1990s, respectively.

Grass production on degraded ranges is 30-50 per cent lower than on normal rangelands; animals who graze denuded land lose weight rapidly. Changes in grass yield and animal carcass weight are illustrated in Tables 6 and 7. respectively.

Table 6: Average Animal Carcass Weight in Different periods in Qinghai (kg)

Animal	Year		
	1965	1977	1981
Adult yaks	112.0	50.0	40.0
Adult sheep	22.5	15.0	14.0

Table 5: Quantity and Distribution of Degraded Rangelands on the Qinghai-Tibetan Plateau (x10000 ha)

Region	Available range	Percentage of degraded ranges		Percentage of degraded ranges of black soil	
		1980s	1990s	1980s	1990s
Tibet	6,636.12	18.12	30.00	15.35	16.44
Qinghai	3,161.03	28.29	31.82	13.20	21.18
NW Sichuan	1,416.04	27.31	33.00	9.00	13.21
Gansu	1,607.16	44.36	49.00	8.00	12.84
Total	12,820.35	3,212.41	4,251.10	3.97	7.03

Since 1992, the Department of Grassland Sciences, Gansu Agricultural University, has been developing local forage resources for supplementary winter feed. These initiatives are supported

Table 7: A Comparison of Rangeland Grass Yields in Different Periods in Qinghai (fresh grass based kg/ha)				
Region (County)	Measuring time	Grass yield	Decreasing (%)	Note
Gangcha	1980 1992	2,607.2 1,399.8	-46.30	
Zeku	1974 1982	5,200.9 3,544.9	-31.87	
Guinan	1974 1982	3,066.7 2,083.3	-32.07	
Gonghe	1974 1982	3,287.4 2,188.8	-33.42	
Nangqian	1965 1982	1,708.5 1,172.5	-31.37	dry grass
Yashu	1964 1981	1,678.2 1,321.1	-21.28	dry grass

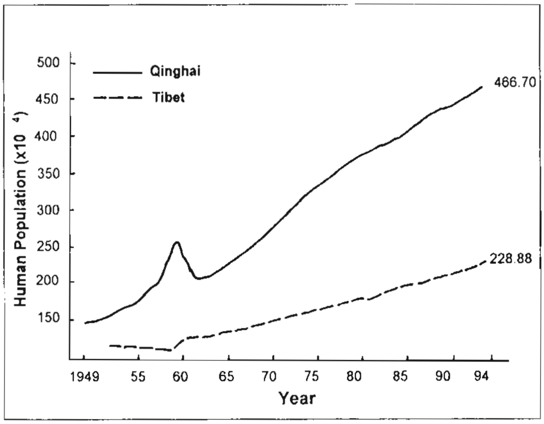


Figure 3: *Human Population Dynamics from 1949 to 1994 in Tibet and Qinghai*

by IAEA/FAO and IFS (International Foundation for Science) in Gansu and Qinghai. Since the beginning of last year, the Urea Molasses Multi- nutrilite Block (UMMB) has been used to supplement yak feed during winter, producing favourable results. These projects will be continued until 1998.

YAK MANAGEMENT SYSTEMS

From 1949 to 1994, the livestock population drastically increased in Qinghai and Tibet, while the ratio of pasture areas per animal decreased rapidly in both regions (Table 8). Overgrazing rates increased from 12.11 to 102.87 per cent and from 1.25 to 35.33 per cent in Qinghai and Tibet, respectively. The human population has also continuously risen (Figure 3).

Yaks graze on summer pastures from June to August and on spring-autumn pastures in September, October, April, and May. They graze on winter pastures the rest of the time. In southern Qinghai, Plateau yak cows are milked twice a day, whereas Huanhu yaks are milked once a day. The total milk production within the 150-day milking period of Plateau and Huanhu yak cows is 274kg and 257kg, respectively. The butter-fat content of the milk ranges from 6.37 to 7.20 per cent. The slaughter rate of the Plateau yak is 52.96 per cent, while that of the Huanhu yak is 48.68 per cent. Wool is sheared once a year. White yaks produce 1.6 kg of wool; Plateau yaks yield five kg of wool. The production characteristics of yak farming systems in Qinghai are illustrated in Table 9.

Table 8: The Average Range Areas Occupied by One Animal in the 1950s and 1990s		
Region	Year	Areas per animal (ha)
Tibet	1952 1993	6.81 2.86
Qinghai	1949 1994	4.20 1.40

According to traditional pastoral practices, yaks are grazed on native pastures year round. It has proven difficult for indigenous management systems to increase grass production across native rangelands in different seasons and also maintain a relatively stable yak population (Figure 4). This problem still needs to be solved. Most suggestions derived from area research cannot be adopted by herders. Until last year, yaks were divided among families, though rangelands were community property. Therefore, each family wanted to increase the size of their herds as much as possible.

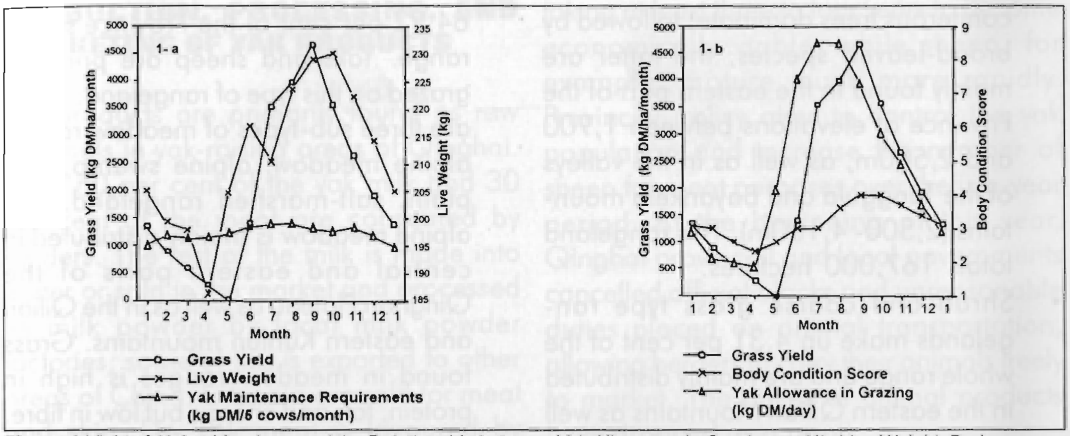


Figure 4: *Yield of Alpine Meadows and the Relationship between Yak Allowance in Grazing and Its Live Weight, Body Condition Score*

Table 9: Production Characteristics of Yak Farming Systems in Various Prefectures in Qinghai in 1991 and 1995

Region	Year	Culling rate (%)	Commercial rate (%)	Mortality (%)	Reproductive rate (%)	Survival rate of calves (%)
Haidong	1991	15.90	10.5	1.50	43.60	93.70
	1995	22.67	24.33	1.95	45.23	92.82
Haibei	1991	18.70	14.50	2.20	53.50	92.60
	1995	19.71	16.08	2.06	51.54	91.12
Hainan	1991	1350	8.80	3.70	51.20	82.90
	1995	25.91	21.39	4.23	58.47	83.92
Haixi	1991	15.00	10.90	3.80	54.40	86.40
	1995	12.84	10.37	8.26	57.19	76.11
Huangnan	1991	12.50	8.60	3.50	54.40	87.00
	1995	15.44	11.29	2.98	57.97	90.57
Guole	1991	9.90	6.10	2.70	50.70	92.10
	1995	17.50	9.76	6.10	48.87	87.02
Yushu	1991	12.70	6.80	3.90	60.10	91.50
	1995	23.08	12.83	8.35	52.66	84.61

Rangelands have been distributed to individual families since last year throughout Qinghai's pastoral areas. In addition, provincial or local governments and herdmen invest in pastoral infrastructure (homes, animal pens, fencing, artificial pastures, etc) in a 5.7:1 ratio in Yushu and Guole, and a 1:1 ratio in the other prefectures. This new system means that each family has to pay more attention to rangeland management issues. This policy has helped control stocking rates and encourage herders to cull more animals each year. Issues of overgrazing and degraded ranges can now be improved through the joint efforts of herders and researchers; rangeland ecosystems and pastoral production systems will be better understood in the near future. However, improving yak management systems means that differences among and within rangelands must be addressed. This is a demanding task, as grass types and pasture ecosystems are difficult to recover if severely denuded or destroyed.

Five primary types of rangeland exist in Qinghai. The description of these different rangeland types is outlined below.

- Woodland and coarse grass types of rangeland include three sub-types: mountainous broad-leaved and coniferous trees and grass. In Qinghai, coniferous trees dominate, followed by broad-leaved species; the latter are mainly found in the eastern part of the Province at elevations between 1,900 and 2,500m, as well as in the valleys of the Tanggula and Bayankela mountains (2,500- 4,100m). This rangeland totals 167,000 hectares.

- Shrub and coarse grass type rangelands make up 4.31 per cent of the whole range and are mainly distributed in the eastern Qilian Mountains as well as in the southeastern Qingnan Plateau — areas where elevations range from 3,400 to 4,500m. This type of grass includes two sub-types of mountainous and alpine shrubs and grasses.
- Dry rangeland accounts for 23.43 per cent of area range. As temperature and precipitation vary in the region, mountainous rangeland (1,700-3,200m) and alpine rangeland (3,400 -4,500m) are found.
- Desert rangeland grasses are mainly scattered in the river valleys of the Chaidamu Basin and in the hilly regions of the Qilian Mountains, covering 7.34 per cent of the Province's grasslands. The sparse shrub and semi- shrub found there are grazed by camels and goats. There are three sub-types of desert rangeland: plain (2,600- 3,000 m), mountainous (3,200-3,600m), and alpine (3,500-4,700 m).
- Meadow rangelands are widely distributed and are, perhaps, Qinghai's most important type, comprising 64.92 per cent of the Province's total range. Yaks and sheep are primarily grazed on this type of rangeland. There are three sub-types of meadow range: alpine meadow, alpine swamp, and plain, salt-marshed rangeland. The alpine meadow is mainly distributed in central and eastern parts of the Qingnan Plateau as well as in the Qilian and eastern Kunlun mountains. Grass found in meadow ranges is high in protein, fat, and energy, but low in fibre.

Provincial and local governments, as well as farm groups, have invested in the improvement of rangeland ecosystems and animal production systems through the Eighth five-year plan (1991 to 1995). More funds will be invested to improve ranges in the next five years (1996 to 2000). Rangeland improvement, livestock industry investments, and results of the Eighth five-year plan are illustrated in Tables 10 and 11.

Table 10: Investment in Animal Husbandary Systems from 1991 to 1995 ($x10^4$ Yuan)*

Year	Province	Prefecture and country	Group of farms	Total
1991	2,334.0	184.3	2,034.8	4,553.1
1992	2,606.0	139.6	2,389.6	5,123.2
1993	2,493.6	203.0	2,533.6	5,230.3
1994	4,111.6	230.6	4,507.2	8,849.3
1995	4,016.7	157.5	5,447.6	9,621.8
Total	15,562.9	914.9	16,912.8	33,389.6

Table 11: Investment Contributions to Rangeland and Livestock Systems During the Eighth Five-Year Plan in Qinghai (x 1000 ha)

Year	Range-land fenced	Artificial perma-nent	Pasture annual	Pasture impro-vement	Animal pen ($x10^4m^2$)
1991	105.44	19394	34.19	34.52	10.84
1992	97.40	18.21	35.28	47.33	14.06
1993	59.93	17.39	46.31	38.80	12.60
1994	108.44	16.68	51.41	69.45	28.81
1995	123.82	15.18	57.30	80.80	38.10
Total	495.03	208.73	224.49	270.90	104.41

* There are 8.30 RMB *yuan* to the U.S. Dollar

PRODUCTION, PROCESSING, AND MARKETING OF YAK PRODUCTS

Yak products are primarily found as raw materials in yak-raising areas of Qinghai. Over 80 per cent of the yak milk and 30 per cent of the meat are consumed by herders. The rest of the milk is made into butter or sold in the market and processed as milk powder by local milk powder factories; some of this is exported to other areas of China. Live yaks are sold for meat and skin. Dry yak meat is favoured by people throughout China and in the surrounding countries. Leather yields a good profit in Qinghai and other provinces. Yak wool is useful for making tents, ropes, and carpets. Yak cashmere sweaters, made in Xining, could be sold both in China and abroad. Yak milk and meat processed as 'green' products from the Tibetan plateau could capture a huge international market in the future. The yak products of Qinghai are listed in Table 12.

Table 12: Yak Products in Various Prefectures of Qinghai in 1991 and 1995

Region	Year	Yak products (x 10^4) tonnes or pieces)			
		Meat	Milk	Wool+ cashmere	Shin
Haidong	1991	1690.2	23817.3	45.1	4.7
	1995	2941.6	20184.7	23.8	3.3
Haibei	1991	9732.7	23298.4	302.0	10.5
	1995	7306.0	20443.0	241.8	9.8
Hainan	1991	8150.4	30620.2	385.0	11.5
	1995	14614.9	29512.0	428.7	26.3
Haixi	1991	2872.7	7571.2	86.7	2.9
	1995	2791.0	5810.0	146.2	3.3
Huangnan	1991	5696.5	20857.8	170.4	10.0
	1995	8105.3	23203.0	183.2	11.9
Guole	1991	9495.6	38251.2	612.8	7.8
	1995	12488.2	31238.9	626.0	13.0
Yushu	1991	12696.3	40272.1	600.7	14.6
	1995	16289.9	41976.0	392.5	17.3

CHANGING ECONOMIC AND DEVELOPMENT FORCES: IMPLICATIONS FOR YAKS

Yak herding was affected by the introduction of a market economy in China in the 1980s. These animals grow slowly, taking at least three to four years to become economically viable, while sheep, for example, mature much more rapidly. Provincial policy aims to control the yak population and increase the number of sheep for meat purposes over the five-year period. At the beginning of this year, Qinghai provincial and local governments cancelled official blocks and unreasonable duties placed on animal transportation, allowing herders to carry their animals freely to market. The prices of animal products have dropped as a result.

Now that the rangelands belong to the herders, individual responsibility for herd and pasture management has increased. Pastoralists must now take more initiative in controlling overgrazing, culling unproductive animals, and monitoring stocking rates.

The heavy snows of last winter have also impacted Qinghai's yak population. Herders lost huge numbers of animals. The prices of yaks and sheep (and their by-products) have risen as a result of these disasters, thereby limiting local purchasing power (see Table 13).

Table 13: A Comparison of Prices of Animal Products in the Autumn of 1995 and 1996 in Qinghai

Year	Yak		Sheep	
	Meat	Butter	Meat	Wool
1995	21.5	30.9	18.0	12.2
1996	14.5	28.5	12.0	5.2

PRIORITIES FOR FUTURE ACTION

Sustainable yak production demands that government officers, researchers, and herders all have a good understanding of the industry. Without appropriate pastoral policies, these systems will no longer be viable. Traditional, indigenous management systems and modern innovations must be integrated to improve yak husbandry. The relationship between rangeland ecosystem dynamics and animal production systems should be adequately understood in order to organise rangeland and livestock development programmes in a holistic manner, rather then operating according to isolated factors.

Government officers and researchers should increase their knowledge of pastoral production techniques and continue to analyse issues and opportunities facing pastoralists. Policies should be modified accordingly. Training courses that attempt to make herders more aware of national and local policies, as well as to introduce new, practical farming techniques, should be implemented.

CONCLUSION

More yaks populate Qinghai's ranges than any other province in China. Qinghai also boasts the second largest areas of natural pasture used by yaks among the different provinces and autonomous regions of the Qinghai-Tibetan Plateau. Yak and rangeland production systems must remain sustainable.

Animals, rangelands, and human populations are the three most significant components of the diverse Plateau ecosystems. The protection and development of this unique environment require that these three factors work in conjunction with each other, not in opposition. As such, understanding the social issues surrounding pastoral management and development is just as important as scientific enquiry.

The improvement of yak-herding systems should include the development of appropriate pastoral policies and a greater understanding of rangeland ecosystems. Indigenous pastoral production systems should also be understood and incorperated into improvement strategies where feasible. Only then will the long-term viability of Qinghai yak farming systems be protected and improved.

Yaks in Xinjiang

Luo Ning, Gu Jinhe, and Aireti

INTRODUCTION

Yak, *Bos grunniens*, is one of the world's largest species of *Bovidae*. The wild yak is thought to have first appeared in northern Siberia during the late glacial epoch. Gradually, the wild yak dispersed across Central Asia. Its current distribution area, however, is now limited to the Qinghai-Tibetan Plateau due to climatic changes and hunting (Zuojian 1986; Dehao *et al.* 1991; Li *et. al.* 1996). In Xinjiang, wild yaks are found throughout the Altun and Kunlun mountains and the eastern part of Kalakunlun Mountain Range, an area on the northern fringe of the Qinghai-Tibetan Plateau (Jinhe 1987).

From June to July 1982, and from May to July 1984, scientists carried out an integrated study of the wildlife (particularly ungulates) in the eastern Kunlun-Altun Mountains. This study increased the knowledge about wild yak populations. In September 1992, Xinjiang's yak population was surveyed.

DOMESTICATED YAKS IN XINJIANG

The domestication of animals by humans dates to the late Stone Age, approximately ten thousand years ago, and proof for the domestication of yaks can be found in archaeologyical materials dating back approximately 5,000 years (Cai 1996). The development of agricultural and agro-pastoral civilisation necessitated the taming of wild yak as a beast of burden. Several views are upheld regarding the domestication of wild yaks in Xinjiang. According to local literary tradition, the Qiang people inhabited Xinjiang for centuries, during which time they domesticated yaks to help meet survival needs. About one thousand years ago, the Qiang people retreated from Xinjiang, taking with them their domesticated yaks.

Oral tradition sanctions the view that the recent history of yak husbandry in Xinjiang dates back about one hundred years. In 1920, Senle Living Buddha, the uncle of the Manhan king, Chukejiabu, bought 206 yaks in Lhasa, Tibet, and brought them to Bayinbuluke in Xinjiang's Tianshan Mountains. Breeding, cross-breeding, and further domestication of wild yaks continued for many years; however, only Mongolia's yak population increased substantially in numbers during this time (Shan 1992). As more people became aware of the benefits of raising yaks, Xinjiang's yak population and distribution began to expand to other areas. For example, the yak became one of the most important domestic animals in the Kirgiz Autonomous District during this time.

Table 1: **Statistics of Wild Yak in Xinjiang**

Time	Sample length (km)	Observed animal	Mean density (ind./km^2)	Investigation area (km^2)	Yak numbers in investigation area	Distribution area in Xinjiang (km^2)	Estimated numbers in Xinjiang
1982-84	1351	182	0.067/km^2	45,000	3031	120,000	8040
1992	253	16	0.058/km^2	1500	87	120,000	6960

THE STATUS OF THE WILD YAK

Distribution and Numbers

Wild yaks can be found in the Altun Mountains, Kunlun Mountains, and in the eastern regions of the Kalakunlun Mountains. The identification of the western distribution limits of the wild yak requires further investigation (see Map 1). Wild yaks mainly inhabit hilly areas at altitudes above 3,800 metres, often travelling up to four or five thousand-metre grazing lands. The yak observed during the above-mentioned surveys, however, were living between three and four thousand metres. According to the 1982 and 1984 survey results, the mean density of wild yaks in Xinjiang is 0. 067/km (Jinhe 1987). If the total of yak habitats in Xinjiang is calculated as 120 thousand square kilometres, the total yak population will amount to 8,040 individuals; if calculated according to the mean density determined in 1992 (0. 058 ind./km; Ning 1993), then 6,960 yaks should be found in Xinjiang (Table 1).

According to the surveys carried out in 1986 in Kumukule Basin (Gu and Zhenqin 1988), there are 2,000 wild yaks in the Kaerdong area, a region of approximately 3,010 km. These results, which correspond with previous survey data, reveal that Kaerdong hosts the most dense population of wild yaks.

Group Structure

Throughout the three years of the investigation, scientists observed 51 groups (961 individuals). Among these animals, males accounted for 36 groups and 92 individuals; females and juveniles accounted for 10 groups and 829 individuals; only one mixed group of 16 individuals was observed. The structure and composition of the five remaining groups were unclear.

Adult males always live alone or in small groups and were found primarily on slopes at altitudes of from 4,200 to 4,400 metres. These males were often seen feeding on open, snow-covered ranges at 4,000 metres. Groups averaged 2.63 individuals, with a maximum size of eight animals. The adult female, sub-adult, and juvenile yaks often combined to form large groups. These animals tended to occupy niches slightly higher in altitude than their male counterparts. The highest altitude across which yaks ranged were grasslands at 4, 800 metres. These female, sub-adult, and juvenile groups averaged 82.9 individuals with the largest group reaching 260 head. During the last ten days of June, newborn calves accounted for about 25 per cent of the juvenile group.

Measurement of Skull

Forty-one yak skulls were accounted for during the surveys. Among them, 38 were male, eight to ten of which were eight years old, 24 of which were 11-16 years old, and six of which were 16-18 years of age. Only three female skulls

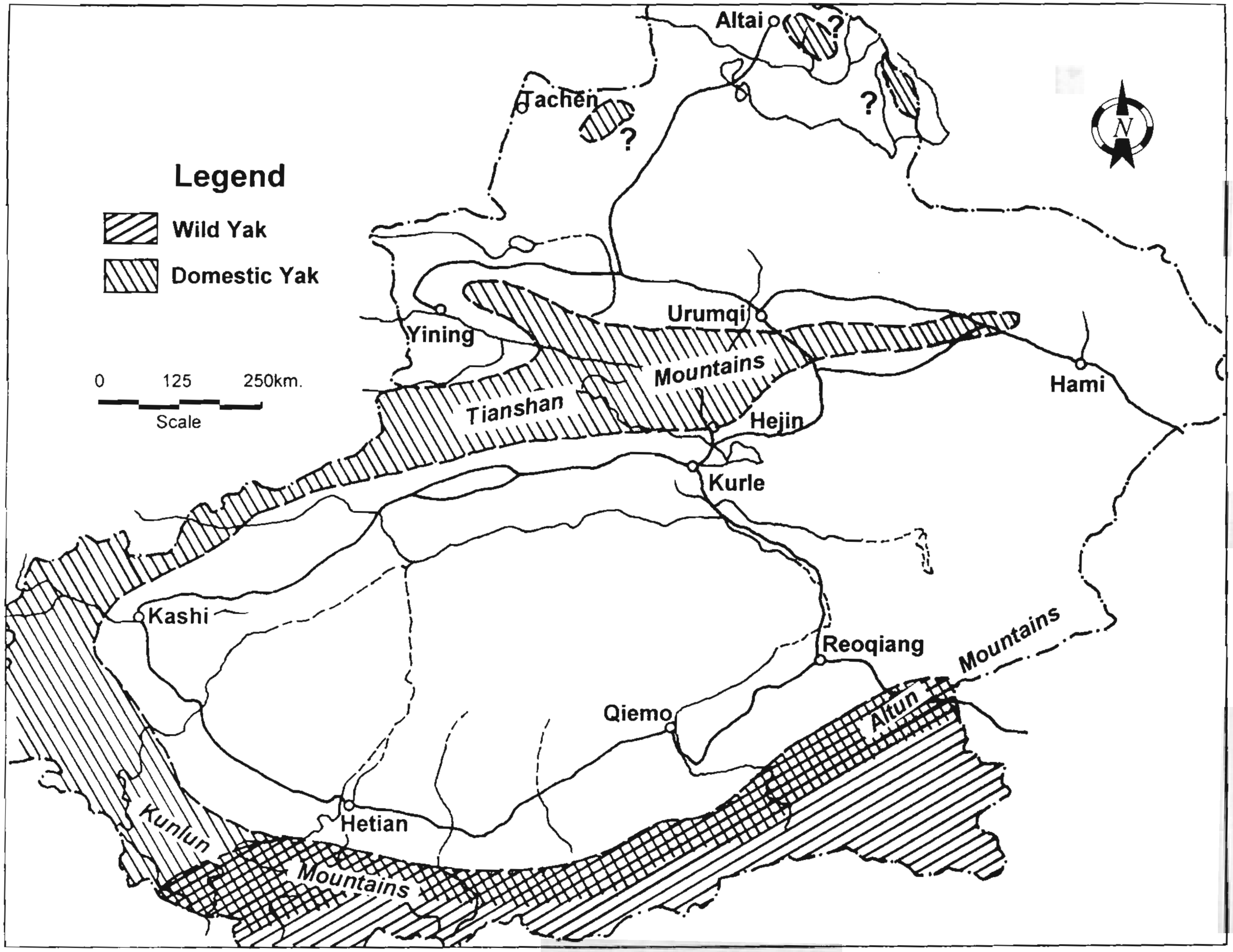


Figure 1: *Distribution of Yaks in Xinjiang Province*

Table 2: Skull Measurement of Wild Yaks

sex	Age	Condylo length (mm)	Condyob-sal length (mm)	Length of teeth on maxillaries (mm)	Width of zygomatic (mm)	Length of horn (mm)	Distance between hirnbase (mm)	Round length of hornbase (mm)
Male	6-10	575 (530-620) n=2	513 (460-565) n=5	135 (130-145) n=6	313 (275-330) n=9	743 (650-820) n=9	197 (152-215) n=7	410 n=1
	11-15	582 (530-630) n=10	539 (510-562) n=9	131 (118-142) n=10	318 (290-370) n=22	790 (710-985) n=21	267 (133-300) n=25	411 (380-460) n=5
	>15	582 (560-595) n=3	525 (510-535) n=3	--	309 (290-330) n=5	773 (680-900) n=6	189 (162-218) n=6	410 (390-420) n=2
Female	5	--	--	--	--	520	165	180
	6.5	--	--	135	--	430	165	--
	14	--	--	--	--	500	185	180

were recovered and dated as six, seven, and 14 years old (Table 2).

Conservation and Management

The influence of human activity on wild yak populations has been relatively significant, though gradual, as wild yak habitats are some of the most remote and precipitous highland regions on earth. Hunting has caused the most severe impact on wild yak populations. At the beginning of the 1960s, large-scale hunting resulted in the destruction of wild yak populations in some areas. The Yak Head Valley in the Kumkule Basin, for instance, is so named because a pile of more then thirty yak skulls was found there — evidence that a male- juvenile group was wiped out at that location. A similar event is said to have occurred in the Withered Grass Valley. From the end of the 1980s, a large number of people entered this area to mine gold, killing wildlife for food and destroying the habitat as a consequence. Local herdsman have also killed wild yaks for food. The increased presence of domestic yak grazing throughout the Kumukule Basin since the beginning of the 1980s has further impacted the number of wild yaks in Xinjiang.

In 1979, between four and six hundred domestic yaks herded by a Qieme County food company were surrounded by wild yaks; those domestic yaks can be observed today. According to local herdsmen, wild yaks can mate with domestic yaks in oestrus, producing offspring that are larger than their pure domestic equivalents.

As such, the preservation of wild yaks has important implications for improving the quality of domestic yaks in terms of increasing the size, productivity, and genetic diversity of domesticated animals. Wild yaks are now recognised as 'endangered' and ranked first in terms of national protection; wild yaks are also listed in Appendix 2 of CITES. In response to survey findings, the Altun Mountain Reserve was established in the Kumukule Basin in the mid-1980s. This reserve, which spans 46, 000km, was the country's largest reserve at the time it was established and plays an important role in protecting ungulates and their habitats.

THE STATUS OF DOMESTIC YAK PRODUCTION AND MANAGEMENT

Yak-raising Areas and Yak Populations

Compared to other yak-raising areas, the number of yaks raised in Xinjiang is small, due in part to the relatively recent history of yak husbandry in this area. The estimated yak population in Xinjiang was 150,000 in 1982, 180,000 in 1987, and 230,000 in 1995 — an annual rate of increase of 4.1 per cent. Xinjiang's yak-raising areas centre around the Kunlun and Altun Mountains, the Pamir Plateau, and the Tianshan Mountains (Map 1), covering 36 counties and 10 Production and Construction Corps and Farms.

The Bayinguolen Mongolian Autonomous District, Xinjiang, is home to the largest yak population in this Province. This region includes the following eight counties: Yuli, Hejin, Heshuo, Yanji, Bohu, Qiemo, and Ruojiang, as well as the city of Kurle. In 1996, the number of yaks raised in these areas totalled 66,900, 29.1 per cent of the total of Xinjiang. The off-take amount was 15,700 animals, 39.3 per cent of all the yaks in Xinjiang. Other yak-raising areas include the North Tianshan Mountain area, Bayinbuluke, and Baluntai, as well as the Aqiang and Qimen pastures along the Kunlun-Altun Mountains. The main productive area is Heging County, in which yaks numbered 62,600 in 1996.

Kirgiz Autonomy District is the second largest yak-raising area; 47,200 yaks were found in this area in 1996, making up 20.1 per cent of the total in Xinjiang. Other pastoral regions include the Pamir plateau and the Southern Tianshan Mountains. Aktau County, the most productive yak-rearing area in these regions was home to 24,600 yaks in 1995.

Breeding and Cross-breeding

For the most part, the yaks of Xinjiang mate by natural methods. Mating is monitored by local tradition. Breeding selection is not widely practised. These methods of breeding and cross-breeding have resulted in low overall productivity. The negative effects of long-term inbreeding and low reproduction rates have diminished body size as well as virility, strength, and ability to combat disease.

At present, yak-breeding selection has drawn great attention, both from government officials and from peasants and herdsmen. Fine breeding bulls have been imported to Xinjiang since the late 1980s to improve local yak productivity. For example, in 1989, the Harnor Pastoral area of Hejiang County introduced eight white male yaks from Tianzhu to carry out cross-breeding experiments. Cross-breeding and proper selection eliminated wool impurities and low-level reproductivity. White yaks now total 460 head; F1 and F2 generations of these crosses are more resistant to disease and cold, enjoying higher reproductive rates than their purely local counterparts; the average amount of wool and undercoat fur increased by about 160 grammes.

Xinjiang herders and officials have also established and standardised breeding systems; and this has included the introduction of the breeding male yak family system. Such efforts have helped to limit inbreeding. The Bayinguolen Mongolian Autonomy District, for example, has finished drafting methods for the stanardisation of breeding methods for the Ba-Zhou yak species. Methods include identifying an entire group of yaks, eliminating inferior specimens from the breeding pool, and setting up core breeding groups, thereby improving the productivity of the entire species.

Technical research on the use of frozen semen for artificial insemination (AI) has also been conducted in Xinjiang. Some areas are trying to set up artificial breeding stations to improve the availability of high-quality male yaks. AI is being used as a means of further improving conception rates and levels of productivity and milk, wool, and beef production.

Additional research on the effects of the common crosses and yak-cow crosses is also being carried out; and the research has included studies of the transfer of cow embryo to yaks, with satisfactory results.

Nutrition, Health, and Management Systems

Yaks rely primarily on free-range grazing to meet their nutritional needs. These animals wander through pastoral areas according to season. Few yaks are ever given supplementary feed, or are 'hand' fed. Traditionally, yak management systems remain lax; animals are often left on their own. These practices have resulted in extreme weight loss in winter, due to inadequate access to fodder and corresponding increases in disease and mortality rates and a reduced resistance to cold. When winter snows are heavy, yaks suffer greatly and often die of malnutrition. Similarly, lack of rain precipitates a shortage of grassland resources and, therefore, increases yak mortality rates. (Female and calf mortality rates, in particular, increase significantly.)

This traditional grazing model must be improved upon. Pastures must be improved and artificial grass bases should be established in order to increase the amount of fodder available, particularly in winter. According to Hejing County's eighth five-year plan, they have formed 25.3 sq.km. of newly built artificial pasture, 20sq.km. of naturally limited pasture, and 22.7sq.km. of reformed grassland. These efforts guarantee the additional increase of 45,580 tonnes of fodder, creating a substantial base for yak development.

Shelters and fences designed to protect yaks from cold and predators such as wolves, will also improve overall yak productivity in Xinjiang.

It has been proved by experiment that beef yaks can live not only in cold, highland grasslands but also in agricultural environments and fenced-in areas created specifically for fattening them up. The Bayinguolen District has begun using feed supplements to hasten weight gain before yaks are slaughtered. Within a 30-60 day period, the average weight gain is 300-500 ounces per day.

The yak's resistance to disease and response to cures must also be studied and improved upon. The Bayinguolen District has promoted a systematic research programme that is investigating the primary infectious disease affecting local yaks: parasitosis *in vivo* and *in vitro*. Other infectious diseases under investigation include anthrax, brucellosis, and pasteurellosis. Hejiang county holds regular veterinary tours for the treatment and prevention of diseases.

Production, Processing, and Marketing of Yak Products

Due to the comparatively small population of yaks in Xinjiang, as well as the remote and poor nature of most yak-raising areas, mass production and marketing of yak products remains low. These factors restrict the rapid development of such enterprises. Yak milk is produced mainly for self- consumption and is made into butter, cheese, and grease. Yak beef is sold at local markets for prices similar to those for cow beef. Wool and undercoat fur garners low market prices — about 70 *Yuan Renminbi* per kilogramme.

As rural economies continue to develop, however, the production and marketing of yak products will be an important factor in raising local income and standards of living. Such products must also be standardised.

Yak beef and milk are both rich in nutritional value and unique in taste. These products are suitable for the expansion of the yak product market. Dried cheese and yak meat, for instance, is also easy to store and transport. Large investments in areas that raise a significant number of yaks are necessary, however, to realise these production goals. In the future, not only raw materials but also processed items, such as sweaters and cheese, should be made available to a wider market.

PRIORITIES FOR FUTURE ACTION

The wild yak is the natural forefather of the domestic yak; wild yaks remain vital resources for improving the productivity and genetic diversity of domestic animals. Gansu and Qinghai provinces are currently trying to improve domestic yaks through the introduction of wild yak traits via cross-breeding. These efforts have gained notable achievements (Xiaolin 1996). In Xinjiang, wild yaks exist only in the Kunlun and Altun mountain ranges. Wild yak research in Xinjiang remains minimal; biological and ecological research about the wild yak should be encouraged so as to provide basic theories and guidelines for the protection of wild yaks. Research on domestic yak reproductivity should be improved in order to solve productivity problems. Yaks should be selected according to their specific uses (i.e., wool, milk, or meat). Superior species should be introduced for breeding purposes, and high-quality local breeds should be protected from the negative effects of inbreeding.

Xinjiang includes 73,300sq.km. of alpine highland pasture suitable for yak husbandry; however, only a small portion of this grassland has been used for yak production and development. Xinjiang's yak-raising capability is quite low compared to the capabilities of Sichuan and Qinghai provinces. Presently, administrators have recognised that developing yak production is the only way to help increase the standards of living of remote herders. The ninth Five Year Plan and the 2010 Far Prospect Programme designed in Xinjiang demand that, by the end of the Plan, the region's yak population reaches 300,000, an increase of about seven per cent; by the year 2010, these levels should be up to 500,000 head. Other yak-herding regions have drafted similar development strategies.

In order to fulfill the above goals, the following actions must be taken.

- Change the structure of groups, raising the producing female yak's ratio from 40 per cent to 44 per cent by the year 2000 and 60 per cent by the year 2010.
- Reduce the death rates of adults and calves from the current six per cent to four per cent by the year 2000, and under two per cent by the year 2010.
- Adopt a no-hunting policy for breeding wild yak, including productive females and calves.

CONCLUSION

Xinjiang is a chief location for the development and advancement of animal husbandry, particulary yak rearing. Based on present grasslands, it can be calculated that Xinjiang should be able to host one million yak. In order to achieve the goals presented in the ninth Five Year Plan and the 2010 Year Programme, vast investments for additional research and programmes aimed at improving management strategies should be made. This, in turn, will help expand the market for yak products. Concomitantly, the study and protection of wild yaks must also be a priority.

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Present Conditions and Future Prospects of Yak Husbandry In Gansu Province, China

Han Jianlin and Zhang Rongchang

YAK PRODUCTION IN GANSU

Approximately 900,000 yaks *(Bos grunniens)* reside in Gansu Province, China. This population of yaks accounts for seven per cent of the total yak population in China. Yak production is located in two regions: Gannan Tibetan Autonomous Prefecture in southwest Gansu and the Qilian Mountains in west-central Gansu. The altitude of these areas varies from 1,400 to 4,700masl. The average annual temperature of these yak-raising areas is 1.15°C; the recorded low temperature is -29.6°C. Yearly precipitation averages 582mm and the annual relative humidity is 63 per cent.

Gansu's human population nears 510,000; of these, 45 per cent of the population are ethnic Tibetans. Gansu Prefecture includes seven counties: Maqu, Luquj, Xiahe, Zhuoni, Diebu, Lintan, and Zhouqu. The total yak population in each of these counties is 240,000; 130,000; 230,000; 70,000; 25,000; 23,000; and 16,000, respectively.

Many of the remaining yaks found in Gansu are located in the Qilian Mountain region in areas 2,000-4,800m in height. This mountainous area has an annual average temperature range from -0.1 to 0.2°C with lows reaching -33.1°C. Annual precipitation ranges from 300 to 416mm; yearly relative humidity is 58 per cent. Tianzhu Tibetan Autonomous County, Jingchang City, The National Shandan Horse Farm, Sunan Yugur Autonomous County, and Subei Yugur Autonomous County are the primary habitats for yaks found in this region; yaks total 82,000; 6,000; 15,000; 50,000; and 6,000 in each of these counties, respectively (see Figure 1).

As noted in the *Annals of Livestock and Poultry Breeds in Gansu*, two distinct yak populations live in Gansu: the Gannan yak and the Tianzhu White yak. Only the Tianzhu White yak, however, was listed in the 'Annals of Bovine Breeds in China'.

DISTRIBUTION AND CONSERVATION OF WILD YAKS

About 130 head of wild yaks are found in Gansu. According to Zhonglin (1994), the Qilian type of wild yak is distributed throughout the high, cold pasture and desert regions in the western Qilian Mountains, the Arjin Mountains to the east, and in northern Gansu, particularly within the Subei and Sunan Yugur Autonomous Counties (Xiangting 1991).

The wild yak was listed as a 'first class' endangered animal under China's National

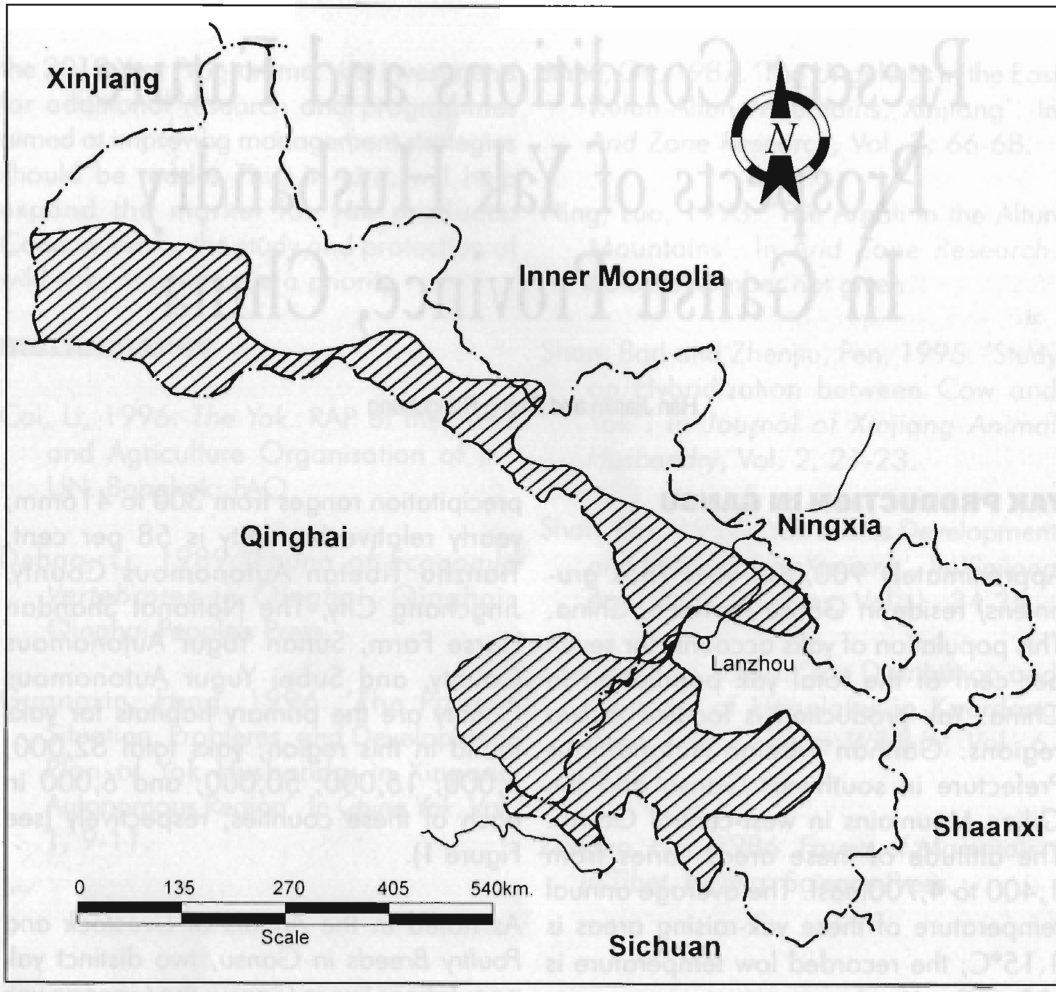

Figure 1: *Distribution of Yaks in Gansu Province*

Wild Animal Protection Regulations. Subei County currently manages a natural protection district for wild yaks. Despite these conservation efforts, wild yak numbers continue to decline for a variety of reasons. More attention must be paid to conservation efforts; including supplying wild yak populations with stable, undisturbed environments and feed supplements such as dry grass and feed blocks in winter and spring.

UTILISATION OF WILD YAKS FOR CROSS-BREEDING IN GANSU

The wild yak was first tamed and bred to produce domestic animals nearly 4,000 years ago. Since this domestication occurred, however, herders have paid little attention to selection and breeding criteria due to limitations arising from political, cultural, and economic issues in most yak-producing areas. Yet the cross-breeding of wild and domestic yaks has recently been proven a successful technique for improving the quality, productivity, and genetic diversity of domestic yaks. This cross-breeding method has been employed in Gansu since the 1980s.

Two male wild yak calves were obtained from Subai Yugur Autonomous County in July 1981 and June 1983. These animals were subsequently tamed over a four-year period so that their semen could be collected and then used to artificially inseminate domestic female yaks. The F1and F2 generation hybrids produced from these cross-breeding methods were much stronger than their domestic counterparts (Zhonglin *et al.* 1990).

PASTURE MANAGEMENT SYSTEMS AND OVERALL LIVESTOCK POPULATION

During the last decade, pasture management and animal husbandry have shifted from being government-owned ventures to private enterprises. A certain area of pasture is now contracted out to individual herders and their families by local governments; this space is allocated according to household and community population.

Livestock numbers have increased as a result of this change. Most herders believe that they will reap economic benefits if they increase the size of their herds. Without options for improving the productivity levels of individual animals, increasing herd size is one of the only ways to raise overall profit. The number of yaks kept by individual families in Gansu now ranges from 50 to 200.

Although increasing livestock numbers has benefited local herders in some respects, overall rise in overall yak population in Gansu has resulted in much overgrazing. In addition to the damage incurred by the grasslands, overgrazing also creates negative impacts on animal health and, therefore, productivity. Traditional methods of animal husbandry, combined with the effects of privatisation, have negatively impacted yak husbandry, in both Gansu and other areas of China.

NUTRITION, MANAGEMENT, AND HEALTH ISSUES OF GANSU YAK

The increase in herd size and subsequent problems of overgrazing have severely impacted overall feed supplies, particularly in winter and spring. Poor nutrition can lead to lower growth and development rates, retarded sexual maturation, and lower oestrus and fertility rates. Thus, poor pasture management that results in overgrazing negatively effects yak growth and development, thereby hampering dairy and meat production — two of the primary benefits of raising yaks. Nevertheless, farmers, as well as provincial and local governments, have paid more attention to the control and prevention of common infectious diseases than they have to fodder supply and management problems.

The weight of yak carcasses decreased by 20 per cent from 1960 to 1980 in China (Zhengkong *et al.* 1994). An investigation in 1988 indicated that the height, length, heart girth, and weight of one group of Gansu yaks were 7.2cm, 14.14cm, 16.01cm and 68.12kg lower than these respective measurements in a herd from Renmei Township, Gannan.

According to this same investigation in 1988, average oestrus and conception rates in Gansu were about 51.46 (range: 48 - 68%) and 80 per cent (range: 61 - 98%) respectively. The highest average conception rate in Gansu — 81.9 per cent — was recorded at the National Shandan Horse Farm during the six-year period from 1966 to 1972. During this time, yaks were fed supplements of feed each year.

The reproductive rate of yaks in Gannan and Tianzhu ranged from 56 to 73 and from 39 to 61 per cent respectively. The live birth rate of yaks in Gansu reached approximately 95 per cent. These figures support the assertion that nutrition and management practices significantly affect the reproductive performance of yak herds. If feeding practices were maintained at optimum levels, one-third of the female yaks in a given herd would give birth every year.

Natural mating is used in most yak-raising areas throughout Gansu. In general, the mating ability of males is poor; some cows need to be bred several times in one oestrus period in order to conceive; this is a result of poor nutrition and rough handling methods. Artificial insemination (AI) technology is practised only in some national farms in Gannan. Expansion of AI technology to other areas has proven difficult due to lower conception rates and poor organisation and monitoring of breeding facilities. In addition, the genetic background of breeding bulls is often not well-known and selection criteria are weak. Consequently, production and performance remain low.

Yak routinely lose about one-third of their body weight from October to June. No measures are taken to prevent or offset this weight loss. In Gansu, as in other areas of China, animals are expected to recover from harsh winters in late spring and summer; fat built up in summer must sustain these animals through the cold months.

The simple greenhouse was introduced in Gannan in 1990 as a means of keeping yaks warm in winter. Yaks having access to this greenhouse on the coldest days of winter only lost eight kilogrammes over the entire winter. (Control group animals kept inside the greenhouse for 120 days gained an average of 21kg.) This technology requires little input and is easily extended to remote areas. Given the positive results of this experiment, as well as the simplicity of this innovation, greenhouses should be used over a wider area.

SELECTION AND BREEDING OF THE TIANZHU WHITE YAK

In 1981, the Provincial Bureau of Animal Husbandry and Veterinary Medicine endorsed an initiative devoted to the 'Conservation and Improvement of the Tianzhu White Yak'. The programme's objectives were to increase the productivity and preserve the unique genetic make-up of the Tianzhu White yak. Local animal husbandry specialists and researchers from the Department of Animal Science, Gansu Agricultural University, cooperated for seven years on this project. These collaborators produced several technical documents during this period: 'Selection and Breeding Strategies of the Tianzhu White Yak', 'Rules of Conservation of the Tianzhu White Yak', and 'Evaluation Standard of the Tianzhu White Yak'.

By the completion of the programme's first stage (1987), body measurements had changed significantly (Yuchang and Yanhong 1994) (Table 1). Three selection methods were determined from this programme: to select and breed from top bulls; to exchange breeding bulls among herds over a two- to three-year cycle; and to establish nucleus breeding herds and a

Table 1: **Live Weight Data and Body Measurements of Adults before and after Selection (Unit: cm, kg)**

	Males		Females		Castrated	
	in 1981 (8)	by 1987 (20)	in 1981 (3)	by 1987 (44)	in 1981 (5)	by 1987 (20)
Height	108.10	110.16	104.25	104.70	105.20	108.35
Length	113.60	115.88	111.00	111.57	114.40	115.93
Heart girth	141.30	154.20	145.00	151.46	149.65	157.20
Live weight	189.70	199.19	171.40	179.59	206.01	222.90

Note: () No. of animals. *: live weight = heart girth (m)2 x length (m)x70 national key breeding farm to supply replacement bulls to farmers. This programme is considered the most successful attempt to improve and conserve the local yak population through selection within China.

The second stage of the programme began in 1992. A new programme for 'Conservation of the Genetic Resources of the Tianzhu White Yak' was supported by the National Agricultural Administration in 1995. This long-term scheme aims to establish a natural conservation district for the Tianzhu White yak to promote the use and conservation of this population, as well as tourism, in the region (Yuchang 1994).

OTHER CROSS-BREEDING INITIATIVES

In Gannan, from 1981 to 1985, cross-breeding tests of two types of Jiulong yak bulls (Henduan Alpine type) and Gannan yak cows (Qinghai-Tibetan Plateau type) were conducted. Results indicated that no significant differences in meat and milk productivity exist between cross-breeds and local pure-breds living under similar conditions (see Table 2). These results were confirmed by a similar test carried out at the Datong Yak Farm in Qinghai (Zhonglin, *et al.* 1990). Consequently, some experts believe that it is impossible to improve yak production levels through cross-breeding among different types or populations (Rongchang 1989).

Several contradictory points of view regarding genetic improvement have also been asserted. Selections made from within a population for the strongest breeding bulls, as well as the production of F1 and F2 cross-breeds from wild yak bulls and domestic yak cows, are believed to increase yak productivity and performance. In relatively remote agricultural regions, cross-breeding cattle sires (local cattle, Hereford, Charolais, Simmental, Aberdeen Angus, and Holstein Friesian) to female yaks has been practised for some time; lactation and meat production are said to improve among F1 and F2 generation offspring.

PROCESSING AND MARKETING YAK PRODUCTS

Meat is the most important product derived from yaks in Gansu; about 5,000 tonnes are produced each year. Yak meat is thought to be a 'green' food, unaffected by pollutants. The price of yak meat reflects this higher quality; yak meat is more expensive than cattle beef, for example, and the demand for yak meat exceeds the supply. Over 70 per cent of the 70,000 culling yaks raised each year in Gannan are sold to Muslims from the Linxia Muslim Autonomous Prefecture; sale of yaks is the main source of cash income for local Tibetans.

Two-thirds of the milk produced by yak cows each year is consumed by calves; the other one-third provides Gansu's Tibetans and other herdsmen with a basic food source. These people not only drink the milk but also make butter and cheese. Some herders sell milk to the Gannan Milk Powder Factory. Given its high fat content,

Table 2: **Comparison of Meat Quality of F1 Cross-breeds of Jiulong Yak (Male) x Local Yak (Female) with Local Yak (unit: kg, %)**

Items	Age (year)	No.	Live weight	Carcass	Slaughter rate	Net meat	Net meat rate
F1	0.5	2	89.2	37.67	42.1	29.1	32.5
F1	1	2	122.75	54.62	44.5	43.8	35.7
Local Yak	0.5	7	91.4±14.5	38.30±7.6	41.9	28.9±5.6	31.6
Local Yak	1	7	127.2±21.4	56.22±9.7	44.2	43.9±8.6	34.5

yak milk is ideal for the production of milk powder.

Yak wool has been used by herders for centuries to make clothing, tents, and other supplies. In recent years, new kinds of products (sweaters, shirts, etc.) have been made from yak wool. These items can be sold for prices equivalent to goods made from cashmere.

Yak blood is rich in a property called superoxide dismutase. When extracted, this by-product is widely used in medicines and for cosmetic purposes. Other biochemical products, such as serum albumin, liver catalase, etc, are also marketable yak by-products.

PRIORITIES FOR SUSTAINABLE DEVELOPMENT OF YAK HUSBANDRY

The following list gives priority measures for the improvement and sustainable development of the yak industry in Gansu Province, China.

- Herd structures should be optimised so that reproductive rates increase from 40 to 50 per cent.
- The number of yaks should be controlled to avoid overgrazing.
- Artificial grasslands should be developed to ensure that yak herds have sufficient feed in winter and spring.
- New technologies, such as feed blocks, simple greenhouses, and artificial insemination, should be extended to more yak herders.
- Top bulls should be selected, bred, and supplied to herders; this can be accomplished by establishing two to three nucleus herds in Gannan.
- Research on the causes of infertility among F1 and F2 males in yak/cow cross-breeds should continue.

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Conservation of Yak Biodiversity and Its Development Potential in Western Sichuan, China

Wu Ning

INTRODUCTION

People always associate the high, frigid rangelands of the Qinghai-Tibetan Plateau with yaks (*Bos grunniens*). The yak is a multipurpose, high altitude large mammal belonging to the *Bovidae* family under the tribe *Ruminantia*. It is the only species of bovine that can adapt itself to the physical environment of the Plateau (Scholtz 1995). It is difficult to imagine animal husbandry on the Qinghai-Tibetan Plateau without the presence of yaks. Yak breeding and raising are inextricably linked to life on the Plateau and the daily life of Tibetans.

Yak-breeding patterns can be interpreted as organisms and societies adapting to specific historical and ecological processes. As economic, cultural, and social phenomena, these patterns are based on several prerequisites such as suitable physiological adaptations to the Plateau environment, a certain degree of property differentiation and private ownership of yaks, and, opportunities for the division of labour. Archaeological evidence indicates that the earliest domestication of yaks, sheep, and goats occurred in various locations on the Qinghai-Tibetan Plateau about 5,000 years ago (Cai 1989).

Most areas of the Qinghai-Tibetan Plateau lower than 4,500m are unsuitable for cropping, with the exception of a few river valleys in the south and east. Extensive areas of rangeland (167 million hectares, comprising 42% of China's total grassland) exist in Sichuan. The amount of large livestock (yak, horse, and cattle) was 17.2 million in 1986 — 14.5 per cent of all national large livestock. Goat and sheep total 37.7 million, comprising 20.9 per cent of the national total. Animal products from this region, such as wool, cashmere, hair, mutton, and beef, account for 12.32 - 13.47 per cent of the national production (Xu and Peel 1991). The Qinghai-Tibetan rangelands have attracted pastoral societies for hundreds of years. Even now, more than half of the regional populations are nomadic or semi-nomadic herders and raisers of livestock.

Yaks now extensively populate China's plateaus and alpine and sub-alpine regions at altitudes ranging from 2,000 to 4,500 metres. The animal has spread to adjacent territories from the central 'core' (the Qinghai-Tibetan Plateau) of the yak's distribution. Western Sichuan is located in the easternmost region of the Qinghai-Tibetan Plateau and plays an important role in economically and ecologically connecting the Plateau and China's hinterlands. This region, at present, is an impoverished plateau area in need of development; yet it has a long history of yak breeding with pronounced local economic characteristics. Following Qinghai and Tibet, Sichuan Province has been ranked the third most important yak-breeding region in China; the number of yaks in Sichuan accounts for 26 per cent of the national total.

Yak-raising Areas - Geo-ecological Background and Distribution of Yaks

Introduction to Western Sichuan

Lying in the west of China's subtropical zone, Sichuan Province is located in the transitional zone between the Qinghai-Tibetan Plateau and the middle and lower plains of the Yangtze River (*Chang Jiang*). Sichuan's tilted topography runs northwest to southeast and contains a variety of land forms, vertical changes, and relatively great regional differentiation. Generally, the *Longmen* Mountains, *Daxiangling* Mountains, *Daliangshan*, and *Xiaoliangshan* mountains are taken as the limits of the Province. Chengdu Basin is situated to the east; high mountains and plateaus lie west. The structure of animal husbandry in Sichuan can be differentiated by region. Pig breeding occurs in the Basin; cattle, goat, and pig breeding occur on the periphery of the Basin; and yak and sheep breeding are limited to the western plateau (Wu 1996).

Western Sichuan refers to the vast area between the *Longmen* Mountains and the *Dadu* River and *Jinsha* River (the upper reaches of the Yangtze River), located between 97° 26' - 104°27' E and 27°57' - 34°21' N. The area of this region is about 236,000sq.km., 41.6 per cent of the provincial total, among which there are 13.9 million hectares of rangeland, 12.18 million of which are available. Administratively, this region is divided into the Garze and Aba Tibetan Autonomous Prefectures and the Qiang Autonomous Prefecture. This area forms the base for yak breeding in the Province. The pastoral area in western Sichuan is characterised by flat plateau, rugged plateau, or alpine grassland; elevations range above 3,500 metres and the climate is frigid and ideal for transhumant yak and Tibetan sheep grazing systems.

Geo-ecological Background of Raising Areas and the Ecological Adaptation of Yaks

Yaks are the only large mammals that live between 2,500 and 6,000 metres with ease, yielding products and performing necessary labour. Yaks live in habitats with rarefied air, scanty grass resources, and a wide diurnal temperature fluctuation and low atmospheric pressure (below 110 mm). High altitude yak pastures (above 4,000m) are often inaccessible in the winter due to snowfall. During this period, yak herds move down to altitudes below 3,500 m — areas in which sun melts the snow during the day, uncovering edible grasses and shrubs. The annual precipitation in yak distribution areas in western Sichuan is 600-700 mm and the relative humidity is 60-65 per cent. These numbers are lower at the Plateau's centre.

Yaks are more physiologically and anatomically endowed for living in cold regions than other bovines. Natural selection over hundreds of years (Cai 1989, 1992) has produced animals who can counteract rarefied air conditions and freezing temperatures well due to their plentiful coats, surefootedness across all types of terrain, close grazing abilities, and substantial respiratory exchange. Their ability to graze on snow, their short gestation and lactation periods, the low birth weight of

Table 1: Distribution of Yaks in Sichuan Province

County	Amount (head)	County	Amount (head)	County	Amount (head)
Serqu	445193	Yajiang	62616	Nanping	56261
Dege	286820	Batang	42102	Heishui	51491
Sertar	258947	Daochen	35723	Xiaojin	51149
Garze	172986	Danba	25382	Jinchuan	29900
Litang	147320	Xiangchen	22881	Lixian	18581
Baiyu	116072	Jiulong	21951	Songpan	18490
Luhuo	112028	Zoige	309055	Maoxian	10527
Kangding	108036	Hongyuna	281367	Muli	36656
Xinlong	102308	Aba	228888	Barkam	70376
Dawu	89561	Zamtang	124271	Others	26144

Source: Cai 1989

calves, and their ability to survive under scarce feeding conditions also help yaks thrive in the Plateau environment.

Distribution of Yaks in Sichuan

According to Cai (1989), temperature is the singlemost important factor determining the distribution and stocking density of yaks. Yaks survive and perform adequately if the annual mean temperature is below 5°C in winter and not above 13°C in summer. Subject to the availability of adequate grazing, the distribution and stock density of yaks increase with altitude. However, altitude is of less importance than air temperature, as the relationship between altitude and latitude can be mediated through air temperature.

In western Sichuan, the distribution of yaks is in relation to latitude. From 31° latitude northwards, the lowest limit of yak distribution is about 2,500m. Yaks cannot migrate below 3,000m from this latitude south. Consequently, the number of yaks in the north generally exceeds those in the south (Map 1). Owing to their special biological and distributive characteristics, yaks play a special role in the regional economy. Furtheremore, they can make use of the vast range resources on this plateau much more efficiently than other livestock.

The largest population of yaks in Sichuan is in the northwestern counties of *Serqu, Dege, Sertar, Zoige, Hongyuan,* and *Aba* where the population in every county exceeds 200,000 head (Table 1). Across the borders of the dense distribution area southwards, there are seven counties where the yak population exceeds 100,000. Generally speaking, yaks are raised in 50 of Sichuan's counties; 37 of these are located in western Sichuan. The other thirteen counties rest along the fringe of the Plateau, but they only comprise 0.2 per cent of the total yaks in Sichuan. Most of these animals were introduced to the area in the last three decades.

Importance and Role of Yaks in Sichuan Province

Given its extensive rangelands, the western Plateau is the most important base for Sichuan for yak husbandry development. Tibetans are the majority ethnic group engaging in yak breeding in this area. Yak breeding remains important both for local subsistence and for the entire national economy, since 59 per cent of the regional total land surface can be considered as rangeland exclusively. In the absence of alternative opportunities of any significance for local employment, most people — about 274,200 in 1990 (Huang *et. al.* 1992) — earn their livelihood from yak husbandry.

Pastoral livestock production is the main economic purusit and comprises nearly 54 per cent of the Gross Agricultural Output Value (GAOV) of western Sichuan. As extensive technical and economic reports mention, the purchasing of animal products has generated no less than half of the overall

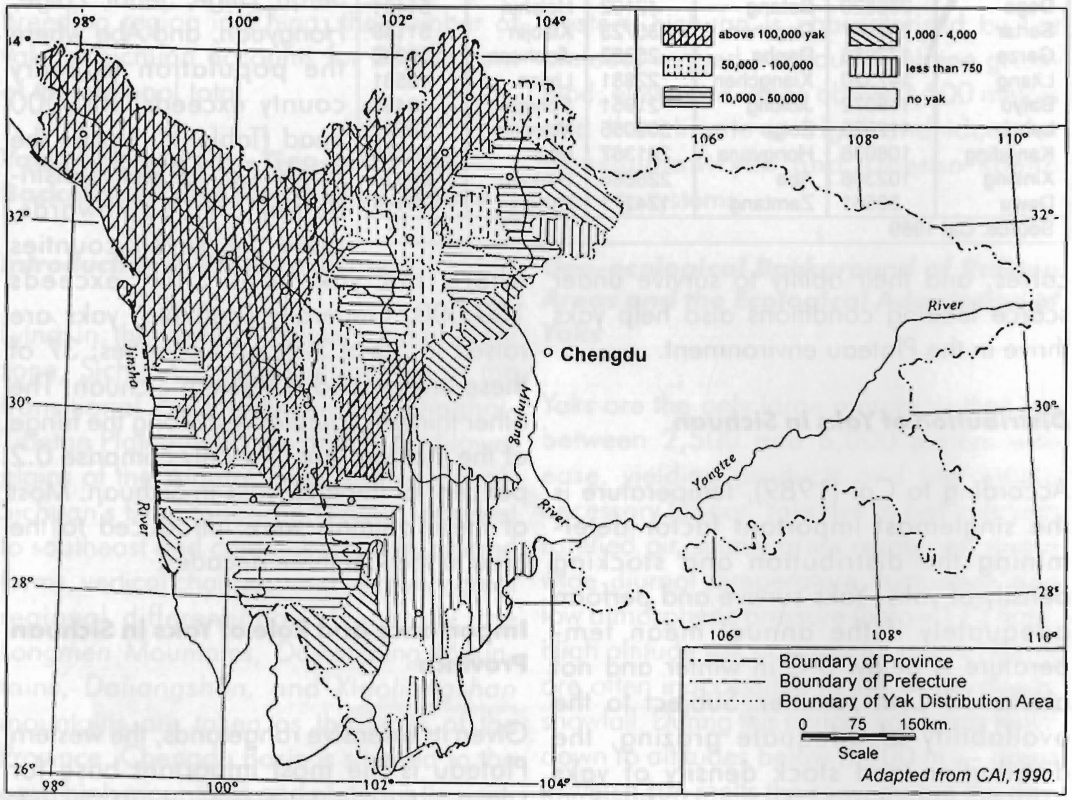

Figure 1: *Density of Yaks in Sichuan*

earnings since 1975. According to statistics from 1991, western Sichuan has 4.32 million yaks, including some cattle and cross-breeds (*dzo* and *dzomo*), 0.35 million horses, and 2.65 million sheep and goats. These animals are grazed on different grasslands all year round.

Different species perform different functions in various livestock production systems. The functions yaks fulfill in a given situation are derived from the interaction between environment, human needs, and custom. Although the compositions of livestock herds in different ecological regions are varied, yaks are always important for subsistence and productivity throughout western Sichuan, contributing meat, milk, and clothing materials (Table 2), as well as manure and manual labour, to the local economy. In western Sichuan, every family operates self-sufficiently. It is also common for yaks to be used for transport and as a form of capital and security in pastoral societies. Yaks may contribute blood to the diet; invariably this animal is used to build and maintain social relationships. Hides and skins are used for housing and water containers as well as for clothing. Dung may be used as fuel instead of manure. Yak hair is woven into tents. Cheese and butter are manufactured by individual households; hides are also tanned. Excess products are sold or bartered with farmers and salesmen. Therefore, the number of yaks kept by nomadic families can be viewed as a kind

Table 2: Different Functions ofthe Yak on the Qinghai-Tibetan Plateau

Crop Production
- tillage (ploughing, ridging, weeding)
- provision of manure
- transport (of inputs and produce; also wood. water, etc)

Consumption
- milk for domestic consumption (and local sale)
- meat. hides, horns, and other by-products for domestic consumption (and local sale)

Household Finance
- investment of crop income (capital growth through herd growth)
- savings (capital storage: for school fees, bride wealth

Social Functions
- ritual purposes (e.g., installation of ancestral spirits, ritual slaughter, bride wealth)
- social status and pleasure in ownership

of insurance in this harsh climate (Wu 1996).

The yak population and its quantitative dynamics are always closely related to range resources. In western Sichuan, the yak population has exhibited an increasing trend in the last four decades — a rise from 1.67 million to 3.82 million between 1950 and 1990, giving a total increase of 128.7 per cent (Figure 2). According to the statistics of the Provincial Animal Husbandry Bureau, 72 per cent of the milk, 15 per cent of the beef, 42 per cent of the bovine skin, and 34 per cent of the hair (including cashmere) came from yaks in 1990. Therefore, yaks are not only vital as domesticated livestock that can use the high, frigid Plateau rangelands, but also as the pillar of regional economics.

Evidence suggests that yaks existed in the ice age (Pleistocene period) in Siberia and continued to live in the Neolithic period, remaining a prized object for hunting. The domestication of yaks perhaps began along with the practice of agriculture in the Neolithic period. It is believed that the present domestic yak is descended from wild yaks caught and tamed by ancient Qiang people in northern Tibet. With the expansion of the Qiang, domesticated yaks came into Sichuan 3,000 years ago. After that, the wild yak population continued to decrease until the middle of this century. Only thirty years ago, wild yaks could still be found in large herds on the rangelands of Aba Prefecture. Due to hunting and degradation of their habitat, wild yaks have become extinct in most of their original environments. Some reports still mention the presence of wild yaks in northern areas of Garze Prefecture, such as *Serqu* and *Sertar,* but it is difficult to assess the accuracy of these claims.

YAK BREEDING AND CROSS-BREEDING

Pure-breeding and Cross-breeding in Sichuan

The different breeds of yak existing today in high altitude areas have been selected by local herders over a long period of time. Due to their multipurpose nature, yaks are not only economically valuable, but are also precious genetic resources. Two types of yaks have been described in Sichuan: the Valley type (Jiulong yak) and Plateau type (Maiwa yak) (Cai 1989). Generally speaking, breeding and cross-breeding of yaks have been practised with two main aims. First, breeding takes place to produce improved or cross-bred animals suited to the specific climatic requirements of a given area. Second, yaks are bred so that their productivity levels meet subsistence needs and market demands.

Grazing and ecological conditions vary according to region. With the expansion of yaks from their original distribution area, pure-breeding and cross-breeding came into practice. According to Chinese sources, the Qiang people migrated to the mountainous region of the eastern Plateau, an area that includes southern Kangding in what is now the Garze Prefecture of Sichuan Province, from the first century B.C. Cross-breds were developed in order to suit new environmental conditions such as steep gradients, large temperature differences between the floors and the peaks of valleys, new alpine meadows, semi-nomadic or transhumant systems, and lack of communication in these regions. The *Jiulong* breed was selected for crossing; it is called the 'valley type' due to its adaptability to valley environments such as that of the *Mula* region of *Yajiang* county of this Prefecture. In fact, cross-breeding was introduced in this area and subsequently spread outwards with the development of the yak industry.

In northwestern Sichuan, the Plateau has many morasses or semi-boggy areas, hill-shaped highlands with gentle slopes, and broad valleys—creating an open topography. The climate is cold with an average annual air temperature below freezing. Slightly higher precipitation and humidity mean that the alpine and sub-alpine meadows are dominated by dense grasses and sedges. Because of the open topography, the seasonal migration of nomads is more horizontal than vertical and yaks tend to migrate freely. Bulls may move from one area to another and mate with individual cows or even whole herds in neighbouring areas, thus leading to some inbreeding between yak stocks in different areas and the blurring of any genetic differences between them (Cai and Wiener 1995). Given these geo-ecological and pure-nomadic conditions, Maiwa breeds (plateau type) are selected for this area, although this practice is only one century old.

At present, marketing requirements always dominate the objectives of breeding or cross-breeding. The defined purposes of selection in China are to accelerate the maturation of individuals and raise body weight levels. The purposes of breeding or cross-breeding vary among different groups of pastoralists. For example, the Maiwa yaks have relatively good quantities of milk with a high butter-fat content. These yaks are clearly multipurpose, although they are primarily used for milk. On the contrary, Jiulong yaks produce good meat and hair and are sturdy draught animals. Selection varies accordingly (Table 3).

Under the selection forces mentioned above, different yak breeds present different physical and productive traits (Table 4). Pure-breeding and cross-breeding are carried out on different scales according to environmental changes and management patterns. In the central area of 'valley type' distribution, pure-breeding is the main method for selection and cross- breeding is hardly practised. In adjacent areas suitable for crop cultivation, some yak-cattle hybrids exist, accounting for 10 per cent of all yak herds; these animals are produced for draught purposes. This is contrasted by the core of the 'plateau type' distribution where hybrids are very common. In *Zoige* County, for example, hybrids comprise 20-30 per cent

Table 3: Selection Index for Jiulong and Maiwa Yaks in Sichuan

Items		Jiulong yak Valley type)		Maiwa yak (plateau type)
Purpose		meat and milk	meat and hair	meat and milk
Body size (dm)	Height (cm)	125-145	120-135	120-140
	Length (cm)	140-170	140-170	
	Heart girth (cm)	190-225	200-230	
Body weight (kg)	New birth	18-20	18-20	
	180 days (stop suckling)	100-120	100-120	115
	1-5 years old	200-250	210-260	135-155
	Adult	350-600	370-630	350-600
Productive properties	Dressing percentage (%)	above 58	above 60	60
	Dressed carcass (%)			50
	Milk yield (kg)	above 1,000	above 1,000	306*
	Butter-fat content (%)	6.2	6.0	above 6.5
	Hair yield (kg)	1.5-2.0	4-12	2-3

Source: Cai 1992: 114; Jin 1996:149
Note: Daily milking for 153 days

of the total yak population. However, in the original location of the Maiwa breed, the number of hybrids is still kept under six per cent and pure-breeding is the main method of yak improvement.

Traditional Breeding Strategies in Sichuan

In the regions where yak products are in great demand, herdsmen have acquired both the knowledge and skills to improve production traits -- even though this may be performed unsystematically and perhaps unconsciously. This is the only explanation for the existence of several localised breeds with apparently above-average performance levels. In Sichuan, indigenous knowledge about traditional yak-breeding methods exists in pastoral societies, but most of these systems have not been described systematically. Jiulong is an exception (Cai 1989, 1992; Cai and Wiener 1995; Jin 1996).

The following is a brief review of the traditional selection procedure used by herdsman in Jiulong area.

Table 4: Comparison of Typical Juilong and Maiwa Yaks

Item	Jiulong yak	Maiwa yak
Centre of distribution	Jiulong, southern Kangding (including Muli, Yanyuan, Mianning, and Shiman)	Hongyuan, southen Zoige (including Aba, Songpan, Nanping and Zamtang)
No. of head	50,000	700,000
History of selection	130 years	about 100 years
Colour of hair	black (most)' black-white (a few)	black (most); black-white, gray, brown and white
Horn	Occurring in all yaks	occurring in most yaks
Body weight (kg)	400-700 (M); 200-400 (F)	300-500 (M); 150-350 (F)
Height (cm)	130-140 (M); 110-120 (F)	120-130 (M); 100-110 (F)
Selecting purpose	meat, milk and hair	milk and meat
Dressing percentage (%)	50-60	50-60
Dressed carcass (%)	40-50	40-50
Milk yield during lactation (kg)	200-500	200-400
Butter-fat content (%)	5-8	6-7
Hair yield (kg)	13-20 (M); 1-3 (F)	2-12 (M); 1-3 (F)
Packing capacity (kg)	60-75**	70-100
Travelling distance with burden (km)	20-25	30

Source: Cai 1990; Jin 1996
Note: ' M = male yak F = female yak.
*** this number was measured with castrated yaks (bullocks)*

Selection of Female Yaks (Cows)

The criteria for female yaks mainly focus on reproduction. Herdsmen eliminate a female yak from the breeding pool when it reaches the age when it should first give birth (4-5 years) but does not produce any calves. Barren or non-pregnant female yaks from three to four years and female yaks who do not exhibit a sufficient maternal instinct to look after their young are also eliminated.

Selection of Male Yaks (Bulls)

Choosing breeding bulls requires more selection criteria than choosing females. Herdsmen examine the bull's ancestors (parents) first and the bull, itself, second. The criteria for selection are summarised in Table 5.

The selection of male yaks (bulls) in the Jiulong area is carried out in three stages: pre-selection at one year, a second selection from among the first group at the age of two years, and a final selection at the age of three or four years. Culled bulls are castrated and used for meat or draught purposes. According to Cai and Wiener, *"After initial mating with cows, bulls which are found to be defeated in the competition among the bulls for mates and those found to have physical defects or bad conformation are then also culled. The herdsmen aim to have two or three successors to an excellent, dominant bull that has been working in the cow herd."* (1995: 23)

Opportunities to Improve Yak Breeding and Cross-breeding

Traditional selection methods for Jiulong yaks appear to have been refined over a period of many decades, perhaps centuries. It is an improved breed of yaks which is highly regarded (Cai and Wiener 1995). However, those involved in pastoral development need to encourage herdsmen to pay most attention to the characteristics of the yak which provide the greatest economic return. The strengthening of yak productive potential usually entails genetic upgrading of indigenous breeds with high-yielding exotic stock.

In Sichuan's yak distribution area, cross-breeding between yaks and cattle (*Bos taurus*) dates back at least 3,000 years when the Qiang people adopted these methods to produce hybrids (*pien niu*, including *dzo* and *dzomo*). The development of cultivation in the mountainous region brought new groups in close contact with pastoral areas. Cross-breeding

Table 5: Traditional Criteria for the Selection of Jiulong Yaks

Ancestors (parents)		Bulls (themselves)
Female (mother)	Male (father)	
- high milk yield; - good conformation (big body); - tame and gentle; - given birth twice to calves	- rich and thick hair; - numerous descendants	- rough bases of horns and a long distance between them; - horns stretching widely outwards; - broad forehead, muzzle and mouth; - thin and long lips; - thick neck, high withers and wide brisket; - wide and flat back, joint and rump; - straight forelimbs and curved hind-legs; - hairy tail and shrunken scrotum; - black coat or black with some white specks on the forehead and at the extremities of the body (e.g. legs, tail)

Source: Cai 1989; Cai and Wiener 1995

increased and a wealth of experience accumulated. Through numerous tests and practices, cross-breeding between male cattle and female yaks was identified as the ideal; local herders also determined that male sterility exists within the hybrids (Fl), but female hybrids (*dzomo*) have the ability to reproduce. However, when *dzomo* continually cross-breed with yaks, atavism occurs after five generations. In Aba Prefecture, cross-breeding is only carried out for two generations. The F1 animals are called *pien niu* and the F2 are called *zai niu*; the latter can be further divided into two kinds: *mao za*, the progeny of male yaks and *dzomo*; and *huang za*, the progeny of male cattle and *dzomo*.

In the last three decades, a great deal of investigation has taken place regarding the use of 'improved' breeds of dairy, beef, and dual-purpose cattle to cross with yaks. The work has been facilitated by the introduction of artificial insemination (AI) and the use of frozen semen. The name which is given to the first cross of yaks with exotic breeds is then called 'improved pien niu'.

The results of such improvement experiments carried out in Sichuan are described below:

Eliminating Za Niu (F2)

This is the earliest traditional method of maintaining and developing stock. Only F1 animals are bred, and all of their progenies are eliminated and even killed. This method intends to increase *dzomo* milk production, strengthen the availability of hybrid vigour, and prevent the degradation of hybrid quality. However, this is not a viable method for poor herdsmen who only own a small stock of animals; such herders refuse to cull any F2 animals.

Wiping out Huang Za and Developing Mao Za

The government encouraged pastoralists to adopt this method of breeding in order to restore and develop yak husbandry in the 1950s and 1960s. Instead of killing all of the *za niu*, this method is based on cross-breeding F2 progenies of *dzomo* with yak bulls. These hybrids retain the adaptability and productivity of yaks better than the *do huang za*; hybrid vigour also degrades more slowly.

This improvement activity stimulated the development of yaks and their hybrids in Sichuan, and these developments and the use of hybrid vigour made great progress. Until the middle of the 1970s, the number of yaks (including their cross-bred progenies) in Sichuan increased from 1.34 million in 1950 to 2.7 million in 1974. The strategy, "*wiping out Huang Za and developing Mao Za*", was accepted and adopted in Aba Prefecture where hybridization traditions exist. It should be mentioned, however, that this method should also be combined with the selection and elimination of F2 hybrids in order to control their proportion in the stock. Otherwise, the population structure of the yak stock will be imbalanced and economic benefits will decline.

Introduction of 'Improved' Bulls and Cross-breeding with Yaks

In the 1960s, eight breeds of cattle (Simmental, Holstein Friesian, Charolais, Hereford, Shorthorn, etc) were introduced from Chengdu, Gansu, and northeastern China in order to use hybrids further, eliminate the defects of local cattle, and increase the economic returns from hybridization. These cattle were raised in pastoral counties such as *Zoige*, *Aba*,

Table 6: **Comparison of the "Local Pien Niu" and "Improved Pien Niu"**

Items	Yak	Local Pien Niu Yak (f) X cattle (m)	Improved Pien Niu Yak (f) X HF (m)
height at withers (cm)	109.7 (f); 123.9 (s)	118.3 (f); 128.7 (s)	121.8 (f); 144.0 (s)
Body length (cm)	038.1 (f); 061.5 (s)	148.0 (f); 173.0 (s)	152.3; 178.3 (s)
Heart girth (cm)	160.3 (f); 198.0 (s)	167.9 (f); 197.3 (s)	182.7 (f); 215.6 (s)
Cannon bone circumference (cm)	16.9 (f); 20.6 (s)	17.0 (f); 20.3 (s)	18.5 (f); 21.3 (s)
Adult weight (kg)	249.0 (f); 443.0 (s)	292.0 (f); 476.6 (s)	356.5 (f); 580.0 (s)
Weight of newborn (kg)	18.7 (7.5-27.5)	17.5	22.5 (14.5-25.5)
Dressing percentage (%)	53.7	52.7	52.0
Carcass percentage (%)	42.0	40.0	41.0
Daily milk yield during lactation kg)	2.0	3.0	8.0
Butter-fat content (%)	6.3	6.0	5.3 - 5.5

Source: 1) Cai 1989; 2) Annual report of Longri, Hongyuan County
Note: f = female; m = male; s = steer (castrated male);
cattle = local cattle; HF = Holstein Friesian or (75%HF + 25% local cattle)

Hongyuan, and *Sertar* and subsequently crossed with yaks. Some of the F1 hybrids improved greatly compared to the locally produced cross-breeds (Table 6).

When these improved breeds were introduced and cross-bred with local yaks, however, the actual socioeconomic benefits remained marginal because the introduced animals could not adapt to local conditions, e.g., the high altitude and the demands of rotational grazing systems. These animals gradually lost their mating ability. In Sichuan, not more than 1,000 progenies of the introduced 'improved' sires (bulls) were produced in 20 years; prior to the 1970s, there were less than 500 *pien niu* produced from these bulls. The use of improved bulls for cross-breeding ended in the 1980s and people have reverted to crossing local yaks with local cattle.

Cross-breeding F1 Generations for Dairy Purposes and F2 Generations for Meat Purposes

Cross-breeding, by definition, involves combining different qualities found in diverse breeds in the anticipation that such crosses will improve the performance and production levels in hybrid offspring (heterosis or 'hybrid vigour'). This improvement plan has been tested and implemented in western Sichuan since the 1980s in order to raise milk yields; meat yields should likewise improve with the cross-breeding of F1 hybrids and 'improved' beef bulls. As such, all the *za niu* are used for beef — a practice that accelerates population turnover and alleviates rangeland pressures. Higher milk yields further increase economic returns. This plan has been popular in pastoral Sichuan. Until 1985, the number of improved dairy *pien niu* reached 3,000 head (Cai 1989).

It should be mentioned, however, that this cross-breeding has been facilitated by the introduction of artificial insemination (AI) and the use of frozen semen. The use of AI has inevitably been restricted to more accessible areas. Moreover, the expense of using AI or having 'improved' bulls means that, except for in a few localities, this plan cannot be effectively carried out without support from governments or development agencies.

The Development of Yak Breeding and Cross-breeding

Improving yak productivity through selection is of great importance to pastoralists. Yaks are integral components of remote social economies; along with sheep, yaks are the primary wealth of herdsmen and their families. However, several factors hamper systematic breeding programmes. According to Cai (1989, 1992) and Jin (1996), the following challenges hamper breeding and cross-breeding systems in Sichuan.

Overstocking

Yaks are still widely regarded, especially among Tibetan people, as a symbol of wealth; this places a great constraint upon the genetic selection of yaks (Cai and Wiener 1995). In fact, this problem not only appears on the Qinghai-Tibetan Plateau, but in traditional pastoral systems throughout the world also. Increasing animal numbers in this traditonal context is often considered a desirable practice. Bolstering livestock numbers provides insurance against winter cold, drought, and other losses. Similarly, if herds are larger, and if circumstances demand that a herder rebuilds his herd, this task is more easily accomplished. Herdsmen know that the larger the herd, the greater the chance that overall loss will be reduced (Grigg 1974, Scholz 1995). Therefore, even if herds are negatively affected by cold and poor grazing conditions, herd sizes are still expanded under 'normal' annual conditions. Since traditional Plateau societies are subsistence rather than profit-driven communities, maintaining or increasing the number of yaks inevitably takes precedence over improvements in quality or productivity.

Non-systematic Nature of Breeding Practices

The absence of necessary performance and parentage records in Sichuan is one of the main reasons why genetic selection by herdsmen — or by extension officers acting on their behalf — is hindered. Despite the fact that local herders claim to possess this knowledge, particularly as it relates to bulls, Cai (1992) doubts the accuracy of this knowledge. Although indigenous knowledge about breeding and cross-breeding has existed in pastoral societies for thousands of years and has developed along rational lines of thinking, not enough technical capacity exists within these communities to systematise this knowledge; 'experts' are always outsiders. Improvement programmes are most concerned with so-called 'modern' approaches and seldom take advantage of the wealth of indigenous knowledge (e.g., oral records) available. Participatory approaches to development remain virtually non-existent.

Poor Understanding of Local Conditions

The survival of the yak in harsh, even hostile, environments is of paramount importance — perhaps even more important than greatly improving an isolated performance trait. Natural selection continues to more accurately and effectively dictate survival rates than any current procedure devised by man (Cai and Weiner 1995). In addition, most government-coordinated projects aimed at yak improvement initiated over the last three decades have been ignorant of ecological, socioeconomic, and cultural factors in yak-rearing areas. As a result, they have not been sustainable. Outsiders, including researchers and administrators, always forget that their responsiblity is to enable herders and other local people to secure their own livelihoods for decades to come.

As mentioned earlier, crosses occupy a different niche than pure yaks in pastoral mountain economies. Cross-breeds are also more prevalent in less severe environments at lower elevations than yaks. Improved female cattle breeds do not survive in typical yak country, nor are such females mated to yak bulls to provide reciprocal crosses. As such, heterosis is more prevalent in local crosses; 'improved' breeds would not survive for long under conditions tolerated by yaks and local crosses. Furthermore, females of such breeds of cattle would not lactate well without supplementary feeding, if they survived. A common presumption is that pure-bred females of improved breeds would yield effectively nothing if kept like typical yaks (Scholz 1995; Cai and Wiener 1995.)

As exemplified above, practical conditions and realistic needs have hindered yak-related improvement projects throughout the Plateau. In order for such projects to be sustainable, the positive effects generated by the project should be able to persist once external support has been withdrawn (GTZ 1993). Disregarding this fact will often result in project failure.

Yak Nutrition and Health

Nutrition Related to Yak-raising in Sichuan

Quality of Natural Pastures

As yaks are primarily free-range animals dependent on area pastures for survival, grass quality studies help illuminate the overall status of yak nutrition and health in Sichuan. Given the environmental conditions, the rangelands in western Sichuan produce high quality grass but in low yields. Analysis of the nutrient composition of mixed grass samples collected on different pastures revealed that rangelands in this area contain high protein nitrogen-free extract (NFE), fat, and lysine in protein, but were low in crude fibre with a high digestion coefficient (Wei and Wu 1988; Huang 1991).

Generally, nitrogen and phosphorus are diluted to lower concentrations in grasses than they are in legumes and forbs. Though the former can produce more biomass in poor soil (low in N and P) than legumes or forbs, their quality is lower (Behnke 1992). In the high altitude areas of western Sichuan, grasses are still the main foodstuff for domesticated animals. Although legumes are not as plentiful as gramineal grasses, they contain more protein, minerals (especially calcium), and vitamins. Additionally, due to the symbiotic nitrogen fixation of legume bacteria and the developed roots, legumes are very important for the improvement of soil structure and fertility on remote rangelands.

Cyperaceae sedges, particularly *Kobresia* and *Carex*, make up the main body of the high-frigid meadows in western Sichuan; these plants have high permissible off-take and contain more nutrients than grasses. *Kobresia* contains an average of 13.49 per cent of crude protein, which is higher than other species in this family. Consequently, *Kobresia* offsets the legume deficit in high-frigid meadows. However, sedges with high silicon contents, changeable yields due to seasonal alternation, short bodies, or other shortcomings are disadvantageous in terms of nutritional quality and yields. (It should be stressed that an estimation of the amount of primary grass production alone is insufficient, since yaks can consume only a portion of this fodder.)

The relationship betwen forage quality and quantity also warrants mention. A quantity of food (in terms of glucose, proteins, lipids, vitamins, minerals, etc) is ingested by an animal per unit of time. The yak requires certain quantities of these elements to maintain its health. If the quantity ingested exceeds this requirement, meat and milk can be produced; if quantities are less than required, yaks must live on their reserves and will lose weight. Obviously, the quality of available forage determines the quantity of forage actually ingested.

Seasonal Dynamics of Quality and Quantity

In the high altitude area of western Sichuan, grasses start to sprout in April or May. At this time, when quality is high but yield remains low, yak grazing demands cannot be met. Grasses grow well in July and August. Yaks eat their fill of high quality forage, rapidly growing and gaining weight. Grasses begin to wither after September. Though this represents peak yield, grass quality continues to decline until pastures become completely withered and give way to winter. Consequently, in summer, yaks regain weight lost the previous winter, get fat in autumn, thin in winter, and risk death from malnutrition in early spring — particularly after a cold winter or in drought years when overall standing biomass is in decline.

The per centage of crude protein increases after April, peaking in July (Zhou 1984). As grass begins to wither, protein and fibre contents gradually decrease, reaching a low in March. The content of crude fibre does not obviously fluctuate from April to September. After that, it increases by degrees with the coming of winter. When forage is green, grass is of good quality and high nutritive value; but, during the withering period, the protein content and nitrogen- free extract diminish by 70-80 per cent. Grasses lose almost all of their vitamin content and the proportion of crude fibre increases as withering continues; digestibility also drops sharply and yield loss reaches more than 15 per cent (Cai 1989). The extensive withering period, as well as the decline in suitable pasture land in winter, necessitates that yaks survive on stored fat during the cold months. Average annual winter weight loss for a variety of livestock is as follows: yaks, 20-30 kg; sheep, 5-7.5 kg; and goats, 3-4 kg (Xe 1988). Weak and thin animals are less resistant to disease.

It is important to note that the duration of annual animal growth rarely exceeds five months. Growing period durations decrease with a rise in altitude, implying that the seasonal variation of forage quality and quantity is not equal throughout the rangelands. This must not be overlooked in attempting to develop the yak industry in these areas.

Sufficiency and Insufficiency of Seasonal Pastures

Tibetan nomads have accumulated a wealth of experience in the use of rangelands. Seasonal migration management systems are well adapted to local conditions. However, some problems have arisen from the uneven distribution of seasonal pastures. In Garze Prefecture, for example, winter pastures on which the grass yield is 29.8 per cent of the total in this Prefecture, make up only 28.1 per cent of the total rangeland; yet grazing on winter pastures continues for seven or eight months per year. Similarly, in three main pastoral counties of Aba Prefecture — Hongyuan, Zoige, and Aba — there are 0.768 million hectares of cold pasture, 37.64 per cent of the total available rangeland. Yet, this area is grazed 210 days per year, 55 per cent of all annual grazing time. The shortage of such pastures leads to overstocking in winter areas and, therefore, insufficient nutritional provisions for yaks during the winter.

The example of Zamtang further illustrates this winter pasture dilemna. Winter pastures in Zamtang have to support animals for seven months of the year, whereas warm season pastures are only grazed for five months. The ratio of cold season pastures to warm season pastures should be 1.4:1. However, there is a serious shortage of winter pastures because there are only 132,969 ha of available cold season pastures in the County. On the contrary, warm season pastures total 166,511 ha, 55.6 per cent of the total available rangeland. In reality, therefore, the ratio of cold season pastures to warm season pastures is 1:1.28 — almost the reverse of what is ideally required.

Because winter pastures are relied upon when grass is withering, both the movement of animals and snowstorms can lead to a decrease in grass available and nutrient loss. Many yaks die of hunger every year due to the shortage of fodder and the fact that grasses are buried by snow in winter and spring. In the pastures of Aba and Garze, herdsmen prefer to mow winter pastures before grazing begins in these areas. However, the amount of hay annually produced by mowing is very limited because grasses are short (only 5-12 cm) at this time of year and vegetation cover is relatively sparse.

Supplemental Feeding Programmes

Winter and spring fodder shortages constrain the nutritive intake of yaks and curtail yak production. Consequently, providing adequate fodder, particularly in winter, has become one of the most urgent issues in pastoral development. In western Sichuan, research on forage development (both indigenous and exotic species) in high altitude pastures is presently being conducted. Since the 1960s, smooth broom (*Bromus inermis*), wild rye (*Elymus nutans*), Siberian wild rye (*Elymus sibiricus*), common oats (*Avenas ativa*), *Trifolium pratense*, alfalfa (*Medicago sativa*), and turnips (*Brassica rapa*) have all been identified as suitable for propagation in this region. Until the middle of the 1980s, more than 200 varieties of forage plants (belonging to 16 families, 49 genera, and 98 species) have been collected or introduced and tested in the pastoral areas of Sichuan (Du 1986).

Despite these efforts, collecting mature seeds of introduced forage species remains very difficult at high altitudes (3,500m+). In addition, only the roots of a few species, such as smooth broom, can be used for propagation. Seed bases must be established in areas where altitudes do not exceed 3,000m; the collection of viable seed bases will springboard into successful fodder development programmes.

Some indigenous grass species have also been improved for the purpose of fodder development. *Elymus breviaristatus* is suitable for artificial hay meadows. Red fescue (*Festuca rubra*) and Sheep fescue (*F. ovina*) have been used in the rehabilitation of degraded pastures. The mature seeds of these species can be collected from high altitude areas for future use. The turnip (*Brassica rapa*) is a popular indigenous succulent forage throughout pastoral and agro-pastoral areas; yet turnip seed production is also concentrated below 3,000m.

Given Sichuan's harsh climatic conditions and rugged terrain, measures to replant pastures or to establish new hay meadows have been difficult. However, it is possible to plant forage grasses in micro-climates in certain localities such as river valleys. Common oats (*Avena sativa*), for example, was introduced to Zamtang in 1978. This plant's average fresh yield can reach 58 tons per hectare. In the autumn of 1991, 40.5 tonnes of seed and 200 tonnes of hay of oats were harvested in 30 hectares of trial pasture in this county. Of these, 21 tonnes of seed were given to pastoralists; the fodder produced helped offset the effects of poor winter pastures. As a result, only eight per cent of the area's yaks died from food shortages in the spring of 1992, compared to a mean mortality rate of 13.5 per cent in the entire county. After sufficient testing, common oats have been planted throughout the county and accepted by herdsmen as a successful means of supplementing available free range fodder. Given Zamtang herdsmen's increasing enthusiasm about this programme, the county government has had to purchase seeds from Gansu and Qinghai to meet demands since 1993.

Supplemental feeding is an important practice, particularly during the long cold season. In pastoral areas where crop cultivation is marginal, hay is mainly produced by cutting natural grasses and cultivating forage grasses. On the contrary, in agro-pastoral areas in which cultivated lands are located near winter houses, hay is mainly composed of planted forage and crop residues. Market exchanges of fodder between agricultural and pastoral areas occasionally occur. In these cases, farming and pastoralism are closely integrated, either through market exchanges or mixed systems of agro-pastoral production.

Western Sichuan faces several problems concerning forage development and cultivation. The construction of hay meadows has developed very quickly in the last two decades. Pastoralists began to plant winter forage with improved seeds with government assistance. However, ammonia-based fertilizers were used in most of these activities. The costs of these fertilizers rendered the benefits of their use debatable. Furthermore, hybrid species of grass tend not to breed true above 4,000-4,500 metres, instead degenerating into their natural form. Indigenous species do not die in seed form and will germinate in the following year, but their seeds are difficult to collect and improve on a large scale. Although many efforts have been made in western Sichuan to introduce legumes, none have been successful. The broad leaves of legumes are susceptible to harsh climatic conditions, particularly hail, which can strip all of the leaves from a plant during germination.

At present, research to examine the effects of supplementary winter feeding programmes and subsequent effects on production has a difficult time finding a fodder source. If the results of such a study were to suggest that supplementary feeding derives worthwhile benefits, the problem of conserving feed for winter use on a larger scale would need to be solved, or non-bulky, inexpensive feed supplements would need to be found. Nevertheless, the difficulty of translating research findings into practical solutions has rarely detracted from the wish or need to gain this basic knowledge (Cai and Wiener 1995).

Yak Health Care in Sichuan

Yaks are considered one of the hardiest large mammals. They rarely suffer from diseases while grazing on high altitude alpine pastures. One explaination for their good health is that yaks graze in rarefied air free from atmospheric pollution. Yaks are most succeptible to disease in winter when they move to lower altitude pastures shared by other ruminants.

Yaks are prone to most diseases that affect cattle world-wide. Although information on production losses from disease is not readily available, consequent economic losses are often high. (Some annual mortality records are kept at animal husbandry and veterinary stations throughout Sichuan.) Common yak diseases that precipitate high mortality rates have been listed and analysed in detail in Cai and Wiener (1995). Given the importance of yaks in pastoral production systems of western Sichuan, a lot of research on yak diseases has been carried out since the 1960s; veterinary services and epidemic prevention programmes have gradually improved. In the 1960s and 1970s, veterinary stations were set up in every county and in many communes. These systems are perpetuated by every *Xiang* (village). Some nomads were trained as veterinarians at this time.

Yak plague and anthrax have now been eliminated within yak populations. Current yak diseases include internal and external parasites such as liver rot, mange, and warbles. These affect the health of the stock as well as the quantity and quality of animal products. For example, 70-80 per cent of the yak hides originating in Zamtang have holes caused by cattle grub. Currently, the government provides anti-helminthic treatment for all animals each spring and autumn. Vaccination is provided free by the state. Improved animal health conditions are especially critical for young animals.

Although such efforts have successfully controlled disease to some extent, incidences of disease remain high in western Sichuan. This can be attributed mainly to a lack of economic incentive for prevention and treatment. The remoteness of area pasture land, the low-cost effectiveness of treatment, and the traditional nature of area pastoralism contribute to the general paucity of disease control and treatment. Also, the successful seasonal vaccination campaigns and disease control measures introduced by veterinary authorities have resulted in an increase in the number of animals in some areas. As such, the improvement of veterinary systems should give rise to a more rapid turnover of livestock and a more effective livestock marketing system.

Yak Management Systems

There is no single management system which applies to all livestock on the Qinghai-Tibetan Plateau. Given the yak's vital role in the pastoralism of western Sichuan, management systems are based primarily on yak breeding. Grazing methods differ by region and are influenced by altitude, climate, and other natural conditions. The proximity of yak-rearing areas to urban centres with markets for yak products also affects patterns of management; the presence or absence of such markets determines whether products are used primarily by yak-herding families or whether certain products, such as milk, meat, and wool, are sold (Cai and Wiener 1995).

Traditional Grazing Practices

In western Sichuan, yak herds are watched by male family members. Although herds vary in size, a herd of about 20 yaks is generally regarded as the minimum necessary to support a family (Cai 1991). Traditionally, nomads would keep an entire herd together, irrespective of age and sex, and allow the yaks to graze together with sheep and horses. The herders would live with their animals and, during the growing season, would move with them as necessitated by the availability of grass and water.

Since the 1950s, these traditional management systems have changed throughout

China. Herds are now divided into different categories of yak; different types of stock are separated. The total yak herd is usually divided into different component herds, including a dairy herd, a *ganba* (dry-cow) herd, a *year* herd comprised of young and reserve animals, and a pack herd. These different herds also vary in size (Cai 1992).

Yaks are reared as free range animals and are never housed, even during terrible climatic conditions such as blizzards and heavy downpours. These animals subsist entirely on pasture, with the exception of lactating animals who are occasionally given barley flour and common salt as supplements. Yaks are not accustomed to receiving any concentrated rations. They begin grazing after lactating animals are milked in the morning and continue to graze until dark. At this time, animals are collected and herded in one place. If enough herdsmen are available, dairy animals are separated from the rest of the herd. Nursing calves are allowed to move with female yaks during the day and are kept in separate enclosures at night.

Yaks are fast and close grazers, adaptable to high altitudes, unpredictable weather, and the short nature of most grasses and forbs. These animals attain their peak productivity during the optimal grazing season; they lose weight and reduce productivity levels when grazing is scarce. It appears (in the absence of actual information on the intake of nutrients) that yaks are specifically adapted to living in areas where food is scarce. It is likely that their ingestion process is slow and that ingested materials are retained in the rumen for quite some time. Microbial activity might ultimately provide researchers with a more comprehensive picture of the animal's nutrient status.

Mobile Livestock Keeping

Pastoral mobility is the basis for appropriate economic and ecological land use and is the survival strategy (Wu 1995) of herders throughout western Sichuan. After leaving their winter territories between mid-April and early May, Tibetan nomads traditionally migrate over a transitive belt. Most routes follow bushy valleys where a grazing path has been formed by the previous movement of animals. At this time, herders take their yaks to grazing areas at altitudes of at least 3,500m. Many nomadic families spend the summer in such areas, sending their herdsmen on to considerably higher pastures as the season progresses. Herders keep their yaks in these pastures through summer and slowly begin moving back down as fall approaches, returning to their winter territory not much later than November. The spatial mobility of grazing herds is always limited by an area's topography.

Although Sichuan's pastoralists depend on yak milk and meat to survive, they do not live on these products alone. Herders have devised various methods of obtaining grain. With the exception of the true nomads living in the northwest where altitudes are so high that it is impossible to cultivate any crops, most pastoralists also sow grain - often Tibetan barley or wheat - in their fields in April or May. These fields are always located in valleys or mountain foothills. Harvest corresponds with the movement of yaks from summer to winter pastures (usually in October).

Two different systems of traditional management practice exist in western Sichuan: the 'two season grazing system' and the 'three season grazing system'. In the plateau area of northwestern Sichuan, it is difficult to distinguish four seasons; however, cold and warm, as well as dry and rainy seasons can be discerned. The natural rangelands are always divided into two parts: winter-spring (cold season) pasture and summer-autumn (warm season) pasture. The 'two season grazing system' which results is essentially rotational. The grazing methods of Yuto, Zamtang County, illustrates this 'two season' system. The inhabitants of Yuto rely exclusively on pastoralism for subsistence. Due to the area's high elevation, no fields are cultivated within the range of cold season pasture; likewise, herders do not maintain permanent winter houses. Cold season pastures are mainly located in a 3,000m valley. These nomads remain in their cold season pastures for seven months, moving north to warm season pastures in the middle of May.

This seasonal migration involves the movement of all livestock and humans, alike. Nomads collect their belongings (including the yak hair tents in which they live) and move to a new campsite. The distance between cold and warm season pastures averages three or four hours on horseback. Warm season pastures are dominated by alpine meadow (primarily *Kobresia*). Nomads remain in these areas until October, as there are no special spring or autumn pastures. However, these pastoralists still move their tents two or three times in summer. The distance between campsites is generally less than 15 km. Therefore, even though nomads remain in the same general area during the warm season, they may move within this pasture area to increase the breadth of land use and minimise foraging pressure by dispersing grazing routes as much as possible.

The 'three season grazing system' prevails in the more mountainous regions of Sichuan. This system includes winter pasture, spring-autumn pasture, and summer pasture. Migration moves vertically; the transitional belt between winter pasture and summer pasture supports grazing activities in spring and autumn.

This system is both more popular and more complicated than the two season system. The region of Gamda in Zamtang County, exemplifies the three season system. Here, grasslands are divided into winter-spring, autumn, and summer pasture; pastoralists also maintain some farmlands in area valleys. Herdsmen stay in winter houses during the severely cold winter and spring. After sowing their fields with barley (about early May), herders migrate to summer pastures, taking with them tents and other necessary belongings. They graze their livestock on these summer pastures until harvesting time in autumn, at which time they drive their livestock to lower elevations and set up their tents in the autumn pastures. Some family members, primarily labourers, will temporarily leave their livestock in order to harvest fields. Once the harvest is completed, these labourers will return to their tents where they will remain until the end of October or the beginning of November.

Barley husks and sheaves are brought to winter settlements and used as hay. Artificial pastures (often oats) are planted around winter houses as supplementary fodder. Although the autumn pasture is only used for a short period (not more than 50 days/year), it acts as the buffer zone for winter pasture. During the cold season, grazing occurs in valleys or at the edge of forests.

Significance of Seasonal Migration and Opportunities for Improvement

The sparseness of natural pastures and their geographic and/or orographic location contribute to the formation of western Sichuan's nomadic characteristics. In general, yak herds must travel great distances in search of food and water — a fact that presupposes seasonal migration.

Scholz (1981) takes the position that pastoralists execute logical risk-averting strategies for livestock. Research studies conducted in Africa (Hubl 1986, Jainzen 1986) and in Mid-eastern Asia (Scholz, 1981, 1982), support the fact that mobile livestock keeping is an "*optimum active human adaptation to the physical environment of arid and semi-arid areas and is probably the only possible way of putting the barren pastures of these regions to economic use without an immense expenditure of capital*" (Scholz 1986:113). Unfortunately, this fact is often disregarded by urban elite and even by development experts.

Rangelands on the Qinghai-Tibetan Plateau are ecologically heterogeneous on a variety of different spatial scales. Exploiting environmental heterogeneity could be thought of as the ecological reason for nomadic movement. In an account of the rangelands of the Qinghai-Tibetan Plateau, Miller (1990) regards the pastoral grouping and mobile raising of yaks as ecologically sound, well-adapted responses to different range and environmental conditions.

In ecological terms, the exploitation of heterogeneity in pastoral societies involves optimisation of forage through local strategies of habitat division and dispersal of grazing pressure. Quantitative and qualitative differences in grazing pressure through 'space' and 'time' are maintained by herding strategies which take advantage of differences in animal diet and mobility according to species, age, or gender. These strategies usually promote sustained-yield resource exploitation whenever land becomes scarce, and, in particular, when seasonal grazing sites are otherwise inaccessible. Furthermore, exploiting variations in animal foraging behaviour and local forage availability in order to maximise production implicates a dynamic balance within the adaptive process. Such behaviour is also linked to ecological strategies that ensure future forage quality and pastoral productivity.

Although no uniform concepts can be applied to all yak-breeding areas due to regional differences, certain concepts are applicable across a number of regions. If taken into consideration in the formation of development initiatives, these strategies could provide a sound basis for pastoral improvement.

- Maximum geographical mobility for yak breeding must be ensured. The dispersal of animals limits the grazing pressure on any one pasture at a given time and is the only way of guaranteeing the greatest degree of rangeland resource conservation.
- For ecological and socioeconomical reasons, rangelands in high-frigid regions should be maintained or opened up by appropriate land-use practices. Although resources are scarce, they are and will be the available base to support local societies. The potential of yak husbandry is also based on these resources and must be used continually.
- The intervention by governments in yak husbandry should be kept to a minimum. However, infrastructural development in pastoral areas should be a priority. The provision of such services is hardly possible without the aid of government-financed programmes.

- Apart from securing basic needs, low-cost measures aimed at promoting self-help should also precipitate the improvement of yak product marketing. However, it should not be forgotten that subsistence needs remain a priority over marketing or economic developments.
- The preservation of nomads' extensive traditional knowledge of their natural environment, as well as their breeding and caretaking skills, remains vital. Indigenous knowledge should be scientifically investigated and integrated into the planning and implementation of development projects.

Production, Processing, and Marketing of Yak Products

Traditional Yak Production and Marketing: Major Challenges and Opportunities

Herdsmen and their families obtain nearly all of their subsistence needs from yaks (Cai and Wiener 1995). Yaks supply their owners with milk, meat, hair and wool, draught power, and dung for fuel. In addition, yak-raising generates secondary income through the sale and trade of these pack animals, transportation needs to which yaks attend, capital accumulation, and the production of secondary animal products. Owners also try to track and exploit major regional, seasonal, and, annual fluctuations in resources in order to optimise herd productivity; reproduction potential is maximised and potential mobility is optimised, in conjunction. In a subsistence economy, managers will be more likely to closely track environmental variations without seriously overstocking their herds because, under these conditions, it may not be possible for a herd owner to reap a profit and then convert stock into other equally usable resources.

The situation throughout Tibetan nomadic environments mirrors those in other pastoral areas such as Africa (Hubl 1986). Nomads are always said to hoard livestock and are reluctant to reduce herd size, keeping more animals than are 'necessary' for subsistence. However, the negative implications associated with such practices are mostly unjustified and the pastoralists misunderstood. When looking at the prevailing composition of yak herds in which female animals predominate, one can easily conclude that male animals have been previously removed from the herd. In addition, there is no known pastoral system on the Qinghai-Tibetan Plateau in which the number of livestock units kept per person exceeds the minimum required for subsistence. Consider the following example. In the sixteenth and seventeenth century, when the Ming Dynasty conquered Mongolia, horses from Tibetan areas became the main source for the recruitment of battle steeds. Meanwhile, due to the shortage of tea on the Plateau, the famous 'tea- horse' trade reached its climax. In the following centuries, pastoral areas of the eastern Qinghai-Tibetan Plateau continued to maintain close livestock trade relationships with neighbouring areas. In Songpan County, the exchange of products and livestock between the Tibetan Plateau and neighbouring areas is governed by the Hui people (Chinese Muslims); the Hui both consume some of these products and sell others across northwestern China, including to Gansu and Ningxia provinces.

Traditionally, the trade of yak products or live animals is always an entrepreneurs' business. Although these private systems were prohibited in the 1960s and 1970s and replaced by communal trade, private trade still functioned on the 'black' market. Since the 1980s, private business has been restored and become another main trading channel besides communal trade. At present, trade dynamics are driven by market forces and operate largely independent of government authorities. In recent years, the state has stepped up its purchase of animal products and supplies of grain to pastoral areas. It is difficult to gather precise statistics about trading from official reports, however, given the private, unofficial extent of trade.

Trading routes throughout the Qinghai-Tibetan Plateau generally lead from poor areas in the west to wealthier areas in the east, or other more urbanised Chinese hinterlands. Trade in yak products mainly occurs in these latter areas. This helps explain why urban authorities always underestimate rural, livestock-based economies.

Market prices of animal products are always relatively low in China. Remote pastoral areas are linked to few central markets. The lack of railways and good roads raises transportation costs. The closest urban centre to Sichuan's pastoralists — Chengdu — is 400 km away. Regional price differences and traders' margins reflect transportation and transaction costs. On the other hand, private sector livestock trade between agricultural areas and pastoral communities is relatively inexpensive and subsistence-oriented. However, pastoralists now own their livestock and have begun to take advantage of the new market economy. The sale of livestock can generate private income exceeding state-contracted income, which, in turn, compels herders to breed yaks for market.

Currently, yak products are crudely processed in western Sichuan. Although most products are processed in Aba Prefecture, there are slaughterhouses in Hongyuan, Zoige, Aba, and Barkam; a new slaughterhouse and small deep-freezing unit was built in Zamtang in 1993. These slaughterhouses produce 2,500 tons of beef per year. Animals are killed and processed by Muslim butchers; by-products are sold to hinterlands and exported to the Middle East. The commercial value of meat has led pastoralists to slaughter livestock earlier in the season. Yak hair (coarse wool, fine hair, and inner cashmere) have also proved marketable, as are a variety of dairy products (milk, butter, ghee, yoghurt, etc).

Many problems confront the marketing of yak products. There is no system for monitoring and evaluating market trends, anticipating supply, demand, and price changes, etc. Weak communication systems also contribute to this problem. In addition, many individual traders who are financially capable of trading livestock and their products do not manage these enterprises well and have previously focussed too exclusively on select markets, ignoring possibilities for extending trade in yak products to new, rapidly expanding markets.

Existing Programmes to Improve Production and Marketing

Most of the recent research and programmes geared towards improving the production and marketing of yak products have focussed on manipulation techniques, i.e., interventions that aim to change particular aspects of yak performance, thereby altering the economics of yak production. Western Sichuan has experimented with different techniques for fattening, slaughtering, and marketing yak yearlings. Calves can be more quickly and inexpensively fattened than adults.

In the 1980s, seasonal animal husbandry was proposed and gradually promoted by local governments. This technique is thought to increase yak production and relies on the use of young animals. Calves are able to digest and assimilate nutrients more quickly than adults; calves also grow faster than mature animals. According to this system, more animals are raised while grasses are growing so that surplus forage grasses are used. Before returning to winter pastures, weak, old, or sick animals are eliminated from the herd. In agro-pastoral areas, thin and weak animals are carried to farms where they are fattened and slaughtered.

The accelerated turnover rate of five yak herds operating under this system is summarised below.

1) Alleviating the Pressures on Winter Pastures and Reducing Spring Mortality Rates

Nearly 88.9 per cent of Plateau counties produce surplus grass during the growth period; however, forage is in short supply during the rest of the year; 48.6 of the counties experience serious shortages.

2) Reducing the Waste of Forage Grasses and Increasing Economic Returns

Under the Plateau's physio-geographical conditions, herbaceous plants are short and sparse. If they are not efficiently managed during the growth period, they are difficult to mow and make into hay in autumn, leading to the waste of precious resources. Grasses should be collected and made into surplus fodder during the summer.

3) Optimising Herd Composition, Accelerating Livestock Turnover, and Increasing Animal Productivity

Herd composition should be adjusted according to climatic conditions. Herd size and fodder yield in grazing pastures must be balanced and will vary according to productivity differences in summer and winter. For example, the carrying capacity of summer pastures is greater than that of winter grasslands; likewise, forage grass from summer pastures is too short to mow for winter storage. To optimise summer pastures, animals should be bred during the summer; herd numbers should be curbed the following autumn.

The low productivity of the livestock on the Qinghai-Tibetan Plateau is usually ascribed to irrational herd composition and the slow turnover of animals (TIST 1993). In pastoral areas of western Sichuan, the number of female yaks of proper bearing age is low, but the number of old yaks no longer capable of reproducing is high. This inevitably affects herd size and composition, increasing fodder demands without improving productivity. In Zamtang, for example, only approximately 33.7 per cent of all animals were females of bearing age. In 1988, herd growth rate only reached 8.17 per cent. Moreover, unproductive pack animals comprised between 40 and 45 per cent of a given herd. These and other unproductive livestock exacerbate slow turnover rates and poor profit margins.

The composition of livestock herds can be regulated by seasonal animal husbandry. Increasing survival, reproduction, and turnover rates and eliminating livestock diseases increase the carrying capacity of rangelands and alleviate pressures placed on winter pastures. This method corresponds to the 'tracking strategy' described by Behnke (1992), in which pastoralists attempt to compensate for fluctuations in forage supply by quickly and deliberately adjusting stock numbers.

Practical constraints such as the lack of or imperfections in markets, the threat of natural disasters, and cultural beliefs have all hindered the widespread adoption of this management technique. Large numbers of animals indicate family wealth and provide 'insurance' against loss from natural disasters. Sustainable production and marketing of yak products remain difficult, given the ecological and environmental conditions of pastoral areas.

Yak rearing for future marketing is characterised by short-term profit seeking production strategies which promote inappropriate land-use practices, as illustrated by the milk industry in Hongyuan. Such marketing strategies also encourage sedentarisation. Market-oriented livestock breeders tend to settle near roads and watering places where products can be easily sold to traders. This behaviour decreases pastoral migration distances, increases stocking rates, and encourages long-term grazing in pastures that are historically used on a seasonal, rotational basis but which are located near permanent settlements. This ongoing concentration of human and animal populations places a heavy burden on the natural environment (Janzen 1995).

Although seasonal animal husbandry and the optimisation of herd composition can increase productivity, some potential risks in this system should also be considered. A rangeland's carrying capacity is dynamic rather than static due to climatic changes. It is difficult, therefore, to accurately determine culling rates which will optimise herd productivity and summer carrying capacity without disturbing future reproduction rates — particularly if the previous winter is harsh. Likewise, if livestock prices, market capacity, and rangeland carrying capacity collapse simultaneously, local herders will face devastating losses. The slaughter of livestock does not necessarily reduce pressure on pasture if herders are specifically breeding for market. Economic self-interest in urban hinterlands may reinforce traditional attitudes towards livestock accumulation in remote areas and discourage slaughter in state- controlled sectors. Such self-interest may also increase the number of animals privately slaughtered for market, which may lead to a further increase in livestock populations. Any benefit gained by taking thin, weak animals to agro-pastoral areas and fattening them up for market would be negated by the remotenes and poverty of nomadic areas.

Consequently, sustainable marketing of yak products requires favourable herding conditions and mobile production units. National development policies should not only improve the quality of animal products and marketing strategies, but should also conserve and rehabilitate rangelands and other environmental resources. Incorporating traditional concepts of pastoralism into rural development concepts is a prerequisite for successful implementation of such initiatives and will also help minimise negative environmental, economic, social, and cultural effects. Seasonal animal husbandry could then function more effectively. The standard of living of western Sichuan's pastoralists would improve; their contributions to hinterland markets and even the national economy would certainly become more important.

Changing Economic and Development Forces: Implications for Yaks

Major Issues Challenging Yak Production and Management

Socioeconomic Changes and Political Transformation

Nomadic yak production developed on the Tibetan Plateau as a result of community adaptation to specific ecological niches created by various geographic, socio-economic, and historical factors. Yak production has remained stable primarily due to nomads' flexible responses to short-term climatic variations and grazing conditions (Miller 1995, Wu 1996). Today, however, numerous demographic and economic changes are triggering adaptive changes that are likely to transform this system. Socioeconomic progress has increased environmental pressure, thereby influencing yak production and marketing, as well as the infrastructure of pastoral areas and nomadic lifestyles (Clarke 1987, Wu 1995).

Attempts to settle Tibetan nomads in western Sichuan Province began in 1958. Permanent buildings for livestock were established, and livestock ownership became communal. In the 1970s, under the *Gongse* (peoples' commune) system, attempts were made to grow forage crops for winter fodder. Veterinary facilities were also established and winter livestock shelters were constructed. Livestock were allowed to graze on state land, but seasonal movements to traditional pastures were still allowed.

In the early 1980s, the government of China sanctioned a major shift in policy, moving away from a planned economy in which the state executed most control and ownership towards a more market-oriented economy. Policies were enacted to encourage private sector initiatives and investment. A series of economic measures signalled the government's new liberalisation. This shift in policy included disbanding the previous livestock marketing organisation, considerably reducing the number of animal product marketing organisations, and ending government-controlled prices.

The failures of collective pastoralism and the great changes brought on by the subsequently introduced 'Household Responsibility System' have reinstated the notion that, in China, the family should be a relatively stable and basic productive unit. However, privatisation raised new questions about collective resource management. Would privatisation disband pastoralists' successful collective management of area grasslands? Would pastoralists be best served by maximising their immediate returns? It became debatable whether the present structure provided enough incentive for herders to preserve this resource. The creation of markets could have, quite literally, cleared the ground, creating a 'tragedy of the commons' scenario.

The government launched a large integrated rangeland development programme in the 1990s to alter the course of rangeland management and privatisation. This programme aims to divide communal rangeland among private families, settle nomads, and construct necessary infrastructure such, as roads, schools, and health clinics, to support pastoralists. The division of rangeland is one of the programme's most complex undertakings and will perhaps create differences of wealth among pastoral families or household groups. Producers' yak holdings will vary considerably, as will their access to essential production elements, income, and expenditure, as a result of different marketing strategies.

The Decline of Animal Diversity

During collective management, herd composition was dictated by government authorities, grazing was highly controlled, and new animals were introduced to certain areas. For example, the government popularisation of improved sheep in Zoige in the 1970s inevitably led to the decline of yak herds and simplified livestock structure. Market demands have the same effect, leading to the increase of herd size to maximise economic benefits without regard to herd composition and rangeland carrying capacity.

The introduction of the Household Responsibility System in western Sichuan encouraged herders to reinstate traditional grazing strategies and herd diversification. Yaks are now allowed to graze with sheep and horses. Herd diversification is practised as an insurance against major disease outbreaks, since different domestic species are generally not susceptible to the same pathogens. In addition, the different dietary preferences of various domestic species allow for a more effective use of pastures. Mixed herds ensure against losses incurred during winter and are also a traditional means of maintaining flora species' diversity based on the maintenance of animal diversity (Wu 1996).

Enclosure of Rangelands

Throughout the Qinghai-Tibetan Plateau, rangelands began to be enclosed at the beginning of the 1960s. At that time, these practices were limited to hay meadows and aimed to supply winter fodder for domestic livestock. In the last two decades, however, this system has come to delineate pasture boundaries, enclose degraded pastures or abandoned fields for forage cultivation, divide pastures for rotational grazing, and protect pastures and livestock from predatory animals.

From a biological persepctive, the construction of fences is undoubtedly beneficial to grass growth. After grasses regenerate, fenced pastures are greatly improved; the physio-chemical characteristics of the soil, the quality of grass, and the overall vegetation structure all benefit from fencing. Furthermore, if such enclosure is only practised on a small scale, (e.g., fencing winter pastures at the bottom of the valley for hay) it will help alleviate winter fodder shortages.

The potential of enclosed range areas is slightly higher than open ranges. However, enclosed ranges are not immune to diminishing range conditions, particularly when grazing management issues or the effects of large-scale enclosures are considered. Stocking densities rarely reflect carrying capacity, but rather suit the demands of the stock owners (Behnke et al. 1993). Additionally, erratic spatial distribution of precipitation or unpredictable snow-storms may reduce forage growth in some enclosed areas. This can lead to temporary but severe overstocking, irreversible rangeland degradation, and the collapse of yak production and marketing systems.

'Sedentarisation'

'Sedentarisation' is defined as a shift in lifestyle from a nomadic to a more sedentary existence (Salzman 1980). On the Qinghai-Tibetan Plateau, nomads settled themselves or were settled by other nationalities during specific historical periods when they maintained military or political control over certain areas. Modern sedentarisation of nomads, however, is always precipitated by the government's market orientation — a common scenario throughout the world.

In western Sichuan, the modern sedentarisation of nomads began at the end of the 1950s, reaching a peak in the 1970s. Sedentarisation allowed seasonal rotation grazing systems to continue; pastures were divided into different sectors, making it easier for administrative units to control the use of communal pastures.

Some of the benefits of sedentarisation for yak production include reliable and easily accessible animal health programmes; increased availability of supplementary feed in winter; a rise in the survival rate of newborns; and lower spring mortality rates. However, shifts from a long-range and highly mobile herding system to a short-range and sedentary or semi-sedentary system involve many potential negative effects.

First, sedentarisation implies an increased risk of environmental degradation, as it is always accompanied by the enclosure of pastures. Short-range herding systems have deleterious effects on range vegetation and soil. Grazing pressure on residual open range is becoming exhaustive and migrations have to be re-routed. Some migration routes or water sources may be closed permanently, thus increasing pressure on remaining resources.

Second, the disappearance of traditional adaptive management systems increases production risks for both individual herd owners and larger industries. One of the main purposes of 'settling down' nomads is to maintain adequate stocking rates and practice some form of grazing rotation. However, almost all pastoral economic strategies not only focus on current production but also relate to long-term production security, given the possibility of severe environmental fluctuations.

Third, sedentarisation is accelerating the breakdown of social structures which previously served as a social security system within herding communities. To understand sedentarisation, one must view it as a particular kind of change that implies a more general process of sociocultural change (Salzman 1980). Governments have thought that the stabilised feed and water supplies provided by sedentarisation would improve the output of animal products. However, such an opinion oversimplifies the diversity of real pastoral situations and undoubtedly neglects some of the diversity of pastoral societies. Nomadic economics rely on sound strategies for both short-term productivity and longer-term insurance. Moreover, pastoralists also use their animals to acquire prestige and influence within their communities. Successful pastoralism requires that one think beyond economics. A nomadic society operates in response to environmental changes and resource availability, as well as economic forces. Pieces of this system cannot be altered in isolation; such an action will create an entirely unbalanced system.

Marketing Forces and Impacts of Tourism

Recent shifts from purely subsistence-oriented production to market-driven production are impacting traditional production systems and land-use patterns. In Hongyuan County, for example, in order to sell surplus milk to a milk factory (located in town) and collect milk from July to August (done along the main roads), herdsmen have to stay a minimal distance away from main roads. The pastures available within this range, however, are winter grazing lands that have just been used during the cold months. As such, marketing forces are impacting vegetation and create rangeland shortages. Herders remain in rich summer pastures two months less than they did before the introduction of the market economy; winter pastures are used an extra month each year. Although the spring pastures provide some buffer, it is also undeniable that winter pastures are overstocked and overgrazed.

Another new impact comes from tourism, although it is still in the embryonic stages in western Sichuan. Presently, not enough survey findings exist to identify the scale and degree of the effects of tourism on yak production. From the symptoms occurring in Hongyuan County, however (the most important county in the pastoral areas of western Sichuan for tourism), some of the economic, sociocultural, infrastructural, and geographic factors have already begun to change. Continuing effects include an increase in the number of tourist accommodations and associated facilities — such as roads — which have created a more reliable communications' system for these remote areas and have provided quicker access to markets. Some small processing factories or cottage industries have been built to produce souvenirs with yak by-products such as bones, hair, and tails. Food and drink prices have also increased due to tourism.

Local incomes have not increased proportionately. Employment opportunites available in town have caused out-migration among the young generation of herders which could lead to labour shortages in rural societies in the future. Young people are less willing to embrace the hardships associated with year-round yak herding. Older people are also seeking alternative forms of production which they find socially and economically more attractive (Cai and Wiener 1995). Thus, the coming of tourists may affect traditional lifestyles. Tourism should not be prevented or begrudged; rather, sound preparations must preclude the introduction of wide-scale tourism to Sichuan.

Keeping Yaks Mobile: Challenges for the Future

Pastoral production is "*based on the use of natural and semi-natural vegetation via domestic animals, in particular ruminants*" (Hubl 1986: 61). Pastoralists' main economic activities are raising livestock and making use of rangelands through a variety of opportunistic pastoral strategies. A large variety of livestock production systems can be found in western Sichuan: agro-pastoralism, semi-sedentary pastoralism, and migratory pastoralism (nomadism), to name a few. Indigenous and improved breeds are used for milk and meat production. Yaks are used for subsistence as well as commercial purposes.

Generally speaking, yak productivity in western Sichuan is low. This relatively low productivity has resulted from the numerous prevailing constraints of the hostile, frigid Plateau. Such constraints can be divided into three categories: normal constraints; disasters and long term constraints; and irreversible changes such as increasing population pressure, market-oriented production, and a constant loss of pastures. The first two categories have always been part of yak production systems; adaptive strategies to compensate for such limitations have existed for centuries. The third group of constraints, however, has developed more recently and lies largely beyond the pastoralists' control.

Normal constraints are seasonal, annual, and spatial variations in relation to climatic conditions and fodder availibility. Traditional pastoralism does not allow for regular, balanced food intake due to dramatic seasonal variations in vegetation resources. Fodder is in surplus during the warm seasons and is in short supply when it is cold. Malnutrition, and consequential negative impacts on health and fertility are common. Yaks are rarely fed supplementary fodder in the winter. Similarly, normal herd off-take in relation to herd increase is frequently disturbed due to insufficient marketing facilities. Cold periods cause excessive reductions in herd size reductions due to emergency mortality sales in late autumn and reduced fertility rates.

Despite the above obstacles and environmental hardships, however, the traditional pastoral systems of the Qinghai-Tibetan Plateau are quite efficient and productive. These pastoral systems seek to optimise the number of people supported per unit area of land and to offer these people maximum food supply security. The nomadic tradition is a multiple goal system in which the production and consumption of milk are far more important than the consumption and sale of meat. Pastoralists are generally poorer than ranchers. This discrepancy, however, is due less to low productivity than to population. Pastoralists try to optimise the number of people supported per unit area, while ranchers aim to optimise economic returns. The pastoral system in western Sichuan directly supports 6.5 people per square kilometre of rangeland. In comparison, ranches in Kenya support no more than 0.5 people per square kilometre and Australian ranches support only 0.002 people per square kilometre.

Pastoralists are experts when it comes to yak and yak production; this simple fact should not be overlooked. *"A global planner might ignore this animal [when considering development projects]. But for the utilisation of the vast grazing resources at high altitudes in central Asia the presence of the yak makes the difference between exploiting these resources or letting them go to waste, and between having an indigenous human population, or a virtually uninhabited wildness."* (Cai and Wiener 1995: 204) The large areas on the Plateau frequented by yak breeders are rich in potential for yak breeding despite resource scarcity. This potential must not remain unused. Because resources are diminishing throughout the world — and will do so in the future — we must use and maintain all potential economic fields. Potential resources, no matter how small, must not be neglected (Scholz 1991).

Priorities for Future Action

Scientific information available on the yak is minimal. A number of studies in Sichuan has been conducted by scientists from yak-rearing regions; but most of the observations were confined to physiology, nutrition, and veterinary care. Such efforts include research on how to influence the reproductive cycle and improve feed utilisation based on an understanding of ruminant physiology and the study of growth promoters. Investigations on optimising herd structure, strategies for sustainable cross-breeding, and the minimisation of inbreeding have also taken place (Zhou 1981, Cai and Wiener 1995).

However, two recurring problems continue to resurface in production-oriented research (Cai and Wiener 1995). First, there is a lack of sufficient numbers to attain biologically and statistically meaningful results. Second, poor experimental design leads to the confounding of factors. Meanwhile, very few studies have been conducted on existing indigenous management practices, grazing ecology, and the adaptability of nomadic societies with the overall objective of improving yak productivity.

As Cai and Weiner write, "*In attempting to identify the gaps in knowledge, it is important to recognise that yak production is part of a system of using natural resources and that different components of the system are interrelated* " (1995: 212). It is necessary to establish an international and multidisciplinary team of researchers committed to the following measures.

- Carrying out surveys on genetic diversity management practices, production levels, cultural diversity, and problems associated with production and reproduction;
- Providing a detailed account of the microbes harboured by the rumen and their role in the nutrient status of the yak, including seasonal variations
- Studying aspects of high-altitude acclimatisation in respect to coat development, respiratory systems, blood circulation mechanisms, reproductive behaviour, and hormonal interactions
- Establishing a small herd of pure yaks on which to carry out observations of performances under different management systems
- Carrying out research on the improvement of yaks for meat, milk, fibre, and draft purposes through selection and cross-breeding with exotic and indigenous cattle
- Conducting research on fodder and development for winter feeding
- Exploring the traditional strategies and indigenous knowledge of the yak herders so that the best aspects of these traditional systems can be incorporated into modernisation plans
- Conducting research on the impacts of marketing forces and tourism on the traditional production practices, management systems, and land-use pattern.

Within the framework of these objectives, development planners, scientists, and local herdsmen should work together. Development's primary aim should be to preserve the yak resource base and conserve biodiversity in yak-breeding regions. The difficult living conditions and constraints to production must be reduced in order to minimise risks involved in pastoral development projects. This can be attained by rapid improvement in living standards and through efficient livestock production. Existing laws and the judicial insecurity of rangeland utilisation and migration resulting from the expropriation of grazing land should be examined. If necessary, legislation should be reworked to meet nomads' spatial needs.

The improvement of social infrastructure in these harsh environments is of major concern. Proper education and vocational training should be strengthened, as should mobile medical and veterinary services. Government authorities ought to concentrate their limited resources on the genuine and sovereign task of national disease control.

In addition to infrastructural improvements, the creation of non-pastoral job opportunities should be the main goal of rural development policy. The construction of small industries for yak product manufacturing at district and regional centres may reduce unemployment among young people and help quell the exodus of young people to urban areas.

Mixed livestock-crop-production systems for the purpose of producing winter fodder (species that grow along rivers and in low altitude areas) should be given both economic and technical support. Ecologically and socially sound land-use patterns must be upheld.

Strengthening a sense of community and personal responsibility is key to the conservation of biodiversity and the rehabilitation of degraded ecosystems. The use and conservation of rangeland ecosystems should be the exclusive responsibility of local people.

Livestock trade has always been a private entrepreneurs' business driven by market forces largely independent of government authorities. This trade is not a perfectly organised branch of the national economy; but it is a functioning and profitable business for the parties involved, albeit on a small scale. Thus, supporting this system should aim to open up new markets and safeguard existing ones.

Although minimal state interference is preferable, the support of government institutions is a necessity, particularly for combating the effects of damage from the cold climate. Any improvement in yak productivity will be impaired without practical and infrastructurally adapted contingency plans against cold.

A large number of scientific publications on the yak is available; interdisciplinary research, however, should be encouraged. Only through intensive research in the fields of natural resource management, human resources, sociocultural structure, political and judicial systems, health care, etc may mistakes in development planning be avoided. Herdsmen's extensive knowledge and capabilities with respect to breeding, keeping and caring for livestock, as well as their knowledge of the natural environment, should be used in planning and implementing projects.

Conclusions

Yak genetic diversity is a critical resource in the interface between environment and development in pastoral western Sichuan, and there is considerable debate about how it can best be maintained. While the storage of genetic resources in gene banks is one option, this interferes with the natural processes of interaction among yaks, people, and the environment. However, innovative means to preserve yak diversity often face numerous obstacles. Yaks are inextricably linked to the culture, religion, and social life of pastoralists.

Due to external pressures and, at a technical level, yak husbandry itself, the nature of yak keeping may change. Though improvement or development strategies are necessary, they are not sufficient in themselves. Such efforts must be part of a broad political, economic, and ideological transformation within pastoral societies. Yak production can only be successfully improved in the long term if schemes are sensitive to existing social structures; otherwise such programmes will fail.

The identity of pastoral societies, such as those of western Sichuan, is rooted in animal husbandry. Consequently, management systems for the conservation, production, sale, and marketing of yaks need to be integrated into an overall philosophy aimed at the sustainable utilisation of area resources and the maintenance and protection of biodiversity.

Western Sichuan has a harsh climate, is high in altitude, and scarce in water resources. Yaks graze in large numbers over the area's rangelands. Pastoralists are the central management figures in this environment. Their attachment to the environment which supports them, as well as their customs, should govern decisions about grassland management. Technological developments should supplement conventional wisdom. Policy reforms at all levels should consider the basic needs of local people and provide direct economic benefits to these pastoral populations. Incentives for rural development must be oriented towards improving living standards and conserving biodiversity.

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Yak Cheese Production in Nepal: An Overview

Tek B. Thapa

BACKGROUND

Yak cheese production began in the Langtang Valley, Nepal, in 1952 and was introduced by the Nepalese Dairy Industry. The FAO provided technical assistance and assigned a Swiss dairy expert, Werner Schulthess, to oversee the project. Schulthess made pioneering contributions to the development of Nepal's dairy industry.

Yak and *chauri(s)* have been herded for the production of butter and *chhurpi* (hard, dried cheese) in the high Himalayas for centuries. These products were traditionally traded for other products in Tibet; however, political changes in Tibet disrupted this trade. HMG established the first cheese factory in Langtang in response to these shifts in transhumance and trade patterns and the subsequent surplus milk supply. Cheese production offered herders an alternative means of income generation at a critical historical time.

Table 1: Measurement of Yak Cheese Contents

1. Standard plate count (SPC)	94 x 10^5 cfu/g
2. Non-lactic count	33 x 10^5 cfu/g
3. Lactobacilli count	41 x 10^5 cfu/g
4. Coliform count	absent in 1 g sample
5. Yeast and mould count	2200 cfu/g
6. Proteolytic count	< 1000 cfg/g
7. Lipolytic count	12 x 10^4 cfu/g

Nepal is one of the first countries in Asia to establish a cheese industry and was the only country in the world producing yak cheese until the 1980s. More than four decades

Table 2: Chemical Composition of Yak Cheese

Parameters	3-month old DDC/yak cheese[1]	3-year old DDC/yak cheese	2-month old yak cheese (Private)[2]	Composition of similar hard cheese[3]
Moisture %	31.8	23.1	39.07	Max 43
TS %	68.2	76.9	60.93	
Fat %			27	
FDMB %	49.4	46.8	44.31	< 42
Protein	-		27.45	
Lactose % by diff.	-		1.93	
Salt %	1.37	3.12	-	
Ash % by wt	-	-	4.55	
pH	5.75	-	-	

1 As reported by Schulthess(1986)
2 As reported by Prajapati(1996)
3 As reported by Sukumar De(1985)

have passed since the founding of Nepal's yak cheese industry. Hard Swiss Gruyère cheese is now produced from *nak* (female yak) and *chauri* (female cross-breed) milk. Bhutan and Mongolia are also now trying to produce yak cheese.

The Nepalese yak cheese industry expanded with the establishment of several cheese production centres in other areas of Nepal after 1952. These projects are primarily under Dairy Development Corporation (DDC) management. Although private sector yak cheese production only began six years ago, private participation in the industry is rising. Twenty cottage-level yak cheese producers are operating in five districts of Nepal: Ramechhap (10), Dolakha (3), Solu (3), Rasuwa (2), and Sindhupalchok (3). Private enterprise now accounts for 50 per cent of the total yak cheese production in Nepal, about 52 MT per annum (see Table 3).

Whereas DDC cheese plants produce cheese in permanent processing sheds, private sector cheese-makers operate in mobile tents under very difficult conditions. Very few private firms have permanent processing sheds for cheese-making. In many areas, however, private yak cheese factories operate close to DDC cheese plants. DDC runs six yak cheese factories in four districts of Nepal (Rasuwa, Dolakha, Ramechhap, and Solu) and is expected to produce 50 tonnes of cheese in 1996. DDC-managed cheese factories are decreasing annually, thereby lowering Nepal's gross cheese production.

Nepal's cheese factories are primarily located in remote areas. This remoteness limits the number of trained cheese-makers from outside the cheese-producing areas who want to work in the industry. No formal cheese-making training programmes are available to cheese-makers from remote areas. Neither a training centre nor fellowships exist for private entrepreneurs to study the technology and management of the cheese industry. The limited numbers of trained cheese-makers in the country are

Table 3: District-wide Yak Cheese Production by Private Producers and the DDC for the 1996 Season (April-October)

Ramechhap District		
1. Ang Rita Sherpa, Himalaya Nambur Yak Cheese, Kyama, Techhim and Chuchure (4 units)	12	MT
2. Sonam, Techhim	2	MT
3. Tendi, Chhehore	3	MT
4. Nagaindeh, Techhim	1.5	MT
5. Temdi, Everest Yak Cheese	4	MT
6. Domserki, Gumdel	4	MT
7. Ngima Pasang, Gumdel	2.5	MT
Total:	**29**	**MT**
Dolakha District		
1. Dukpa Sherpa, Khahare	4	MT
2. Sanu Sherpa, Gaurishanker Himalaya	8	MT
3. Pemba, Dhunge	2.5	MT
Total:	**14.5**	**MT**
Solokhumbu District		
1. Dendi, Everest View Yak Cheese	0.8	MT
2. Fugelgi, Ringmo	1	MT
Total:	**1.8**	**MT**
Rasuwa District		
1. Small-scale private yak-cheese producers(2)	1.8	MT
Sindhupalchok District		
1. Small-scale private yak cheese producers(3)	4.5	MT
Approx.Grand Total:	**51.6**	**MT**
Approximate Yak Cheese Production by DDC Factories		
1. Pike, Solu	3	MT
3. Thodung, Ramechhap	8	MT
4. Chordung, Dolakha	9	MT
5. Chankhu, Dolakha	8	MT
5. Gosainkunda, Rasuwa	18	MT
6. Langtang, Rasuwa	4	MT
Approx. Total:	**50**	**MT**

Total private enterprises - 20 and DDC - 6 all currently employed by DDC. Private yak-cheese producers have learned to produce cheese by observing DDC operations and by practical experience.

The yak cheese industry is of significant importance for rural income and employment. Though the industry is not large, it represents a positive and successful example of agro-industry. More than four thousand people are said to earn their livings from yak cheese production in Nepal. The estimated industry revenue and foreign exchange earnings for 1994 were Rs 31,981,175 and US$ 494,000 respectively. Yak cheese is ideal for the promotion of agro-industry based on livestock products. Due to its high value and market demand, yak cheese could be exported to India and possibly abroad (Colavito 1994).

YAK CHEESE INDUSTRY EXPANSION POTENTIAL

Yak cheese is produced in some of the most remote areas of Nepal's high Himalayas. These regions are significantly different from the rest of the country. Livestock are the main source of income for large numbers of local people. Seventy per cent of Nepal's grasslands are found in this region (Miller 1994). It is estimated that only about 20 per cent of yak/*chauri* milk is processed into yak cheese. Potential exists to increase cheese production in pastoral environments throughout Nepal.

TECHNOLOGY OF YAK CHEESE MAKING

Yak milk differs in composition from cow's milk. The fat content of yak milk ranges between seven to nine per cent, while protein levels are 5.7 per cent and TS is 17-19 per cent. Thapa and Sherpa (1994) described yak cheese production as practised in Nepal's high Alpine regions. This process is outlined below.

Cheese Production

In order to make cheese, raw milk (7-8% fat and 9.5-10% SNF) is standardised to a 3.5 per cent fat content through cream separation. The excess cream is churned into butter. Cheese milk is then 'in-can' pasteurised at 65°C for five minutes by immersing the milk in a boiling water bath. Milk is then cooled to 30°C by dipping it in a cooling water trough.

Cheese milk is transferred to a 200-300 litre copper kettle and put on a traditional fire. Then 0.5 per cent culture (*Str. thermophilus* and *Lactobacillus helveticus* 1:1) is added. After five minutes, a rennet solution (2.5g dissolved in 500 ml boiled and cooled water per 100 litres of milk) is added and stirred for one minute before it is allowed to set at 33°C. The kettle is covered.

The top curd is turned after 30 minutes and allowed to set for another five minutes. The curd is then cut. Curd is then stirred for 25 minutes at 32°C. It is allowed to settle for five minutes before the high temperature scalding treatment is begun.

The curd is heated to 53°C in 30 minutes over an open flame, at which time curd is separated out with cheese cloth once the producer thinks the curd is sufficiently firm. The curd is then placed in moulds and pressed with stone slabs. The block is turned at 15 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 5 hours, and after overnight pressing.

Cheese blocks are brined (22%) for 48 hours. They are then stored for curing at

10-15° C under ambient temperatures (in high Alpine regions between 8,000 and 11,000 feet.) Cheese is given a daily salt washing for three weeks.
Cheese develops a good flavour after five months. Green cheese yield is 11 per cent. Six to eight per cent of the cheese weight is lost after five months of curing.

Chemical Composition

The chemical composition of three-month old yak cheese is 31.8 per cent water, 68.2 per cent TS, 49.4 per cent butter-fat on a dry matter basis (BFDMB), 1.37 per cent salt, and 5.75 per cent P^H. In comparison, three-year-old yak cheese contains 23.1 per cent water, 76.9 per cent TS, 46.8 per cent BFDMB, and 3.12 per cent salt (Schulthess 1986). In comparison, Two-month-old yak cheese produced in the private sector contained 39.07 per cent water, 60.93 per cent TS, 27 per cent fat , 44.31 per cent BFDMB, 27.45 per cent protein, 1.93 per cent lactose, and 4.55 per cent ash (Prajapati 1996).

Issues Surrounding Cheese Production

Although yak cheese is an excellent high-value product, the production of a variety of cheeses would further the scope of the yak cheese industry. Approximately one kg of cheese and about 0.34 kg of butter are produced from 10 litres of yak/*chauri* milk.

Farmers in yak and *chauri*-raising areas do not have any technical knowledge about producing cheese, though they have traditional knowledge about processing milk into butter and making *chhurpi*, *durukho/serghum*, etc. The latter products produce lower economic returns than could be earned through cheese factories. However, local farmers claim the opposite when traditional products are in high demand. This demonstrates that locally-produced yak butter and *chhurpi* have always been profitable and that production is relatively standardised, unlike the 'new' cheese industry.

Private sector cheese is lower in quality than DDC cheese. This is perhaps due to lack of proper training, careless production, lack of proper equipment and reagents, non-adherence to quality control measures, and lack of proper production facilities. Difference in feed availability and feeding practices also affect the quality and quantity of cheese produced in Nepal. Retired DDC employees and local DDC workers are the private sector's main source of trained manpower.

MARKETING

The yak cheese market is well established, particularly in Kathmandu and other tourist areas like Pokhara and Jomsom — places in which demand for these products often exceeds supply. Yak cheese is quite expensive. Approximately 80 MT of yak cheese were produced in 1989/90. In 1994, DDC and private sector cheese producers supplied 77 and 47 MT of yak cheese respectively. DDC has also been supplying 75-80 tonnes of cow cheese and 12-15 tonnes of buffalo cheese each year. The varieties of imported (mostly processed) cheese are increasing in Nepal because cheese demand exceeds supply. Given the unfulfilled demand for cheese products in Nepal, the yak cheese industry, if increased and improved, could capture this market. If production rates, quality controls, and marketing channels were improved and standardised, yak cheese could also be marketed in neighbouring countries and abroad.

PROBLEMS OF AND CONSTRAINTS IN THE CHEESE INDUSTRY

Milk Production

Yak milk production is in decline, inherently limiting Nepal's yak cheese market. Many farmers are not knowledgeable about sanitary milk production and hygienic milk handling. This lack of proper extension services hampers milk production.

In most high mountain areas, research and development, pasture management programmes are either poor or non-existent. This lack of pasture management training decreases overall animal productivity and fodder availability. Most local pastures are low in quality and have poor carrying capacities. The establishment of national parks and the subsequent closing of certain grazing areas have further hindered animal productivity and, therefore, milk yields.

The lack of proper breeding and replacement stocks weakens a herd's overall genetic diversity, and this has a bearing on production levels. Local animal health services are also inadequate; farmers lack proper veterinary knowledge and government veterinarians are often absent or incompetent. Parasitic diseases, red water, HS, FMD, etc are quite prevalent. Animal mortality rates are high due to injuries, accidents, predators, or grass poisoning. Veterinary medicines, feed supplements, and grass seeds are all in short supply. Pack animals must compete for scarce resources and are often undernourished. Local credit systems to enable more people to buy and raise yaks are also poor.

Cheese Production

Very little research has been carried out to develop and standardise the yak cheese industry. Indigenous production methods for *chhurpi*, etc are also poorly understood. Farmers lack technical knowledge about cheese-making. The only cheese-making training is conducted by the Dairy Enterprise Support Programme, a U.S. Agency for International Development Project. Yet the rise in small, private sector cheese producers and the shortage of trained manpower has become more acute, leaving the cheese industry's potential unrealised. No dairy training institution exists in Nepal to consistently impart practical training in milk processing, including cheese-making.

As there is no separate customs' duty schedule for the dairy industry, irrational import duties and tarifs are charged for equipment, packaging materials, and inputs by customs inspectors. Yet starter culture, rennet, and other essential equipment must be imported. Private cheese entrepreneurs, in particular, are poorly treated by the Nepalese bureaucracy. For example, private factories pay substantially higher royalties for firewood than the DDC (Rs 1,000 compared to Rs 7,000).

Technical and physical facilities for cheese production are inadequate, including storage and ripening facilities at the factory level and storage facilities in Kathmandu, the marketing centre. Cheese is produced under very difficult and primitive conditions. Raw milk quality is often poor, both hygienically and in terms of its bacterial load. Likewise, minimum mandatory yak cheese standards have not been formalised under Nepalese law. Mechanisms to monitor hygiene and control quality are shoddy or absent.

Marketing and Export

Marketing presentation is poor due to the lack of packaging facilities available to cheese producers and marketers. No advertising and promotional activities have been introduced by producers or related organisations like NDDB.

The low physical, chemical and bacteriological quality of much of Nepal's yak cheese, inadequate marketing channels, the lack of quality regulations and enforcement mechanisms, and the absence of proper storage facilities all limit yak cheese marketing strategies. These same shortcomings discourage the export of Nepalese yak cheese.

RECOMMENDATIONS TO STRENGTHEN THE YAK CHEESE INDUSTRY

A number of studies, workshops, and forums have identified the constraints of the yak cheese industry and repeatedly made recommendations for its improvement. Responsible agencies, however, have not committed to implementing these suggestions. The most pertinent of these suggestions are discussed below.

Human Resource Development and a Dairy Training Facility

Practical training should be provided to yak and *chauri* farmers to improve pasture management, and, thereby, improve the quantity and quality of milk produced. Cheese-makers should also receive training to ensure production standards. Industry owners should be given training to help them solve storage, packaging, and marketing problems.

Only a permanent dairy training institution equipped with a pilot dairy plant can solve the human resource problem of Nepal's dairy industry. A variety of funds are used to organise training through various dairy development agencies working in Nepal. If these funds are pooled together, a permanent dairy training facility could easily be established. One option would be to convert Lainchaur Dairy plant into a Dairy Training Centre, making necessary modifications. An Asia Regional Yak Cheese Training Centre could also be founded in Nepal. Chordung or Thodung/Ramechhap are possible sites for this venture.

Cheese-making Industry Organisation

Cheese-makers and industry owners should organise themselves into associations to improve their production capabilities. If such groups were formed, they could also lobby the government to provide necessary cheese production facilities and revamp national cheese industry regulations. Industry members would also be able to participate in national and international shows and exhibitions.

If yak cheese producers were to organise themselves, they could also request funding and support from external agencies to help solve transport, storage, marketing, and export problems. Production and processing would run more efficiently and economically. In addition, such groups could establish a proper cheese store in Kathmandu which would help stabilise the yak cheese supply.

Research and Development Activities

Research and development activities should aim to standardise processes for making a variety of cheeses from *chauri* and *nak* milk. This will help diversify Nepal's cheese industry and improve training programmes and skill levels. Without training, such diversification is impossible.

Minimum mandatory standards for yak cheese should be formulated, and the use of a quality mark (NS) should be encouraged. Quality inspection mechanisms should also be established to prevent marketing of low-grade cheeses. Similarly, the packaging, storage, care, and management of cheese before sale should be improved.

Taxes should only be levied on cheese production at production sites and in final sales. Finally, private cheese factories should be allowed to make cheese in unutilised DDC facilities. This would not only improve the quality and hygienic conditions of privatised cheese production but would also safeguard these presently unused facilities, expanding and strengthening Nepal's yak cheese industry as a whole.

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SECTION *Three*

Yak Genetic Resources in China: Evaluation of Chromosome, Protein and mtDNA Polymorphism

Han Jianlin

INTRODUCTION

China is the world's leading yak producing country. Over 90 per cent of the world's yaks (about 13 million animals) live across 120 million hectares of high and cold grassland in southwestern and northwestern China (see Figure 1). As such, the genetic diversity of yaks in China is unmatched.

During the last two decades, scientists have devoted much attention to the investigation and classification of populations and breeds of yak throughout China. From 1980 to 1983, general surveys of yak production and resources in a number of China's yak-raising provinces took place. The provincial annals of livestock and poultry breeds were subsequently updated to include twelve local yak populations (breeds). Yet the standards for classification and evaluation of these populations varied: some focussed on the topographic and geomorphologic characteristics of yak distribution areas, while others emphasised yak body conformation and production types. This paper discusses the several classification systems introduced over the last twenty years in China.

YAK CLASSIFICATION SYSTEMS

In *The Annals of Livestock and Poultry Breeds in China*, Prof. Li Cai (1981) categorised yaks into two distinct types: 'grassland' and 'valley'. In 1982, a survey team of yak experts — Prof. Cai, Southwest Nationalities College; Prof. Li Kongliang, Lanzhou Institute of Animal Sciences of CAAS; Prof. Lei Huanzhang, Qinghai Academy of Animal Science and Veterinary Medicine; and Prof. Zhang Rongchang, Gansu Agricultural University — visited some of China's primary yak production areas, e.g., Haibei Tibetan Autonomous Prefecture in Qinghai, Gannan Tibetan Autonomous Prefecture in Gansu, Aba and Ganzi Tibetan Autonomous Prefectures in Sichuan, and Diqing Tibetan Autonomous Prefecture in Yunnan. This trip aimed to scientifically investigate and document the yak resources available in these areas.

As a result of this field work, the team suggested that two types of yak exist in China: the Qinghai-Tibetan Plateau type (also called the 'Plateau' or 'Grassland' type) and the Hengduan Alpine type (also called the 'Alpine' or 'Valley' type). This distinction was made on the basis of topographical and geomorphological differences in the areas (Cai 1989, 1992; Cai and Wiener 1995). Simultaneously, yak specialist Prof. Lu Zhonglin created another classification system for China's yak based on body conformation, colour, and place of origin. According to Zhonglin, China

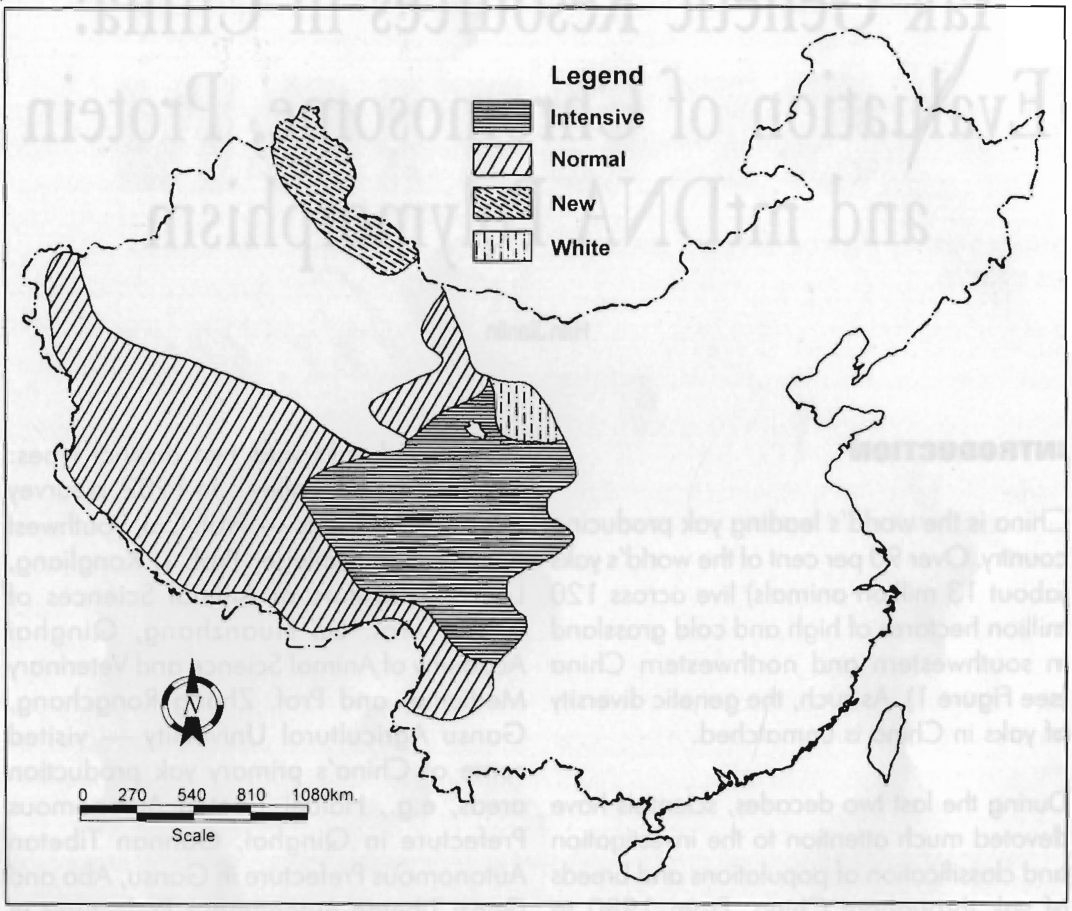

Figure 1: *Yak Distribution Areas in China*

hosts the Qinghai-Tibetan Plateau yak, the Southwest Valley yak, and the Qilian yak. In 1989, Zubo *et al*. recommended yet another yak classification method based on the topography and geomorphology of yak distribution areas throughout China; this system included the Qinghai-Tibetan Plateau type, the Hengduan Alpine type, and the Qiangtang type of yak.

In the first of these three classification systems, the Qinghai Plateau type included yak distributed across the centre of the Qinghai-Tibetan Plateau, including the cold grasslands of Qinghai Province and the Tibetan Autonomous Region, northwest Sichuan Province, southern Gansu Province, and the Qilian mountain area. Yaks in Xingjiang introduced from Tibet also belong to this type. The Hengduan Alpine type is comprised of yak that populate alpine regions of the Hengduan Mountains in the southeastern corner of the Qinghai-Tibetan Plateau (including eastern Tibet), southern Yushu Tibetan Autonomous Prefecture in Qinghai Province, portions of southwestern Sichuan Province, and Diqing Tibetan Autonomous Prefecture in Yunnan Province. These two types of yak are detailed in *The Yak* (Cai and Wiener 1995). In Zhonglin's classification system, yaks distributed in the Qilian Mountains area are considered a separate type. In Zubo's system, yaks of the northern Tibetan Plateau and southern and northern parts of Qinghai Province are deemed distinct. Both the Qilian and Qiangtang types were derived from Cai's Qinghai-Tibetan classification.

MAIN LOCAL POPULATIONS OF YAK IN CHINA

Survey activities carried out between 1980 and 1985 identified several local populations of yak production areas and resources throughout the provinces and regions listed in the previous section. Cai's published work highlights the following 10 local populations: the Jiulong Yak and Maiwa Yak in Sichuan, the Zhongdian Yak in Yunnan, the Tianzhu White Yak and Gannan Yak in Gansu, the Yushu Yak and Menyuan Yak in Qinghai, the Jiali Yak (or Alpine Yak) and Yadong Yak in Tibet, and the Bazhou Yak in Xingjiang (Cai 1981, 1986). In *China Yak* (1992) and *The Yak* (1995), Cai replaced the two local populations in Qinghai listed above with Plateau and Hengduan types.

Rongchang has also identified 10 local populations. In addition to the yaks in Tibet, which he distinguished as the Southeast Alpine Yak and Northwest Grassland Yak, the remaining eight populations Rongchang identified were synonymous with those identified by Cai. In *Chinese 'Yakology'*[sic], edited by a committee of 37 yak experts in China, 11 populations were accepted. The Gannan Yak in Gansu was not included in this classification; yaks in Qinghai were divided into three populations of Plateau yak; the Hengduan yak and the Long Hair yak, and the yaks in Tibet were divided into three populations: Yadong, the Jiali, and Sibu yaks respectively. In contrast, *The Annals of Bovine Breeds in China* only lists five populations: the Jiulong and Maiwa yaks in Sichuan, the Tianzhu White yak in Gansu, the Alpine yak in Tibet, and the Plateau yak in Qinghai (see Table 1).

Table 1: Body measurements and live weights of different yak population (unit:cm, kg)

Population	Site	Sex	No.	Height	Length	Heart girth	ccb*	References
Jiulong	Sichuan	m	15	138	178	219	23.6	Cai Li, 1985
		f	708	117	140	178	18.2	
Maiwa	Sichuan	m	17	126	157	193	19.8	as above
		f	219	106	131	155	15.6	
Tianzhu	Gansu	m	17	121	123	164	18.3	Zhang Rongchang,
		f	88	108	114	154	16.8	1989
Gannan	Gansu	m	31	127	141	188	21.3	as above
		f	378	108	119	155	16.3	
Alpine	Tibet	m	8	130	154	197	22.4	Cai Li, 1985
		f	197	107	133	162	16.1	
Yadong	Tibet	m	59	111	123	155	18.3	Chinese Yakology,
		f	321	109	121	151	15.2	1989
Sibu	Tibet	m	4	132	149	185	21.0	Chinese Yakology,
		f	53	109	127	153	15.9	1989
Plateau	Qinghai	m	21	129	151	194	20.1	Zhang Rongchang,
		f	208	111	132	157	15.8	1989
Huanhu	Qinghai	m	14	114	144	169	18.3	as above
		f	138	103	124	147	15.4	
Long hair	Qinghai	m	7	118	142	175	19.3	Chinese Yakology,
		f	180	101	124	153	15.1	1989
Bazhou	Xingjiang	m	33	127	140	192	20.7	as above
		f	265	111	124	171	16.3	
Zhongdian	Yunnan	m	23	119	127	162	17.6	as above
		f	186	105	117	154	16.1	

* *Circumference of cannon bone.*

All of these classification systems have been determined according to data gathered at the province, county, or prefecture levels. Therefore, it is possible to confuse local populations distributed between provinces or regions. In addition, yak resources in Tibet and southwest Qinghai are not well recognised; confusion over the identification of specific populations might arise as a result.

Rongchang has suggested that the names of local populations listed in various publications should also include some information about the numbers and production levels of yaks in certain areas in an effort to distinguish the diverse genetic backgrounds of these breeds (personal communication 1996). The relative contribution of heredity and environment to population differences can only be accurately distinguished by breeding trails involving different breeds at the same locations (Cai and Wiener 1995). It is for this reason that most yak experts in China prefer to distinguish the word 'breed' from the word 'population' when describing yak resources.

DIFFERENCES IN CHROMOSOME COMPLEMENTS OF FIVE YAK POPULATIONS IN CHINA

According to recent findings, the relative length and centromere position of all the autosomes and the X chromosome were quite similar among the Maiwa, Jiulong, Tibetan, Huanhu, Zhongdian, and Girgizia domestic yaks, as well as among the wild yaks in China. The Y chromosome, however, showed polymorphism among those populations based on the comparison of their karyotypes. Consequently, the relationship between the domestic yak and wild yak is very close (Gang *et al.* 1991). The G-banding chromosome analysis of these five populations in China did not reveal any useful information as no standard for comparing the results obtained in different laboratories has been determined. The C- and NORs-banding chromosome of the Maiwa and Jiulong yaks showed that polymorphism existed between these two populations, among individuals within a given population, and between homologous chromosomes in each cell. Therefore, it is impossible to indicate the genetic marker on the chromosome structure of each population until further comparative studies are conducted.

POLYMORPHISM OF PROTEINS AND ENZYMES IN BLOOD AND MILK OF YAKS

It is well known that polymorphisms among and within yak populations can be used to estimate their genetic differentiation. The study of the polymorphism of proteins and enzymes in the blood and milk of yaks has been the focus of much research, as this procedure is easy to carry out in most laboratories. Over thirty papers have been written dealing with the 41 loci of haemoglobin in nine Chinese yak populations, as well as in yaks found in Mongolia and the former USSR. Below is a list of the loci discussed in these publications.

Haemoglobin(Hb), haemoglobin,8(Hb-,8), albumin(Alb), pre-albumin(Pr), post-albumin(Pa), transferrin(Tf), slow-a-protein(Sa2), amylase(Am), esterase-l(Es-1), esterase-2(Es-2), catalase(Cat), alkaline phosphatase(Akp), lactic acid dehydrogenase-l(LDH-l), lactic acid dehydrogenase-2(LDH-2), adenylate kinase(Ak), carbonate dehydrogenase(Car), ceruloplasmin(Cp), NADH diaphorase(Dia), glucose-6-phosphate dehydrogenase (G-6-PD), malate dehydrogenase(MDH), peptidase-A(Pep-A), peptidase-B(Pep-B),

Table 2: Gene Frequencies of Alb, Akp, LDH-1 and Tf Loci and Heterozygosity in Different Yak Populations

	Huanhu	Tianzhu	Jiulong	Maiwa	Zhongdian	Bazhou	F1 of Domestic Yaks x Wild Yaks
	56	25	25	33	31	5	2
Alb^A	1.000	1.000	0.980	1.000	1.000	1.000	1.000
Alb^B	0.000	0.000	0.020	0.000	0.000	0.000	0.000
Akp^A	0.018	0.000	0.000	0.000	0.000	0.000	0.000
Akp^B	0.964	0.840	0.780	0.742	0.906	0.900	1.000
Akp^C	0.018	0.160	0.220	0.258	0.094	0.100	0.000
$LDH\text{-}1^A$	0.125	0.148	0.120	0.258	0.177	0.100	0.000
$LDH\text{-}1^B$	0.875	0.852	0.880	0.742	0.823	0.900	1.000
Tf^A	1.000	1.000	0.980	1.000	0.970	1.000	1.000
Tf^B	0.000	0.000	0.020	0.000	0.030	0.000	0.000
H	0.009	0.015	0.017	0.023	0.015	0.011	

6-phosphate gluconate dehydrogenase (6-PGD), tetrazolium oxidase (TO), adenylate dehydrogenase (ADA), alcohol dehydrogenase (ADH), guanine deaminase (GDA), glutamine oxaloacetic transaminase (GOT), hydroxybutyrate dehydrogenase (8-HBDH), isocitric dehydrogenase (IDH), leucine aminopeptidase(LAP), malate enzyme(ME), peroxidase (PER), phosphoglucomutase (PGM), phosphohexose iosmerase(PHI) and sorbitol dehydrogenase (SDH) in blood, and α_{s1}-casein, β-casein, κ-casein, α-lactalbumin, and β-lactoglobulin.

Only nine loci, Hb, Tf, Alb, Pa, Pr, Am, Akp, Es, and LDH-1, in blood, and all five loci in milk showed polymorphism in some populations. However, most of these results cannot be compared with each other due to the different nomenclature methods adopted in various studies.

In 1995, Dr. Tu Zhengchang began studying the polymorphism of 34 loci of six populations of the Huanhu yak in Qinghai, the Maiwa and Jiulong yaks in Sichuan, the Tianzhu White yak in Gansu, the Bazhou yak in Xingjiang, and the Zhongdian yak in Yunnan by means of horizontal starch gel electrophoresis. The results of his research showed that only four loci among these populations showed polymorphism (see Table 2). The per centage of polymorphic loci was 0.059 and the average heterozygosity (H) was 0.009 in the entire yak population. Genetic diversity in the yak populations in China is very limited; only 6.25 per cent of the total genetic variations (nuclear genetic variations) found within Chinese yaks can be attributed to differences in populations. Therefore, Zhengchang concluded that no significant genetic differences exist among the various populations in China. Unfortunately, the sample numbers of most populations in his work is insufficient (less than 50). For example, Zhang Caijun (1991) reported that there were polymorphism on the Tf locus with gene frequencies of Tf^A 0.002, Tf 0.995, and Tf^E 0 003 in 455 Huanhu yaks in Qinghai; but Tu did not find Tf polymorphism among the 56 Huanhu yaks he studied.

MtDNA RFLP OF SEVEN YAK POPULATIONS IN CHINA

Animal mitochondrial DNA(mtDNA) is a circular molecule of about 16,500 base pairs. The mtDNA polymorphism revealed by restriction endonuclease digestion has been considered a useful tool with which to elaborate relationships between and within species; the evolutionary rate of nucleotide substitution of maternally inherited mtDNA is more rapid than that of nuclear DNA (Lansaman, *et al*. 1983; Watanabe, *et al*. 1985; Wilson 1985;

Table 3: Percentage of Single Enzyme Site Types in Different Yak Populations

		Jiulong	Maiwa	Zhongdian	Huanhu	Plateau	Tianzhu	Bazhou
		20	20	21	20	7	9	6
Ava I	A	85.00	85.00	76.19	85.00	85.71	88.89	100.00
	B	15.00	15.00	23.81	15.00	14.29	11.11	
Ava II	A	60.00	55.00	71.43	60.00	85.71	87.56	66.67
	B	25.00	25.00	4.76	25.00		11.11	33.33
	C	15.00	15.00	23.81	15.00	14.29	11.11	
	D		5.00					
Bgl II	A	75.00	70.00	95.24	75.00	100.00	88.89	66.67
	B	25.00	30.00	4.76	25.00		11.11	33.33
Eco RI	A	85.00	100.00	95.24	70.00	100.00	88.89	83.33
	B	15.00		4.76	30.00		11.11	16.67
Hind III	A	75.00	70.00	95.24	75.00	100.00	88.89	66.67
	B	25.00	30.00	4.76	25.00		11.11	33.33
Hpa I	A	75.00	70.00	95.24	75.00	100.00	88.89	66.67
	B	25.00	30.00	4.76	25.00		11.11	33.33

Avise 1986). The mtDNA RFLP has also been suggested as a useful genetic diagnostic marker for investigating the variations among and within yak populations (Zhao *et al.* 1994; Zhengchang 1996). The following twenty restriction endonucleases were used to analyse the mtDNA RFLP of 103 samples of the Jiulong and Maiwa yaks in Sichuan, the Plateau and Huanhu yaks in Qinghai, the Tianzhu White yak in Gansu, the Bazhou yak in Xingjiang, and the Zhongdian yak in Yunnan:

Apa I, Ava I, AvaII, B am HI, B al I, Bgl I, Bgl II, Dra I, Eco RI, Eco RV, Hind III, Hpa I, Kpn I, Pst I, Pvu I, Pvu II, Sac I, Sal I, Stu I and Xho I.

Among these samples, 56 morphs were detected. The patterns of Ava I, Ava II, Bgl II, Eco RI, Hind III and Hpa I were polymorphic. Five hyplotypes (I to V) were isolated in the entire yak population (see Table 3). Only 11.61 per cent of the mtDNA variations in all of these Chinese populations resulted from differences among populations. It was concluded that the genetic diversity of mtDNA throughout China's yak populations is also relatively limited. Differentiation among populations was not remarkable; most variations come from differences within a given population. The genetic distances among these seven populations are listed in Table 4. It was found that the Jiulong, Maiwa, and Huanhu yaks had close genetic links, as did the Zhongdian, Plateau, and Tianzhu White yaks. The Bazhou yak was different from those two groups based on dendrogram analysis.

As mentioned by Zhengchang (1996), the results obtained from the protein polymorphism and mtDNA RFLP analysis of the main populations in China did not support the traditional classifications of types and also bore no relationship to the geographic distributions and historical origins of each population. Therefore, intra-population

Table 4: Genetic Distances among Different Yak Populations Based on mtDNA RFLP

	Zhongdian	Jiulong	Maiwa	Tianzhu	Huanhu	Plateau	Bazhou
Zhongdian	0.000000	0.000352	0.000297	0.000112	0.000398	0.00044	0.000869
Jiulong	0.000352	0.000000	0.000115	0.000139	0.000038	0.000472	0.000141
Maiwa	0.000297	0.000151	0.000000	0.000181	0.000154	0.000441	0.000267
Tianzhu	0.000112	0.000139	0.000181	0.000000	0.000187	0.000118	0.000410
Huanhu	0.000398	0.000038	0.000154	0.000187	0.000000	0.000585	0.000126
Plateau	0.000044	0.000472	0.000441	0.000118	0.000585	0.000000	0.000949
Bazhou	0.000869	0.000141	0.000267	0.000410	0.000126	0.000949	0.000000

selection and cross-breeding among populations of yaks will not produce negative effects.

VARIATIONS AMONG WILD AND DOMESTIC YAK CROSS-BREEDS

Zhang Caijun, *et al.* (1994) analysed the polymorphism of Hb, Tf, Am, LDH, haptoglobin, and blood potassium types of the F1 generation of wild and domestic yak cross-breeds. His results showed that the five loci of Hb, Am, LDH, haptoglobin, and blood potassium were polymorphic, whereas the Tf locus was monomorphic. It is difficult to distinguish what proportion of the polymorphism in the F1 population was contributed by the wild yak (2-3 sires). At the moment, the random amplified polymorphic DNA (RAPD) technique is being used to analyse the sperm DNA of wild yaks in our laboratory in order to further scientific understanding of the genetic diversity of wild yaks.

PROPOSED SUBJECTS FOR FUTURE RESEARCH

- Investigate yak resources in Tibet and southern Qinghai by forming a research collective of experts from China and other international organisations.
- Explore wild yak resources in China
- Analyse the genetic diversity of main yak populations in China, including characteristics of body conformation, colour, horns, chromosome complements, polymorphism of protein in blood and milk, mtDNA RFLP and nuclear DNA RAPD; sample numbers must be kept to the same standard for nomenclature and analysis.
- Recognise the genetic differences between domestic and wild yaks.
- Establish a yak genetic resource database with cooperation from IYIC and other international agencies

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Breeding Strategies and Conservation of Genetic Diversity in Yaks

Gerald Wiener

This paper discusses breeding strategies and the importance of maintaining genetic diversity in yak populations in both the interests of commercial practice and of conservation.

Heterozygocity, at the level of the individual animal, is a safeguard against reduced animal fitness and poorer animal performance. Similarly, genetic diversity, at the level of animal population, allows the population to adapt to future changes in the environment and management systems. Without diversity there is no opportunity for genetic change or for adaptation to changing circumstances.

The existence of different breeds of yak may be the key to developing a conservation policy and a new genetic improvement programme for commercial practice. I alluded to the use of different breeds in my talk at the yak conference in Lanzhou in 1994. I will elaborate on these issues in this paper. But first, let me place this topic in the context of current practice.

In practice, a herdsman normally chooses replacement males from among the sons of currently-used bulls - most often from his own herd or from a relatively small group of herds with which he is associated. Effectively, the new young bulls may be the offspring of a very small number of fathers because yak bulls compete with each other for females at mating time. The most aggressive bull will have the largest proportion of the offspring. This process inevitably leads to inbreeding. There may be some herds where positive measures are taken to avoid this situation and where deliberate attempts are made to choose replacement males who are not offspring of the dominant males. Replacement bulls can also be introduced from a neighbouring area. Yet, unless I am persuaded to the contrary, the positive avoidance of inbreeding is the exception, not the rule, in current breeding practice.

The rate of inbreeding is likely to be more significant in small herds or herd groups using very few bulls than in larger units. However, none are likely to escape inbreeding unless positive prevention methods are employed by herders.

Inbreeding reduces heterozygocity in the herd and, as a consequence, leads to poorer animal performance. It does not by itself reduce genetic diversity in the yak population as a whole; reduced genetic variability within herds may be compensated for by increased genetic variability between herds, or groups of herds. If heterozygocity at the animal and herd level is reduced, though not entirely lost, a diversity of genes may still remain in the population as a whole. However, because inbreeding leads to poorer reproductive capacity and poorer survival rates, it is harmful to species' conservation in the broad sense. Natural selection may, to some extent, counteract this trend; but this is a slow process stretching over decades and centuries and not a practical safeguard for herdsmen and conservationists against the primarily negative effects of inbreeding.

The extent of inbreeding -- or, rather, the extent to which heterozygocity is lost -- within yak populations is not, at present, readily measured. The putative evidence for heterosis from the crossing of domestic with wild yaks suggests, however, that increased heterozygocity (in crosses) is beneficial. This evidence also infers that some heterozygocity, or some specific alleles, have been lost in the domestic yak population, perhaps in the wild yak population as well.

A variety of breeds are recognised in the domestic yak population at large. However, these different breeds exist for the most part in different areas of a vast region. To my knowledge, no strict genetic comparison has ever been made between these different breeds in terms of their performance and general attributes, except on a very limited scale in isolated cases. We do not know, therefore, to what extent the breeds differ genetically and in terms of which attributes. It is only known that they appear to differ, to a greater or lesser extent, in external appearance; traits which are usually highly heritable but not very important in terms of the animal's overall genetic diversity vary between crosses. We should be primarily concerned with performance (milk yield, meat, fibre etc), survival rates, and reproductive capacity as opposed to an animal's physical appearance.

Both from the point of view of the practical yak herder and in the interest of conservation we should find out what opportunities are offered by the existence of these different breeds. The practical herder - and his advisors - need to know as much as possible about the available gene pool in order to devise the best breeding plans. The conservationist needs to base recommendations on knowledge about genetic diversity.

The first step towards obtaining this information would be to bring together adequately-sized groups of animals from each of the different breeds found throughout China; if animal health regulations will permit, yak from different countries should also be included. Second, the performance of the different groups at the same location and under the same management should be compared. It would also be beneficial to make these comparisons at more than one location. When animals are taken from one location to another, incomers can have problems adapting to their new environment. Also, the performance of imported animals will be affected by the carry-over effects of the management, nutrition, and health status of the area from which they have come.

For these reasons it is likely that a reliable comparison of the relative merits of different breeds will not be obtained until the next generation of offspring of these different breeds are born in their new location. Various aspects of performances in the offspring generation would then provide information on the degree of genetic difference between these diverse breeds. The data obtained from the foundation population would be useful in a variety of ways but would provide only tentative information on the extent of breed differences.

It might be very practical to keep all breeds at a single, common location. If so, breed comparisons could be spread over several locations with at least one (but preferably more than one) breed common to every location. Additional breeds could then be introduced separately at each location. If this experiment is properly designed and statistically well analysed, such comparisons would provide valid breed comparisons, so long as the breeds only overlapped at different locations. Spreading comparisons over several locations would advantageously involve different regions. This, in turn, should make it more likely that people involved in each region will ensure that final results are relevant to the needs of these areas are credible.

There is, however, another very important reason for using more than one location for the breed comparisons. A breed comparison may be affected by the environment of the location at which it is conducted, including all aspects of local management. Genotype-environment interactions may be a factor of some importance. If different breeds have, in fact, arisen because of different environments in diverse regions, or if they have been developed to exploit a variety of climatic and environmental circumstances, genotype-environment interactions could be significant. We need to determine just how important, or unimportant, such interactions are for future planning of breeding strategies with yaks. The difference between Plateau and Alpine yak types, as exemplified by the Maiwa and Jiulong yak in Sichuan Province, could be a good point to start looking for genotype-environment interaction.

If interactions are important, however, a problem arises in the structure of a breed comparison scheme. On the one hand, it becomes very important to conduct breed comparisons at several locations which differ environmentally from each other. However, if genotype-environment interactions are important, all, or most, breeds must be together at each of the different locations. An experiment design in which only some breeds are common to each location is far less capable of revealing genotype-environment interactions. A design with only one breed in common to all locations would not detect such interactions at all.

Thus, the suspicion or existence of genotype-environment interactions makes it important to replicate the comparisons at several environmentally diverse locations. This requirement also makes comparisons more demanding because of the need for larger numbers and a more complete complement of breeds at each location. Yet breed comparisons, as such, are only a first step in underpinning a strategy for the improvement of yak performance and providing necessary information for the maintenance of genetic diversity in the interest of conservation. Cross-breeding is also necessary. Cross-breeding among the different breeds, as well as concomitant comparison of the breeds, would provide further important information about the nature of any breed differences and how such information might best be used in future breeding and conservation strategies.

Much has been said in the past about the merits of the crossing of yak with *Bos taurus* breeds, both exotic and local. The good performance of these crosses compared to pure yaks, particularly in milk yield and growth rate (depending on the cattle breed used), has been well documented. I believe the evidence, but I continue to question the degree of heterosis that this evidence implies. My question is legitimate; both yak and cattle pure-breeds and their crosses are rarely, or never, kept in the same place at the same time and treated in an identical manner. Estimates of heterosis depend on strict contemporary comparison; otherwise geneticists can only say that the performance of inter-species' crosses is very commendable according to the conditions under which it is measured, and that cross-breed performances are probably better than those of pure yaks if they are identically treated and fed. However, pure yaks and crosses occupy a different niche in the production system, with few exceptions. Sometimes they do not even overlap in their distribution. The comparison of yaks with inter-species' crosses is rarely scientifically rigorous.

Comparison of crosses with cattle breeds contributing to these crosses is even more rare, except perhaps in the case of local breeds of hill cattle. In order to produce a strict estimation of hybrid vigour, crosses should be generated from both yak dams and cattle dams. Such a measure would generate reciprocal crosses which would facilitate the estimation of the importance of maternal effects in cross-breed performance. Some recent, relatively small-scale results from trials in Mongolia involving yaks and local cattle in reciprocal cross-breeding situations are among the few exceptions to the dearth of reliable data on this subject.

When exotic breeds, such as the Holstein, are used for crossing with yaks, the comparison of yaks with pure Holstein and these crosses is not made at all in practice. We are left to guess, or presume, that the performance of the Holstein would be far poorer than that of the yak under the conditions in which the yak typically lives. We have to assume this because we know that Holstein cattle do not survive at the elevations and in the typical conditions of feeding and management tolerated by yaks. Based on this presumption, we would have to conclude that heterosis is a tremendously important factor contributing to the performance of the Holstein-yak crosses. Such an argument is, however, somewhat specious as it owes its existence to genotype-environment interaction.

Similarly, heterosis is said to be expressed in crosses of wild with domestic yaks, though not of the same magnitude as yak-cattle crossbreeds. The relative importance, however, of additive genetic effects and of heterosis, is clearly not known. Wild and domestic yaks are never strictly compared with each other under identical conditions or alongside their crosses. Yet circumstantial evidence for heterosis exists: hence the presumption of differences in gene frequencies among different yak populations.

This reiterates the point that cross-breeding should occur in conjunction with breed comparisons. If yak breeds are indeed found to differ genetically in terms of reproduction and survival - the so-called 'fitness' traits - and if they also differ genetically in respect to performance, we would expect immediate benefits from cross-breeding. Some of the improved performance would arise from hybrid vigour and some from counteracting the harmful effects of inbreeding. Any useful additive genetic effects from differences between breeds would also contribute to improving levels of performance.

A programme devoted to yak-breed comparisons associated with breed crossing would provide yak researchers with a basis for further discussion and for national and international action. The design for such trials would need to ensure that numbers of both pure breeds and crosses are adequate to produce statistically sound results based on a genetically meaningful hypothesis. These experiments should be carried out at more than one location. Pure-bred and cross-bred animals have to be generated at the same time and in the same place.

The initial number of animals of different breeds must be brought together at one or more locations. The number of required animals should be quite large in order to allow both pure breeding and crossing to occur; the actual numbers needed would depend on assumptions about the magnitude of breed differences for various traits, variability in performance in these traits, and the expected reproductive rate. Apart from the desirability of replication at more than one location, the strict need for replication would depend on the evidence for, or the views taken about, the importance of genotype-environment interactions.

The number of females needed per breeding cell should most likely exceed 30 or 40 head. Thus, if four breeds were compared with each other at one location and crossed in all possible combinations, 120 to 160 foundation females would be required for each breed (150 to 200 per breed if five breeds were involved). In addition, a large number of bulls — perhaps 20 of each breed — are necessary to represent their respective breeds. However, not all bulls are needed at the same time. They can be introduced in stages with new stock being brought in over the first few years (provided year and bull effects do not become totally confounded). The total number of animals at any one location would, of course, rise substantially as progeny, both pure and cross, are born and kept for further breeding.

Other designs of this experiment which rely on a smaller number of animals of each breed are possible; but an increase in the overall number of represented breeds (perhaps 15-20) would be necessary in this case. These multi-breed designs are not relevant, however, to the yak situation: a population of animals with a relatively small number of presumably distinct breeds. Multi-breed designs were developed primarily to provide an estimate of the overall range of genetic diversity, not information about specific breeds and crosses.

Taking into account the fairly low reproductive rate of the yak and its long generation interval, a project that attempts to assess cross-breed performance in addition to breed comparisons must last about 15 years. If only a breed comparison is carried out and the project is cut short, the results could lead to breed substitution on a large scale. In other words, herders might be tempted - and government officials may wish - to insist that local breeds are replaced by breeds which appear better on the basis of initial trials. Such a course of action would greatly reduce the overall genetic diversity needed for the long-term survival and improvement of the yak and would remove the opportunities to benefit from cross-breeding.

Given a government-supplied location, the costs incurred for conducting such studies are primarily those associated with the acquisition of animals and technical support for controlling mating and taking relevant observations. In other respects, the yak herd should be self-supporting, as they would generate income from products such as milk, meat, and wool. That being said, it is obvious that my suggestions imply an ambitious scheme which could only be carried out with national and perhaps international support.

Perhaps some of my colleagues consider the implementation of such an initiative an unattainable goal. Part of the purpose of this paper, of course, is to stimulate thought on some unanswered questions about yak genetics; these queries have implications both for future breeding policy and for conservation. However, a joint, coordinated approach to providing answers to some of these important questions should be considered. A project such as I have outlined would give rise to national and international benefits as far as yak production is concerned. Such a programme would provide a basis for future yak-breeding policy and for conservation plans. Provided several locations are involved in the trials, the importance of genotype- environment interactions would become apparent and significantly guide future breeding policy.

If, as I suspect, the results were to show a useful amount of heterosis from breed crossing, these trials would generate widespread opportunities for improving yak fitness and productivity. This would not necessarily involve the continued use of pure breeds to generate crosses, but could arise through the development of crossbred types as new ('synthetic') yak breeds. This option could be explored as a simple and natural extension of the first cross-breeding stage in the proposed scheme. The mating of cross-breeds to cross-breds - with concurrent selection, if necessary - is an option which does not exist with inter-species' crosses due to male sterility in such hybrids.

The breed comparison scheme would also provide useful and necessary information for those herders continuing to practice traditional pure-breeding, and for people advising these herders. It would suggest, for example, whether inbreeding is as serious a problem as I and others believe it to be. As long as pedigree records are maintained in such trials, ample opportunity would exist to derive other (inter-breed) genetic parametres such as heritabilities. Clues about genetic correlations could also be determined, albeit less accurately. All of this information is necessary in the construction of future breeding plans. The information reaped from such breed comparisons and cross-breeding would also directly aid any strategy for the identification and conservation of genetic diversity in yaks.

In conclusion, breed comparisons and the crossing of yak breeds would be a valuable means of identifying genetic diversity. It would provide pertinent information about the relative importance of additive and non-additive genetic effects in yaks, and, if conducted at more than one location, on the importance of genotype-environment interaction. Such coordinated comparisons would help answer questions that need to be asked about yak breeding. At present, many research workers often toil in isolation with inadequate resources, despite their commitment to their research. A coordinated programme of breed comparisons and cross-breeding, associated with in-breed evaluation would provide a scientific basis for conservation plans. Perhaps more importantly, such a programme would also expedite the development of better breeding plans for local yak herders. This would, in turn, lead to the improvement of yak performances for the next century and perhaps even ensure the longer-term survival of the yak, as well as the culture and people it supports.

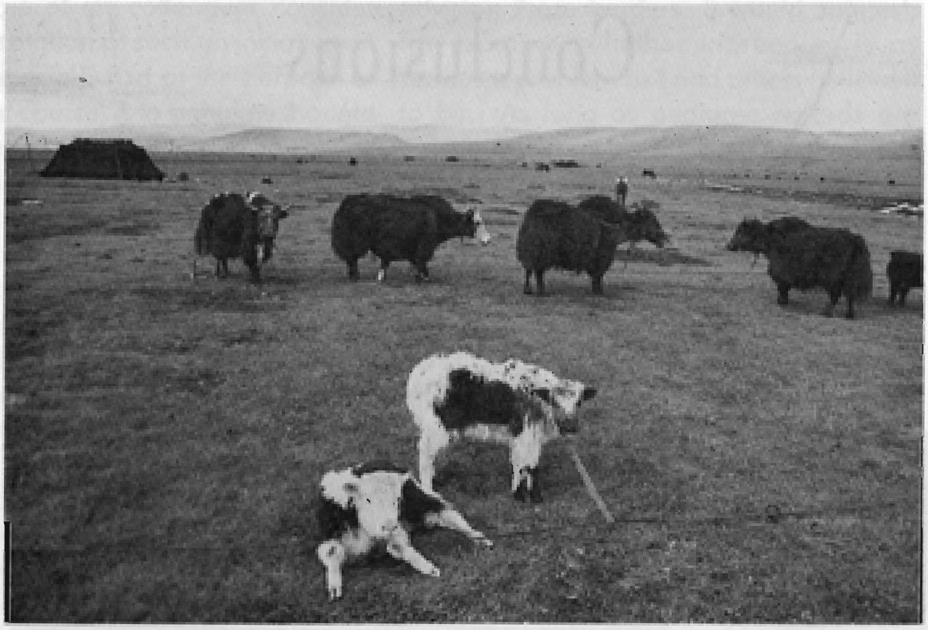
Conclusions

Daniel J. Miller and David E. Steane

Yak breeding bull, Merak, Bhutan
Yak herders have developed local yak types, often recognised as distinct breeds with different characteristics. However, there is little scientific data available about the genetic variations that exist between these breeds. Research needs to be carried out to determine if there is genetic difference among breeds.

In organising this Regional Workshop on Conservation and Management of Yak Genetic Diversity, we believed it would be valuable to provide a format to ask yak specialists writing the country (and China provincial) reports to follow in preparing their papers. It was thought that, if the papers followed this format, most of the information we were seeking to present during the workshop would be supplied. With the papers following this proposed format (see Box 1), we also thought we could ensure a certain level of standardisation in the reports that would facilitate discussion of the major issues regarding yak genetic diversity, yak production systems, and opportunities for improved management of yaks. We were delighted with the amount of detailed information authors provided and the high quality of the reports prepared. The papers in this proceedings are a testimony to the fine work on yaks that is being carried out by yak specialists under difficult working conditions in yak-raising areas.

This workshop has made a significant contribution to the expansion of knowledge on yaks, on yak production systems, and on yak genetic resources in particular. Programmes now need to be introduced to ensure



Yak calves and cows ready for milking, Hongyuan, Sichuan Province, China
Research is necessary to measure performance (milk yield, meat, and fibre), survival, and reproductive capacities among different breeds to determine differences between one breed and another. Such a programme would have to compare several yak breeds in one location under identical conditions and management.

that the yak's unique genetic diversity is actively conserved and managed in order to improve yak production for future generations of yak herders, as well as other people connected with yaks and yak products for their livelihood. It is also clear from the discussions held during the workshop that there is an urgently need to implement programmes to secure a future for wild yak populations, from which domestic yaks descended thousands of years ago. Finally, improving yak production and maintenance of yak genetic diversity depends on better management of the rangelands and the forage that yaks depend upon.

Background

All of the country papers presented during the Workshop emphasised the important role that yaks play in the economy of pastoral areas. In pure pastoral areas, where cultivated agriculture is not possible, yaks enable people to live and, in many areas, live quite well. Yaks are important sources of animal food and fibre, are used as pack animals, and their dung is burned for fuel. People simply could not live in many areas of Central Asia without the yak. The yak makes life possible for man in one of the world's harshest environments. In the mixed pastoral areas where both animal husbandry and cropping is found, yaks and yak-hybrids are also an important component of agricultural production systems. Yaks and their crosses are also a vital means of transporting supplies in pastoral areas and between pastoral regions and agricultural communities. Many of the yak-raising regions of the world will continue to rely on yaks for transport as motorable roads will never be practicable in many mountain localities.

Since many of the yak-raising regions are often remote, the yak has not received the attention it deserves from development agencies. The impor-

Proposed Format for Yak Country (Province) Reports

1. **Background**

- Importance and role of yaks in the country (province)
- Yak raising areas (brief description, area-provide a map)
- Number of yaks (total by country, state, district, county, etc)

2. **Status of the wild yak (if any) in the country (province)**

- Numbers and distribution
- Issues related to conservation of wild yaks
- Existing conservation and management programmes for wild yaks
- Opportunities for improved management of wild yak populations

3. **Yak breeding and cross-breeding**

- Issues (major problems and challenges)
- Traditional breeding strategies (briefly describe)
- Existing breeding and breed improvement programmes
- Opportunities for improving yak breeding and cross-breeding

4. **Yak nutrition and health**

- Issues (majors problems and challenges)
- Traditional feeding and veterinary care practices
- Existing nutrition-related improvement and health care programmes
- Opportunities for improvement

5. **Yak management systems**

- Issues (major problems and challenges)
- Traditional management practices (describe briefly)
- Existing programmes to improve management practices
- Opportunities for improvement

6. **Production, processing and marketing of yak products**

- Issues (major problems and challenges)
- Traditional yak product production, processing, and marketing
- Existing programmes to improve production, processing, and marketing
- Opportunities for improvement

7. **Changing economic and development forces and implications for yaks**

- Changes in yak production/management that have taken place
- Challenges for the future

8. **Priorities for future action**

- Research requirements
- Development programmes

9. **Conclusions**

Yaks ploughing fields, Zamtang, Sichuan Province, China
Yaks will continue to be important draught animals in many areas for years to come. Improving animal draught power efficiency will be an important challenge for development workers in pastoral areas.

tance and value of yaks and yak production systems are generally not well appreciated by development planners. Yet, the future of these pastoral areas, and the improvement in the livelihood and well-being of pastoralists, will have to depend on yak production. Although, as a global species, yaks are not as important as other animals; in Central and South Asia where almost all of the worlds' 14 million yaks are found (there are some yaks in England, Canada, and the United States), yaks are an important animal. Conservation of yak genetic diversity in these regions is necessary and needs to be given higher priority.

Status of Wild Yaks

The wild yak is the progenitor of all yak populations. There is little doubt that the presence of wild yaks, and their later domestication, was the single most important factor in the adaptation of civilisation on the Tibetan Plateau. Superbly adapted to the rugged conditions of the highest plateau on earth, wild yaks are a keystone species: their presence identifies the last, great unspoiled

Yaks and yak herders, Hongyuan, Sichuan Province, China
Domestic yaks are descended from wild yaks which were first tamed about 4,000 years ago. Crossbreeding domestic yak with wild yaks is becoming increasingly popular for improving yak productivity. Offspring of crosses with wild yaks are bigger and more productive.

ecosystems of Central Asia. Wild yaks characterise the harsh wilderness of the Tibetan Plateau. No other wild animal so evokes the raw energy and beauty of the landscape. The wild yak is a totem animal of the Tibetan wilderness and long ago achieved mythical status in Tibetan life.

Wild yaks once roamed throughout the Tibetan Plateau and early explorers estimated their numbers in the millions. Unfortunately, wild yak populations have been decimated by hunting in the last century and can now be found only in the most remote regions, far from people. Wild yaks are probably the wildlife species under the greatest threat on the Tibetan Plateau today. Except for limited information from surveys, the current distribution and status of wild yaks are not well known. Current estimates of wild yak populations indicate that about 15,000 animals remain. Little is known about wild yak ecology. Despite being an animal fully protected by both national and international wildlife laws and conventions, illegal hunting of wild yaks continues and wildlife officials are often ill-equipped and trained to adequately protect them. Active protection of the remaining wild yak herds is a must if the animal is to survive.

Much greater effort needs to be made to determine the current status and distribution of wild yaks. Research is also required on wild yak ecology to develop a better understanding of the animals and their role and function in the ecosystem. Such research should include assessments of population structure and dynamics, the identification of limiting factors, and the monitoring of population trends. Habitat requirements, including seasonal movements in response to shifts in forage availability, need to be studied. Studies on range use where the wild yak overlaps with use by domestic livestock, with the concomitant risk of interbreeding, diseases, and competition, are required. The impact of hunting on wild yaks should also be assessed. Finally, in areas where wild yaks are found along with pastoralists, balancing wildlife conservation and pastoral development will be a major challenge, but a challenge that must be urgently addressed. Wildlife and livestock can often exist together if a multiple-use approach is taken, but this will require information not only on the wildlife species (and, in particular, the wild yak) but also on pastoral production systems and the active involvement of pastoralists.

Shrine with wild yak skull and other wildlife, Mustang, Nepal

The grazing lands of the Tibetan Plateau will experience a tragic emptiness if wild yaks are allowed to be exterminated and only their bleached skulls are found on shrines. Preserving wild yaks is a priority for biodiversity conservation.

Nomad camp near Zoige, Sichuan Province, China
Nomads usually maintain a mix of animal species. Maintaining diverse herd compositions is a strategy employed to reduce risk of losing animals from disease and snowstorms.

Yak Breeding and Cross-Breeding

All the papers dealing with yaks and yak production systems highlighted the existence of different 'breeds' of yaks and the elaborate cross-breeding practices that exist; not only those within pure yak herds but also cross-breeding practices with cattle. The main problem appears to be that good information on the genetic variations that exist between these different yak breeds is scarce. No proper genetic comparison has yet been made between the different breeds to evaluate their performance and specific traits. What are the genotype environment interactions with yaks? Are yaks genetically adapted to specific regions?

Research needs to be carried out to measure performance, survival, and reproductive characteristics among the different breeds of yaks. Such a programme would enable yak researchers to determine how much one yak breed differs from another. Evaluations of different yak breeds and comparisons of the crossing of yak breeds would help determine the extent of genetic diversity in the yak population. It would also provide a scientific basis for yak genetic conservation plans as well as the development of improved breeding plans for yak herders to follow. This could then lead to improvements in yak production in future. Any such programme, however, must ensure that the yak herders themselves are involved and that research is not just restricted to government farms.

A number of papers emphasised the problem of inbreeding in yaks. Many of the current yak-breeding practices lead to inbreeding which reduces heterozygocity, results in poor reproductive capacity and lower rates of survival, and lowers yak performance. Selection of superior breeding stock is necessary to avoid inbreeding. In many parts of the Himalayan region (India, Nepal, Bhutan), inbreeding is viewed as a major problem due to restrictions placed on the movement of animals across the border with China. Previously, there was much greater exchange of yaks across the border with breeding animals from Tibet, which are highly prized in the countries to the south. Acquiring superior yak-breeding stock from Tibet could help alleviate this problem. Provision of yak semen, both from domestic yak and wild yak bulls, now available in China, could assist with the inbreeding situation, although implementing AI programmes in the inaccessible yak-raising areas of the Himalayas will never be practical on a large scale. Much better data are required, however, regarding these claims of inbreeding before the issue can be tackled. Is inbreeding really a problem and, if so, how extensive is the problem?

Breeding, nutrition and health, and yak management practices are all related factors in improving yak production, however, and superior breeding stock will never realise their potential if they are not well fed and managed.

Yak herders, Sakten, Bhutan

Yak herders are 'experts' and their indigenous knowledge of yaks and rangeland ecology needs to be much better understood and incorporated into pastoral development planning.

Yak Nutrition and Health

Improving yak productivity requires well-fed, healthy animals. Yaks that are in poor nutritional condition have reduced production and fertility and are more susceptible to many diseases and health-related problems. In many yak-raising areas, a major issue is the reduction in forage available at the same time that livestock numbers are increasing. A lack of adequate forage in the winter and spring is a serious problem throughout the region where yaks are found. Many yak cows only have their first calf at four years of age and calve every other year. This long calving interval is widely believed to be due to lack of sufficient forage, as there are reports from some areas, where forage conditions are better, of yaks calving every year. In some regions, competition for forage between yaks and wildlife is believed to be a problem. Reports from Bhutan indicate competition between yaks and wild blue sheep, and in Tibet there are accounts of conflict between yaks and the Tibetan wild ass. What is the extent and degree of this

Yak herders, Sichuan Province, China

Women play a vital role in yak production and the overall rhythms of pastoral lifestyles. They often do most of the milking and processing of dairy products. Yak development interventions need to target more programmes directly at women.

competition for forage? Nutritional studies on yaks have been limited, however, and there is a need for more research on yak nutrition and foraging habits. What harm does weight loss in winter do to yaks? What is the critical level of weight and condition that yaks need to maintain? Are mineral imbalances in yak diets a problem? When is the critical time to supplement animals with hay or feed? Which animals should be fed? These, and other nutrition-related questions, are important topics for study.

A number of options was discussed that could help alleviate the forage deficit problem for yaks. Providing additional forage or feed supplements in the winter/spring is a promising technology for many areas. This could either come from reserving pastures for winter grazing, harvesting hay (either natural grass hay or from hay fields that have been planted), and by providing feed supplements (grain, urea-molasses blocks, etc). Reducing livestock numbers on the range is often proposed as a means of improving the condition of overgrazed rangelands, but implementing such programmes is often difficult in pastoral areas. It is hard to tell a yak herder to reduce his herd when his animals are his only means of survival. Improved rangeland management techniques may hold some promise in certain areas when complemented by growing hay. However, before proposing new interventions, there needs to be greater appreciation of traditional yak pastoral management strategies and practices, that have the evolved over the centuries, and which are increasingly being viewed as efficient exploitation strategies in a harsh pastoral environment.

Yak health and disease prevention and control are closely linked to yak nutrition. Since many yak-raising areas are remote and often inaccessible, the delivery of veterinary services to these areas is difficult. Regular surveillance of diseases should be implemented and veterinary services, by using para-vets in remote areas, need to be considered.

Tibetan yak herder, Sichuan Province, China
Pastoralists across the Himalayas and the Tibetan Plateau need to play an active role in yak research programmes and the planning of yak development interventions.

Yaks imported into Nepal from Tibet for slaughter, Mustang, Nepal
Trans-Himalayan trade networks are important parts of pastoral systems. Yaks are traded, primarily for slaughter and breeding purposes, throughout and between the Himalayas and the Tibetan Plateau.

Yak herders at a summer festival, Dolpo, Nepal
Yak herding is more than a simple economic venture. Transhumance patterns, for instance, are integrally linked to religious calendars and monitored by complex social structures. Analysis of the socioeconomic processes in pastoral systems is a key challenge for researchers working on yak production.

Yak Management Systems

Yak herding is thousands of years old. Over the centuries, herders have developed complex and, very often, extremely efficient pastoral systems for managing rangelands and livestock in the harsh, high altitude environment where yaks are found. Herders possess a vast body of knowledge about the rangelands and the animals they herd on a daily basis. The fact that numerous unique and, in many cases, prosperous yak herding societies remain to this day bears witness to the extraordinary skills of yak herders.

In recent decades, however, many profound changes, with implications for the future of yak herders, have taken place. These changes include the modernisation process itself, which has brought improved access and services to previously remote pastoral areas and increased demand for livestock products; an increase in the number of livestock in many pastoral areas; the expansion of agriculture onto rangelands and decrease in the amount of grazing available for yaks; disruption in Trans-Himalayan trade networks which were often an important part of yak pastoral systems and allowed for exchange of breeding stock; and the expansion of the protected area system with increased regulations limiting livestock grazing. These changes are transforming traditional yak production systems and grazing use patterns on the rangelands. Keeping pace with these changes requires that those responsible for managing rangelands and raising yaks keep up to date with the latest information available. It also requires that development planners and yak specialists incorporate new concepts and ideas emerging about pastoral development and the functioning of rangeland ecosystems.

Unfortunately, the efficacy of traditional yak production systems and the indigenous knowledge that herders possess are not well appreciated or understood by researchers, development planners, and others interested in improving yak production. Too often there is a reliance on 'new' technologies and scientific methods that, while practical on government farms or research stations, are often not widely applicable in the pastoral context in which the majority of yaks are raised.

The major issues related to yak management include: decline in rangeland productivity and rangeland degradation; overstocking of livestock on many ranges; and a lack of understanding of the socio-economic characteristics of yak production systems. While the extent and severity of rangeland degradation in yak-raising areas are not well documented, it is widely believed that many rangelands are being overgrazed. Too often, however, the processes leading to degraded rangeland are not well understood. Yaks and other species of livestock are often blamed for the degradation. Traditional yak grazing practices are often labelled 'backward' and 'unscientific', yet there is little evidence to support these claims. Rangeland degradation is undoubtedly a problem in many yak-raising areas, but it is important to develop a better understanding of the rangeland ecosystem processes at work before coming to hasty conclusions and faulty prescriptions for 'development'.

Yak herders have acquired intricate ecological knowledge and understanding of the rangeland ecosystem in which they live and upon which their livestock production economies depend. Local climatic patterns and key grazing areas were recognised, allowing herders to select favourable winter ranges that provided protection from storms and sufficient forage to bring animals through times of stress. Forage plants that had special nutritive value were identified; other plants were known for their medicinal properties or as plants to be avoided since they were poisonous. A wide diversity of livestock and grazing management techniques was employed that enabled yak herders to maintain the rangelands (see Figure 1.).

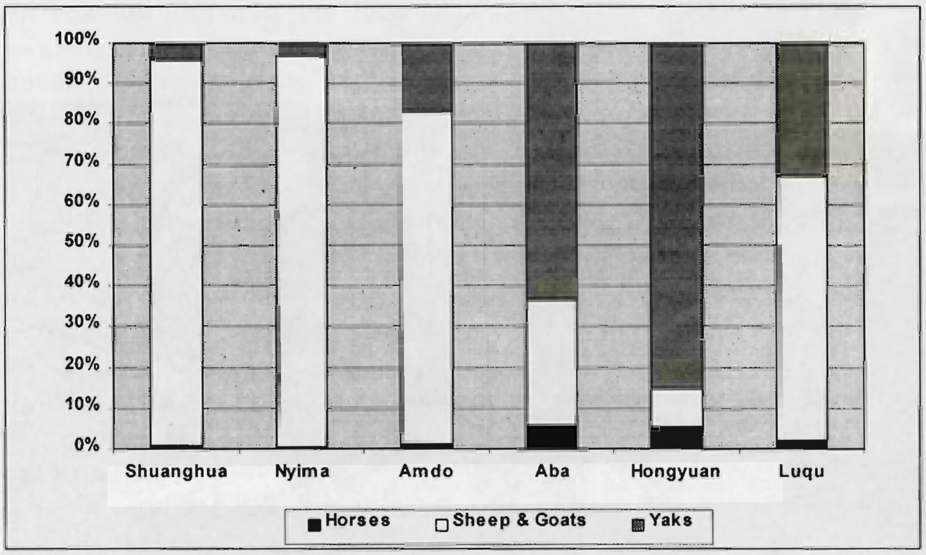


Figure 1: *Livestock Herd Composition (% of Total Animals) for Different Countries on the Tibetan Plateau*

Nomad camp near Aba, Sichuan Province, China
Despite yak herders' remarkable skills for managing livestock in a harsh environment, the efficacy of traditional pastoral strategies are not well understood or appreciated by many development planners or yak researchers.

Complex forms of social organisation developed within yak-raising societies that aided allocation of rangeland resources and, through trade networks with other nomadic and agricultural communities, secured goods not available in pastoral areas.

This expanded appreciation for the complexity and ecological and economic efficacy of traditional yak-herding systems provides hope that the vast indigenous knowledge that yak herders possess will be better understood and used in designing new interventions. Greater awareness of the need to understand existing yak production systems should also help ensure that the goals and needs of yak herders are incorporated into new programmes and that they become active participants in the development process.

Production, Processing, and Marketing of Yak Products

A wide variety of yak products are produced for home consumption and

Yak herder family, Luqu, Gansu Province, China
Planning pastoral development in yak-raising areas is a challenging task, but there are ample opportunities for increasing rangeland productivity, conserving yak genetic diversity, and improving the incomes and livelihoods of people dependent upon yaks.

Collecting yak milk for a milk powder factory, Hongyuan, Sichuan Province, China
Modernisation throughout China has brought improved access and services to previously remote nomad areas. Many pastoralists have now entered the market economy. The increasing demand for yak products should encourage herders to invest in improved animal husbandry practices.

marketing. Yaks are used for the production of both fresh and dried meat. Yak hair and wool is used in textiles, carpets, and specialised products. Yak tails and bones are marketed as special/sacred objects. Yak milk is marketed and processed into a variety of indigenous products capable of being stored for long periods of time.

Two major issues concern the economic uses of yak cross-breed products: the effects of poor market access and remoteness of production on yak herding and the lack of awareness of yak products even in potentially large markets.

The remoteness of most yak production areas has resulted in the use of yak products for subsistence and the reliance of herders on marketing traditional products through traditional channels. This has resulted in most production practices and marketing of products remaining highly traditional. Yak herders have not yet been able to tap into speciality markets for the products that could bring higher prices. This is mainly due to the inability of yak product marketers to advertise and develop high-value products. In the case of China, where yak meat is believed to have medicinal value and special appeal, product value could be improved by targeting wealthier markets in major Chinese cities with choice cuts of yak meat. There is also strong evidence from Nepal that yak cheese advertising could be highly profitable. Quality improvement and advertising for yak products would require the cooperation of yak producers and processors to pool resources and meet specified standards. This is difficult, since yak herders and rural processors have limited skills, operate in a poor business environment, and would think a joint investment in marketing and advertising risky.

Changing Economic and Development Forces and Implications for Yaks

In many areas, yak production is changing dramatically as economies modernise. There are now increased opportunities for alternative income-generating activities. Yak herding is a difficult life in areas with few services and, in many cases, offers low returns when compared to opportunities in more urban areas. The impact of this is more pronounced in yak-raising areas closer to urban areas. However, even in remote, pastoral areas, yak herders are subject to the attractiveness of alternative employment. In parts of the Himalayas, notably the Mount Everest Region, yaks are now mainly kept for packing supplies for expeditions and trekking. Yak herders

Yak herders returning home, Hongyuan, Sichuan Province, China
Despite modernisation, many pastoralists continue to be marginalised. Traditional pastoral practices are often considered 'backward', but there is increasing evidence that pastoral systems are often ecologically sound and economically efficient means for raising livestock in a harsh environment.

and the processors of yak products, through private entrepreneurial activity will have to take the lead in increasing the value of their products. In Nepal, where yak cheese is produced, private and public producers of cheese operate as monopsonies in their local markets, resulting in low prices and returns to yak herders. Herders have not organised themselves to bargain for milk price or to produce cheese in cooperatives due to extremely low organisational skills.

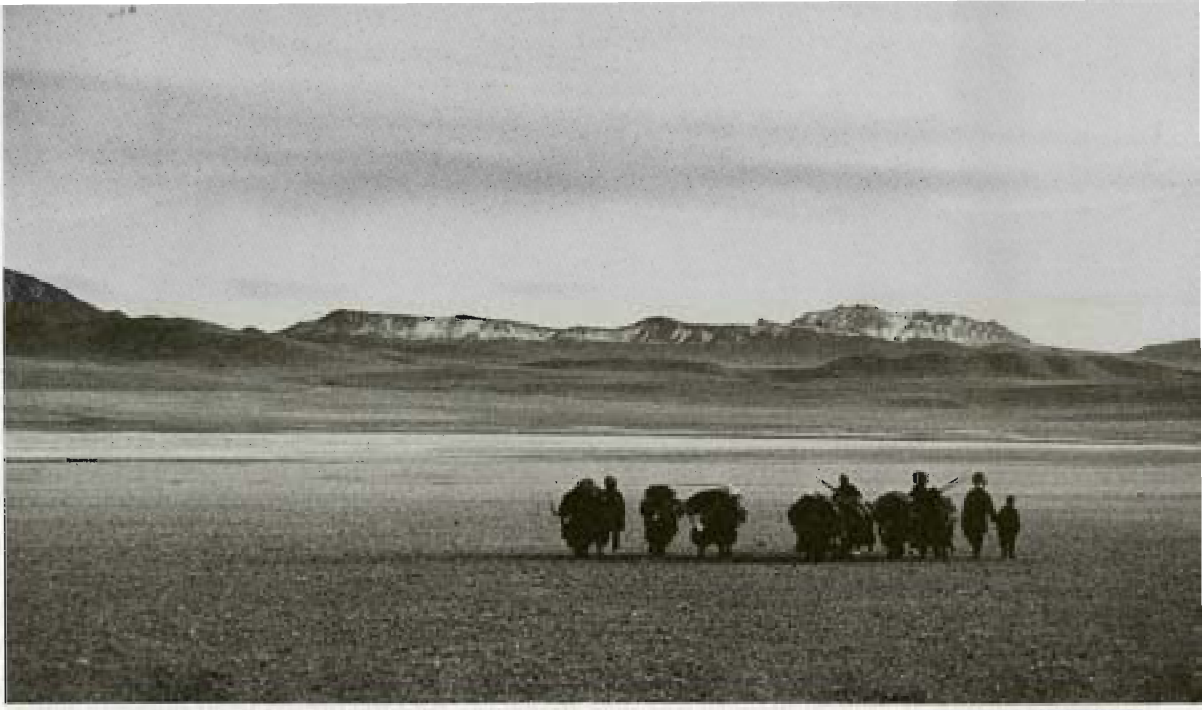
The improvement of services in yak-producing areas, as the pastoral areas develop, should increase the ability of yak herders to obtain a better return for their yak products. To realise these opportunities, however, will require improved extension services to address animal health, product quality, and yak product marketing. A general improvement in the education level of yak herders would also enable them to organise themselves more effectively to increase the value of their raw products.

Priorities for Future Action

Conservation of Wild Yaks

With respect to the conservation of wild yaks, the number one priority is to control illegal hunting. Wild yaks are fully protected under existing Chinese wildlife laws; they are a Class 1 protected species in China. Unfortunately, they are still widely hunted and wildlife officials are poorly trained and usually ill-equipped to deal with poachers. Wildlife officials require support and training if they are going to save the remaining herds of wild yaks.

The current distribution and status of wild yaks is still poorly known, and surveys are urgently required to develop a better understanding of the situation regarding wild yaks. Population estimates vary among researchers — from about 10,000



to 40,000 — but the most reliable estimates indicate a wild yak population of about 15,000 animals left on the Tibetan Plateau, mainly in the Tibetan Autonomous Region. Ecological studies of wild yaks are also necessary, especially to determine their population dynamics. Assessments also need to be made of the degree of conflict or competition between wild yaks and domestic livestock. Finally, the protected area system on the Tibetan Plateau should be expanded to include areas in the western Qinghai Province of China were wild yaks can still be found in considerable numbers. Qinghai Province currently has no large protected area offering wild yaks a sanctuary. The Chang Tang Wildlife Reserve in Tibet should be extended to the east to protect wild yaks in the Kunlun and Kokoshili Mountains. Simply designating parks on paper will not protect wild yaks, however. Reserves, and the wildlife and livestock found in them, need to be actively conserved and managed.

Extent of Yak Genetic Diversity and Yak Breeding

Lengthy discussions were held on the question of the extent of yak genetic diversity. A number of options exists to determine genetic diversity in yaks: breed comparisons and evaluation, DNA fingerprinting, within breed improvement and maintenance of all breeds, and hybridisation. Each of these options have numerous implications.

For breed comparison and evaluation the implications are: (1) if one site is used, there should be no genotype/environment interactions; (2) sufficient resources are available to conduct the large trials necessary; (3) all relevant measurements known and measurable; (4) several locations probably needed — linkages are essential but can have fewer breeds at each location; (5) answers will be relevant when available, which may take 12-20 years; (6) will answers provide adequate data for decisions

Yak herd returning to camp near Garco, Chang Tang Wildlife Reserve, Tibet, China
Yak herders residing in protected areas often complain about wildlife competing with their livestock for forage and destroying fences around winter pastures. Assessments of wildlife-livestock interactions are a priority research need.

Tibetan Golok nomad camp, Qinghai Province, China

Domestic yak production will continue to be one of the major means of supporting pastoralists across Central Asia. While yaks are not a major species globally, their existence is crucial to human survival in these high altitude environments and is vital for the maintenance of domestic animal genetic diversity.

on either breed substitution or use of crosses to provide new breeds (trials will prove estimates of additive and non-additive components); (7) there is time to achieve this and sufficient differences to justify investments; and (8) the affect of breed substitution on genetic diversity is acceptable.

For DNA fingerprinting, the implications are: (1) the technique is adequate to identify diversity and genetic distances; (2) primers are available in sufficient numbers to fulfil 'Barker' specifications; (3) diversity as measured is adequate for decisions on usefulness; and (4) countries will be willing to provide DNA outside of national boundaries.

For within breed improvement and maintenance of all breeds, the implications are: (1) objectives are known and can be measured; (2) genetic differences do exist within and between breeds; (3) each population is adequate in size and can be maintained without serious inbreeding; (4) investment funds are available and for long-term research; and (5) dissemination of improvement is practicable in a cost-effective manner.

Regarding hybridisation, the implications are: (1) there are adequate economic advantages; (2) the system is sustainable, i.e., pure yaks will always be in sufficient supply to support the system; and (3) the most efficient cattle crosses are identified for the specific purposes; and (4) there is a niche below the 'yak line' for such crosses.

The above options are not mutually exclusive and for a comprehensive long-term strategy all options are necessary. However, funding is not freely available and priorities have to be identified.

The initial efforts should be addressed at developing existing breeds within the location in which they are normally found. It is important that the physical environment is adequately measured and described so that potential uses can be better evaluated.

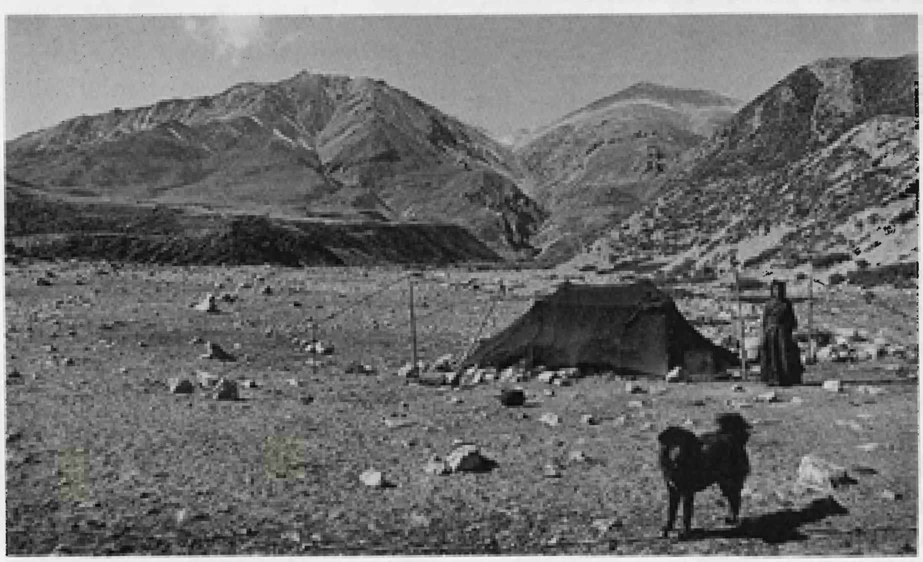
The problem of dissemination is one which needs considerable attention, especially given the normal sites for yak mating (high mountains in rainy season). Artificial insemination is not likely to be an easy solution. Equally, given the normal competition between bulls, the introduction of improved bulls from outside a herd is unlikely to meet with great success unless actions can be taken, either to control mating or to castrate all males not selected for breed improvement.

DNA sequencing, if sufficient primers are available, will provide a useful measure of genetic diversity given that proper breed sampling is carried out. However, this technique will not properly describe breeds or their attributes, since it cannot be related directly to performance traits. It is considered to be the second priority given the level of investment relative to that required for proper breed evaluation and comparison.

Breed comparisons of the type needed are costly and often difficult to operate; this is likely in the environment in which yaks live (recording problems, controlled mating, etc.). However, when done the answers should be comprehensive and allow decisions to be made taking into account all relevant data. This is not possible without such a trial. The cost is high and the trial long, but if there are real effects of heterosis (genotype by environments-interactions, etc.) then at least future genetic work can take all of this into account.

Hybridisation is clearly popular in many places, but these are usually not the same locations as for pure yaks so hybrids can never replace the yaks. There has to be sufficient yak available to maintain the pure breed as well as to provide the crosses. No work has been carried out to evaluate the different dairy crosses (usually the reason for the cross) and maintenance costs of the adult are usually not 'costed' in present evaluations. This research would be useful where such crossing can be supported and a large population of the cross can exist.

Breeding strategies for yaks should, therefore, compare breeds and crossbreeds (within pure yaks) to find out if the breeds differ genetically. This could then lead to improved yak-



Yak herders' camp, Mustang, Nepal
Yak herders will continue to practice the animal husbandry skills that have been handed down to them from their ancestors. With proper development assistance, nomads should be able to use their traditional skills and practices, along with new information and techniques, to improve yak productivity and their livelihoods.

breeding plans and a strategy for conservation of yak genetic diversity. Such a programme would have to compare several breeds in one location under identical conditions and management. If possible, the programme should be replicated in several locations.

Yak Nutrition and Health

Efforts need to be made to address the forage deficit problem by growing hay and providing feed supplements in order to improve yak production. Studies on yak nutrition need to be conducted as well as assessments of their grazing habits. What plants do yaks prefer? What is the nutritional quality of these plants in different seasons? Is the yak diet adequate for maintenance, gestation, and lactation? There is a whole range of nutrition-related topics that require investigation in order to understand yak nutrition and how to improve the current situation.

Competition for forage between yaks and wildlife also needs investigation. Does competition actually exist and, if so, to what degree?

Yak disease surveillance needs to be carried out and efforts need to be made to provide improved, regular veterinary services to yak herders. The use of para-vets should be encouraged and herders themselves should be trained to handle more disease problems.

Yak Management Systems

It is imperative that greater efforts be directed towards developing a better understanding of existing yak production systems. Yak production varies considerably throughout the region where yaks are found and these differences need to be analysed. Why do herders maintain a mix of animals? Why are yaks more important in some areas than in others? What constraints to improving yak production are recognised by the herders themselves? What forms of social organisation exist for managing yaks and rangelands? How have these practices changed in recent years and what are the implications of these transformations? Analysis of the socioeconomic processes at work in yak pastoral areas is a key challenge for researchers. It will also be important to determine which aspects of indigenous knowledge systems and traditional pastoral strategies can be used to design new interventions. Pastoral specialists will also have to ensure, in the future, that research findings are incorporated while forming new policies and development programmes for yak-raising regions.

One of the most important development interventions for yak raising areas may be to try to reduce the isolationism that exists and forge better links between yak herders and external markets and resources. This means facilitating the movement of goods and livestock through trade or marketing systems and external economies which can consume and distribute products to and from yak-raising areas, as they become available. By assisting in the movement of livestock and livestock products to markets, herders' incomes and access to goods can increase and their dependence upon the local pastoral environment for subsistence can decrease. With increasing accessibility of many yak areas, this is becoming more feasible. Finally, improved social services in the form of education, health services, and alternative employment for yak herders need to be pursued.

Production, Processing, and Marketing of Yak Products

Improving the production, processing, and marketing of yak products is a major task, especially in the remote areas where most yak production takes place. Still, there appears to be ample opportunity to improve the processing and marketing of yak products. The forming of yak producer associations in pastoral areas could be one way to help address the marketing of products. Yak producer associations could, over time, develop systems to provide inputs they require. They could work with retailers to advertise yak products and improve product presentation. Associations could also lobby governments for needed policy changes and provide an interface for development aid assistance.

Conclusions

The yak is a magnficent animal. Yaks are also one of the most important animals in the pastoral areas of Asia. Yak production will continue to be one of the major means of supporting pastoralists in the high altitude environments where few other domestic animals can survive. Greater attention needs to be directed towards improving yak production, conserving of yak genetic diversity, and improving the livelihoods of yak herders.

New generation of yak herder, Zoige, Sichuan Province, China
The lives of yak herders are changing as previously remote pastoral areas modernise. Keeping pace with these changes is a major challenge for nomads and researchers working with yak production systems. Despite the transformations taking place in pastoral areas, the future for nomads, and the yak they rely on for their existence, looks promising.

ANNEXES

Annex 1
Workshop Shedule

TUESDAY, OCTOBER 29, 1996

Opening Session

0900-0930	**Registration**
0930-0945	**Welcome Address** by ICIMOD's Acting Director General, Dr. Mahesh Banskota
0945-1000	**Overview of FAO's Conservation and Use of Animal Genetic Resources' Programme**, David Steane
1000-1015	**Objectives of the Workshop**, Daniel Miller, ICIMOD
1015-1045	**Overview of Yaks**, Daniel Miller
1045-1100	**Discussion**
1100-1130	Tea/Coffee/Refreshments

Country Reports

Daniel Miller and David Steane, Chairmen

1130-1200	**Bhutan**, Dr. Lam Tshering, Dr. Pema Gyamtsho, and Tshering Gyaltshen
1200-1230	**China**, Mr. Guo Shijian and Mr. Chen Weisheng
1230-1300	**India**, Dr. M.L. Madan
1300-1430	Lunch
1430-1500	**Mongolia**, Mr. Myadagiin Davaa
1500-1530	**Nepal**, Dr. L. Sherchand and Dr. N.P. Karki
1530-1600	**Pakistan**, Mr. Rash Khan
1600-1630	*Tea/Coffee/Refreshments*
1630-1700	**Summary of the Reports**, David Steane and Daniel Miller

WEDNESDAY, OCTOBER 30, 1996

Country and China Provincial/Autonomous Region Reports
Daniel Miller and David Steane, Chairmen

0900-0930	Comments on Situation in Other Yak Raising Countries, Gerald Wiener
0930-1000	Xinjiang Uygur Autonomous Region, Mr. Luo Ning
1000-1030	Tibetan Autonomous Region, Mr. Huang Wenxiu
1030-1100	Sichuan Province, Dr. Wu Ning
1100-1130	*Tea/Coffee/Refreshments*
1130-1200	Qinghai Province, Dr. Long Ruijin
1200-1230	Gansu Province, Mr. Han Jianlin
1230-1300	Summary of the Reports, Gerald Wiener and David Steane
1300-1430	*Lunch*

Other Reports Related to Yaks
David Steane and Daniel Miller, Chairmen

1430-1500	Status of Wild Yaks, Cai Gaiquan and Daniel Miller
1500-1530	Yak Cheese Production and Processing, Tek B. Thapa
1530-1600	Yak Genetic Resources in China, Mr. Han Jianlin
1600-1630	Yak Breeding Strategies & Conservation of Genetic Diversity, Gerald Wiener
1630-1700	Summary of the Reports, Daniel Miller and David Steane

THURSDAY, OCTOBER 31, 1996

Issues Discussion

Session One: Dr. Joe Fox and Daniel Miller, Chairmen

0900-0930	Conservation of Wild Yak and Domestic Yaks/Wildlife Management Issues

Session Two: Dr. Gerald Wiener, David Steane, and Daniel Miller, Chairmen

0930-1000	Yak Breeding
1000-1030	Yak Management Systems
1030-1100	Nutrition and Health
1100-1130	Conservation of Yak Genetic Diversity

1130-1200	Tea/Coffee/Refreshments
	Session Three: David Steane, Daniel Miller, Chairmen
1200-1230	Marketing, Economic Forces, and Development Potential
1230-1300	Summary of Morning Discussions
1300-1400	Lunch
	Session Four: Gerald Wiener, David Steane, and Daniel Miller, Chairmen
1400-1530	Setting Priorities for Research and Action
1530-1545	Tea/Coffee/Refreshments
1545-1645	Conclusions of the Workshop
1645-1700	Closing
1800	Dinner

Annex 2
List of Participants

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ICIMOD

Founded out of widespread recognition of degradation of mountain environments and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

ICIMOD WORKSHOPS

ICIMOD Workshops are attended by experts from the countries of the Region, in addition to concerned professionals and representatives of international agencies. Professional papers and research studies are presented and discussed in detail.

Workshop Reports are intended to represent the discussions and conclusions reached at the Workshop and do not necessarily reflect the views of ICIMOD or other participating institutions. Copies of the reports, as well as a Catalogue of all of ICIMOD's Publications, are available upon request from:

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Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bhutan
- India
- Nepal
- Bangladesh
- China
- Myanmar
- Pakistan

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