CLIMATE VARIABILITY AND SOCIAL VULNERABILITY ON THE TIBETAN PLATEAU: DILEMMAS ON THE ROAD TO PASTORAL REFORM

With 3 figures and 2 tables

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Zusammenfassung: Klimatische Variabilität und soziale Vulnerabilität auf dem Hochplateau von Tibet: Dilemma auf dem Weg der Reformen in der Weidewirtschaft

Die Winter auf dem Hochplateau von Tibet stellen nicht nur harte Bedingungen für die Viehhaltung dar – die dazu führen, dass die Tierhalter eine mobile Tierhaltung betreiben –, sondern sie stellen auch eine besondere Herausforderung an die Politik in dieser Region. Winterkälte ist daher ein Schlüsselfaktor, der sowohl die Weidewirtschaft als auch die sozio-ökonomische Entwicklung auf dem Hochplateau beeinflusst. Zunächst wird die Region, die auf dem euroasiatischen Kontinent traditionell durch nomadische Weidewirtschaft genutzt wurde und Teil des altweltlichen Trockengürtels ist und von den Autoren als „Winterkalte Zone" bezeichnet wird, geographisch definiert. Die folgende Diskussion geht vor allem auf die Auswirkungen des extrem kalten Klimas auf die extensive Viehhaltung der Tierhalter und die gegenwärtige Politik der Quasi-Privatisierung des Weidelandes in der Winterkalten Zone ein. Dies wird verdeutlicht anhand von Beispielen aus dem Hochplateau von Tibet. Schließlich werden die Unstimmigkeiten der Innovationen innerhalb dieses Rahmens der gegenwärtig stattfindenden Entwicklungsprogramme in der Weidewirtschaft auf dem Hochplateau von Tibet und Möglichkeiten zu deren Behebung detailliert diskutiert.

Summary: The winters of the Tibetan Plateau not only create harsh conditions for livestock management – causing local herders to practise mobile animal husbandry – but also pose particular challenges for policy-making in this region. Winter cold, therefore, becomes a key climatic factor which impacts pastoral production and socio-economic development on the plateau. At first, the geographical region traditionally used by nomadic pastoralism on the Eurasian continent is defined; this region is subordinate to the Old World Dry Belt and called 'Winter Cold Zone' by the authors. The following discussion mainly considers the effects of the extreme cold climate on extensive livestock management by pastoralists and the current policies of rangeland individualization in the Winter Cold Zone with reference to the Tibetan Plateau. The incongruity of the innovations within the frame of the ongoing pastoral development program on the Tibetan Plateau and the options for their remedies are finally discussed in detail.

1 Introduction

The winters of the Tibetan Plateau not only create harsh conditions for livestock management leading local herders to pursue mobile livestock husbandry but also pose particular challenges for policy-making in this region (GOLDSTEIN a. BEALL 1990; MILLER 1995; SCHOLZ 1995; WU 1997a). Every year governments, organizations or local communities are involved in the relief of unpredictable snow disasters. The struggle against animal starvation and pastoralists' poverty resulting from snowstorms puts an enormous strain on the region's financial resources. Winter cold, therefore, becomes a key climatic factor impacting pastoral production and socio-economic development on the plateau. In order to cope with these disasters, Tibetan pastoralists have developed many strategies to adapt to environmental dynamics, and the Chinese government also has adjusted its policies and technical approaches on pastoral development (MANDERSCHEID 1999; MILLER 1995; 1998; WU 1997a; 1997b). These human interventions, driven by political and economic forces, have profoundly mitigated the influence of winter cold on these high-frigid rangelands, but some side-effects of incomplete plans or methods have led, or will inevitably lead, to negative impacts also, requiring correction and further regulation in the near future.

Within the territory of the Old World Dry Belt, where nomadic pastoralism is mainly distributed (SCHOLZ 1991; 1995), two sub-regions can be identified on the basis of the ecologically driving force of pastoral mobility (Fig. 1). The first is the tropical and subtropical dry rangelands, extending from the Atlantic shores of the Sahara through the Arabian Peninsula and Iran Plateau to Pakistan, and where the periodic alternation of rainfall leads to the large-scale migration of pastoralists. The second is the temperate rangelands and high-altitude rangelands obviously characterized by a cold winter, which mainly include the pastoral areas of Central Asia[1], Inner Asia[2] and the Tibetan Plateau[3]. The seasonal change of air temperature is the main driving force for pastoral movements between seasonal

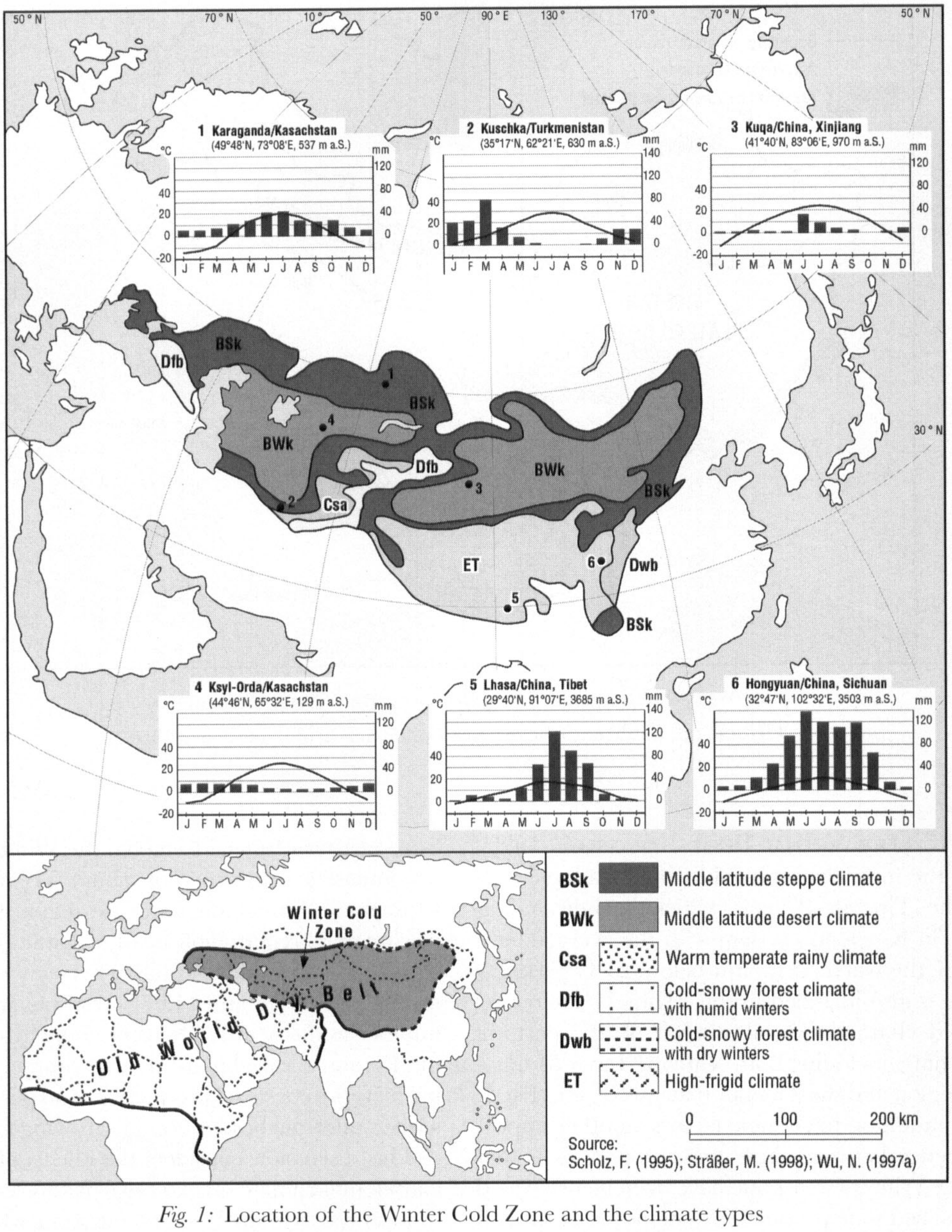

Fig. 1: Location of the Winter Cold Zone and the climate types
Lage der winterkalten Zone und der Klimatypen

pastures (MILLER 1995; WU 1997a), although a semi-arid or arid climate is also common here.

This latter sub-region, called the Winter Cold Zone, is roughly in conformity with the modified Koeppen region BSk and BWk as a whole on the Eurasian continents, where the mean annual temperature is below 18°C and the mean temperature of the coldest month

[1] Central Asia as used here refers to the five former Soviet Republics of Kazakstan, Turkmenistan, Uzbekistan, Kyrgyzstan and Tajikistan, as well as pastoral portions of the Russian Federation, such as the area on the northern bank of the Caspian Sea and the Caucasus region.

[2] Inner Asia refers to the Republic of Mongolia and the Xinjiang-Inner Mongolia Arid Region of China (Fig. 2).

[3] The high-altitude rangelands in the Winter Cold Zone include not only those on the Tibetan Plateau but also those on other highlands of the Hindu-Kush Himalayan Region.

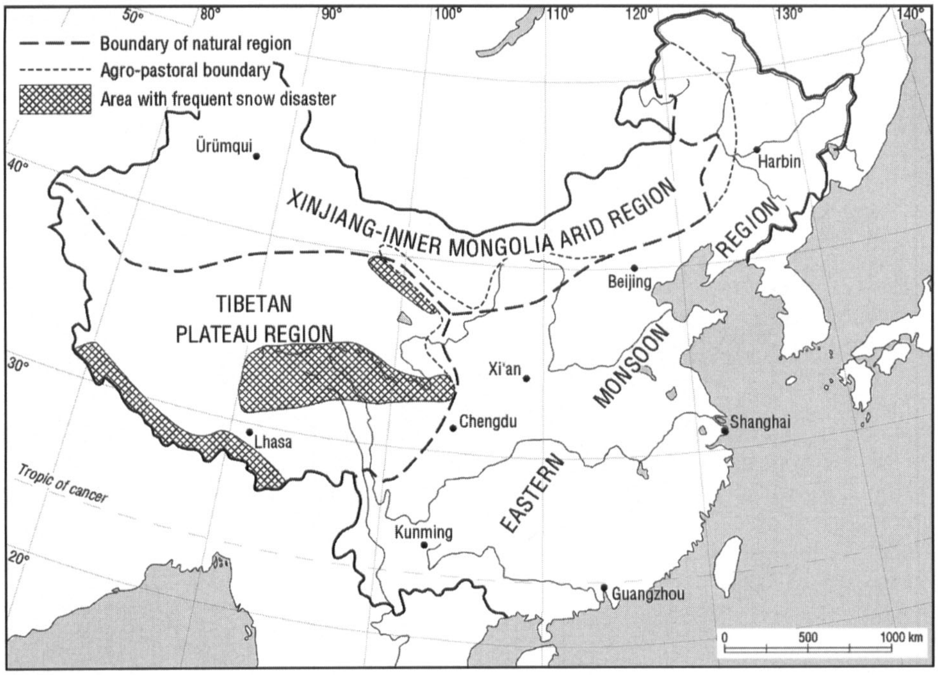

Fig. 2: Areas with frequent snow disasters on the Tibetan Plateau
Gebiete mit häufigen Schneekatastrophen auf dem Tibetischen Plateau

below 0°C (TREWARTHA 1954; STRAESSER 1998). Owing to the more extreme cold winters, a large portion of the Tibetan Plateau, which is indicated as region ET in Koeppen's system with the average temperature of the warmest month below 10°C (STRAESSER 1998), is also included in this regime[4]. Therefore, winter cold characterizes almost all of the pastoral areas in China, including both Xinjiang-Inner Mongolia Arid Region and the Tibetan Plateau Region (Fig. 2, Tab. 1). In addition to climatic factors, another important difference between these two sub-regions is that areas of the Winter Cold Zone have been incorporated into centralized state production systems for about half a century, and are undergoing a process of privatization and commercialization (HUMPHREY a. SNEATH 1999; KERVEN a. ALIMAEV 1998; KERVEN a. LUNCH 1999; MUELLER 1999; JANZEN a. BAZARGUR 1999). Climatic impacts interwoven with political effects resulted in a distinct process of pastoral development in sub-region two. Stretching from the eastern bank of the Black Sea to eastern Inner Mongolia, the Winter Cold Zone encompasses a territory of about 11 million square kilometers. Within this immense region there are approximately 51.2 million head of cattle, 182.2 million sheep and goats, and 8.7 million horses[5], which account for 3.4%, 10.31% and 14.07% respectively of the total number in the world (UN 1999). Long distances to the market and harsh climate are the common major limiting factors to pastoral production, and perennial forage species offer the best option for growing feed.

This discussion considers the effects of an extreme continental climate on extensive livestock management by pastoralists in the Winter Cold Zone which has cold-dominated winter regimes. The hypothesis is that climate variability not only has a direct impact on rangeland ecosystems but also influences the decision-making process and socio-economic adapting mechanism related to pastoral development. On the basis of the authors' several expeditions and case studies in western China, the Tibetan Plateau will be exemplified as the target region for our discussion owing to its typical, extremely harsh winters. The case study considers the geo-ecological features of snow disasters on the

[4] The abbreviation ET, meaning tundra climate in Koeppen's system, symbolizes the Tibetan Plateau region in climatic maps (see TREWARTHA 1954; STRAESSER 1998), but its definition does not exactly tally with the climate there. In line with tradition the present authors borrow this symbol to indicate the high-frigid climate on this huge plateau.

[5] These statistics do not include the part within the territory of the Russian Federation.

Tibetan Plateau, the impacts of climate on the current policies of rangeland individualization, the inconsistencies of these policies and the options for their improvement. Comparisons are drawn with other regions in the Winter Cold Zone, where similar climatic and management conditions prevail.

2 *Snow disaster on the plateau and its impacts*

2.1 Geographical distribution of snow disaster

Covering approximately 2.5 million square kilometers, the Tibetan Plateau is one of the world's major rangeland ecosystems. With rangeland accounting for nearly 70% of the total land area, the plateau includes three of China's most important pastoral regions, southern Qinghai, the northern TAR and northwestern Sichuan, all of which fall into a cold-winter category (LINZIDUOJIE 1996; MILLER a. BEDUNAH 1993; WU 1997a). Over 80 percent of the land area is above 3,000 m in elevation, and about half is over 4,500 m. As such, the plateau is an extremely harsh environment and was even regarded as one of the Earth's harshest pastoral areas still used extensively by nomads (MILLER 1998). Temperatures of minus 30°C are often reached in winter and snowstorms are not uncommon even in summer. Annual precipitation varies from about 700 mm in the east to less than 100 mm in the west, with most of this falling during the summer, often as wet snow and hail.

On the Tibetan Plateau snow disasters frequently occur in three regions (CHEN 1996; LINZIDUOJIE 1996; SHI 1996; YANG a. HE 1987). The first one is located to the east of Nyainqentanglha Mountain, Bayan Har Mountain and the uplands to the south, i.e. the northeastern part of the Tibetan Plateau, which includes southern Qinghai, northwestern Sichuan and the northern TAR in administrative terms (see Fig. 2). With the immense surface of this area, each snowstorm occurs on a large scale, which may affect as much as 200–300 thousands of square kilometers or even more. This area averages as many as 110 snowfall days a year, ranking at the top of the areas with frequent snowfall days on the Tibetan Plateau, and it is also the area with the most snow disasters. The second area is the southern TAR, i.e. the northern slope of the Himalayas. The third area is located on the southern slope of the Qilian mountains, i.e. the northeastern Qinghai, where the impacts of snow disasters are comparatively less serious than in the former two areas. Apart from these three areas snowstorms also occur frequently in other parts of the plateau, but disasters seldom follow snowfalls because of the lower elevation or latitude. In relation to precipitation, snow disasters in Qinghai mainly occur in the zone within the isohyet of 400–500 mm annual mean precipitation, but in Sichuan they mainly occur within the isohyet of 500–700 mm (YANG a. HE 1987; WU 1997a).

2.2 Snowstorms and their disasters

When heavy snowfall obstructs human productive activities and subsistence, it becomes a natural disaster, snow disaster. The accumulated snow-cover may prevent domesticated animals from grazing any perennial grasses or herbs in winter. If there is a steep drop of air temperature after snowstorm, snow cover always changes into ice cover on rangelands and many animals inevitably die from lack of food. In the following spring, furthermore, when animals give birth, withered grasses have been eaten away and the spring grasses have not yet sprouted. Starvation and feeble health cause animals to lose their adaptive ability to resist harsh climate, which finally results in a higher abortion rate of female adults, and increasing mortality of young and old animals. Generally speaking, the time of snowfall does not necessarily coincide with the time of disaster. Livestock mainly dies about one or two months after the snowstorm (YANG a. HE 1987; CHEN 1996).

On the Tibetan Plateau snow disasters mostly occur between October and the next April. In Qinghai 25% of snow disasters start in October, 54% in November, the rest in December. In the southern TAR they occur from November to February owing to lower latitude. In the areas of Bayan Har Mountain and Tanggula Mountain snow disasters happen from October to May and have the longest duration. Snow disasters in the Qilian mountains are generally of short duration. Snowfall in March and April may also lead to disaster, but always lasts for a shorter period. Snow disasters also have their vertical law. Above 4,800 m, snow disasters mainly occur between October and April; above 4,500 m between November and next March; above 4,200 m mainly between November and next February; and above 4,000 m between December and the following January (WANG a. SHAO 1986).

At the end of winter and at the beginning of spring snowstorms frequently hit the immense pastoral areas and snow accumulates on the ground. The annual average number of days with snowfall is 60–80 days in the northern TAR and southern Qinghai, 30–60 days in the southern TAR, 50–70 days in northern Sichuan, and 10–40 days in south Sichuan and northwestern Yunnan (LINZIDUOJIE 1996; YANG a. HE 1987; WU 1997a). Because temperatures are lower in southern

Table 1: Comparison of climatic factors in the pastoral regions of China

Vergleich der klimatischen Faktoren in den weidewirtschaftlich genutzten Gebieten Chinas

Pastoral region	High-frigid region (Tibetan Plateau)		Western region*** (Xinjiang)	Northern region (Inner Mongolia)
	Western*	Eastern**		
Duration of growing season (>5°C) (days)	<90	150 ~ 210	150 ~ 250	140 ~ 180
Accumulated T during growing season (°C)	<1200	1500 ~ 2500	3000 ~ 4700	2000 ~ 3000
Annual frost-free period (day)	< 120		120 ~ 180	100 ~ 150
Average T in January (°C)	–17 ~ –3		–26 ~ –6	–28 ~ –10
Annual range of T (°C)	22 ~ 23		32 ~ 44	34 ~ 46
Annual Precipitation (mm)	70 ~ 400	400 ~ 700	30 ~ 450	50 ~ 400
Percentage of precipitation in warm season (May - Sept)	75 ~ 90%		60 ~ 85%	80 ~ 85%

Note: * including northern TAR (Tibetan Autonomous Region) and southern Qinghai; ** including western Sichuan, southeastern Qinghai and southern Gansu; *** including pastoral portions in Xinjiang, northern Qinghai, northern Gansu and Ningxia

Source: OUYANG a. WANG 1997; XU a. PEEL 1991

Qinghai than in the TAR, snow cover melts more slowly and can accumulate for a longer time. The annual average duration of snow cover in southern Qinghai is 50–100 days, in the northern TAR 25–50 days and in the southern TAR 10–25 days (LINZIDUOJIE 1996; YANG a. HE 1987). This is the reason why the frequency of snow disasters in southern Qinghai ranks the highest on the whole plateau.

Based on the climatic data in Qinghai, the amount of snowfall from October to March is generally above 50 mm and the accumulated mean temperature within this period is below –72°C (YANG a. HE 1987). The depth of snow cover during snow disasters in southern Qinghai and the northern TAR is normally 15–20 cm. In the southern TAR the depth is 30–40 cm, but the greatest depth in some micro-habitats, such as the sheltered sides of slopes, is as much as 1–3 m (LINZIDUOJIE 1996). Winter snow depth is around 30 cm in northwestern Sichuan and becomes higher in the more northerly alpine meadows (WU 1997a).

The occurrence and effects of snow disasters depend mainly on the amount of snowfall during winter and spring and the duration of snow cover, but the persistence of accumulated snow on the ground depends on the air temperature. Generally speaking, the eastern part of the Tibetan Plateau experiences mean winter temperatures of –10°C and brief growing seasons of three months or even shorter (WU 1997a). In western Sichuan winter temperatures are the lowest in Shiqu County, with means of –30°C. Even in Hongyuan County, located on the eastern fringe of the Plateau, the mean January temperature is –18°C with the minimum temperatures of –45°C (see Fig. 2). Similar extreme winter temperatures and short growing periods are also common in the TAR.

In western China snow disasters occur frequently in the Altai region of Xinjiang, Nagchu Prefecture of the TAR, Yushu and Guoluo prefectures of Qinghai Province and Aba and Garze prefectures of Sichuan Province (LINZIDUOJIE 1996). During the 81 years from 1907 to 1988 snow disasters in Inner Mongolia occurred 34 times, with a frequency of once every 2.4 years (SHI 1996). In the southern part of Qinghai Province the frequency of small snow disasters was 3.5 (once every 3.5 years) from 1956 to 1976, but medium-sized snow disasters may occur once every five years, and a serious disaster every ten years (YANG a. HE 1987). It was estimated that the impact of snow disasters has increased since 1980, because rangeland degradation has reduced the availability of forage as a safety net (CHEN 1996). In the case of the TAR, the frequency of snow disasters in the north is as high as 2.5 and even 1.7 in the south (LINZIDUOJIE 1996).

2.3 Disasters impacting on pastoralism

On the Tibetan Plateau snow disaster is considered to have the greatest impact on pastoral production of all climate-induced disasters (GOLDSTEIN a. BEALL 1990; MILLER 1995; 1998; WU 1997a; 1997c). In other areas of the Winter Cold Zone the situation is similar. Although climatic drought is another impacting factor in these areas, it always exacerbates the impact of snow disaster (HUMPHREY a. SNEATH 1999; KERVEN a. ALIMAEV 1998; KERVEN a. LUNCH 1999). Since most days of snow and strong winds are concentrated in winter and spring and the facilities for fighting natural calamities are in short supply in those remote pastoral areas, livestock inevitably suffer hunger and cold, lose the balance of energy budget, and in the end many of them lose weight, emaciate and even die. Moreover, because snowstorms always lead to road blockages and even human fatalities, they are not only a destructive factor for pastoral production on the plateau but also for the socio-economic system as a whole.

The degree of coldness varies by latitude, altitude, slope aspect and wind chill factors. These variables have a critical effect on vegetation composition and productivity by location and season. Cold winters have regular annual impacts on rangeland vegetation production and thus on livestock dependent on rangelands. At first, dormancy is the principal plant response mechanism to cold winters in high-altitude areas, with annuals and many perennials ceasing above-ground biomass production during winter and conserving seeds or translocating nutrients below ground. Both the quantity and quality of forage in winter is lowered, as shown in the case of Sichuan's alpine meadows where winter forage yields are about half of those in summer while digestible protein in winter drops to a quarter of the maximum level in spring time (Fig. 3) (WU 1997a). During the winter, effective physiological radiation only makes up 30–40% of the total radiation and the usable efficiency of solar energy is less than 0.1%. Because the consumption period of matter and energy is longer than the accumulation period, the reversal flow of matter and loss of energy in rangeland ecosystems lead to forage plants having to consume the assimilated nutrients in order to support their biological activities (WU 1997a). Apart from the direct freeze damage, therefore, low temperatures can directly affect the ecological processes of living beings and the production of livestock husbandry.

Secondly, a normal effect of winters in higher altitudes is that some pastures cannot be used by foraging animals over the winter period, owing to snow depth or cold temperatures. Alpine pastures located at high altitudes are inaccessible in winter, but they are the summer destination of migratory pastoralists using seasonal migration in response to temperature changes on the upland areas of the Tibetan Plateau. The shortage of winter pastures is a common problem facing all of the high-altitude pastoral areas. In western Sichuan, for example, the area of winter pasture only makes up 28.4% of the total area of rangelands in this region,

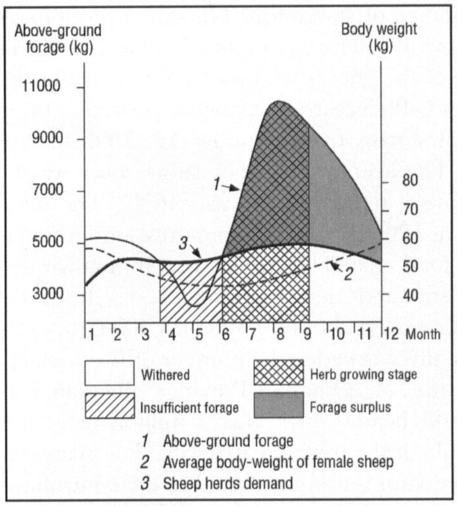

Fig. 3: Forage supply imbalance due to cold winters
Ungleichmäßiges Futterangebot aufgrund der Winterkälte

but the grazing time lasts for as long as even seven or eight months (WU 1997a). With regard to the pastoral regions on the Tibetan Plateau as a whole, winter pastures generally account for one third of the total rangeland area and support two thirds of the year's grazing time.

Finally, in cold-season environments, the physical condition and productivity of livestock suffer from the low quality of available forage; thus animals lose weight or fetuses fail to develop properly. Production and reproduction suffer as a consequence. In the TAR, where livestock does not receive much supplementary feed, yaks and sheep routinely lose up to 30% of their body weight over winter (OUYANG a. WANG 1997; MILLER 1998). Generally speaking, all livestock will have an increased demand for nutrients in the middle of winter when the ambient temperature can drop to –30°C (LONGWORTH a. WILLIAMSON 1993). Winter climatic events – sudden deep snowfalls, exceptionally severe cold temperatures, and thaws followed by freezes – can have devastating immediate effects upon animals by rendering natural forage resources temporarily inaccessible or causing death by freezing.

Grievous losses always follow a serious snow disaster, which can even cause mass mortality of up to fifty percent among livestock. In Qinghai, unusually heavy snow cover during the 1997–1998 winter, with an especially cold period (temperatures of down to –35°C) lasting almost one month, led to severe dislocations and heavy losses: 1,400 people and 330,000 animals had to make emergency moves away from the worst affected areas. Over 9,000 animals froze to death, and nearly

12,000 died of starvation. The direct economic cost of the snow disaster was estimated at about US$ 445,000 in one of the poorest counties in China (MILLER 1998). In Yushu Prefecture of Qinghai province, there were 48 snowstorms from October 17, 1995 to April 17, 1996. The average depth of snow cover was 0.33 m. The lowest temperature was –46°C. The devastated area was 120,000 square kilometres, amounting to 60% of the total area of the prefecture. In that winter alone, it is estimated that economic losses from livestock deaths reached about 80 million US$ (CHEN 1996). In the last three decades, the number of livestock in Yushu Prefecture of Qinghai Province fluctuated around 4 million head, which was 3 million head less than the ecological carrying capacity[6]. The reason for this phenomenon is also attributed to the controlling effect of snowstorms (Tab. 2) (CHEN 1996).

Livestock in the TAR are also subject to snow disasters which are especially damaging in late winter or early spring and could decimate a herd. The winter of 1997–1998 was recorded as one of the worst in recent history across much of the nomadic pastoral area in the TAR. Unusually heavy snowfall in late September followed by severe cold weather prevented the snow from melting. Additional storms deposited more snow, which finally lead to the loss of over 3 million head of livestock in the TAR, amounting to 13% of the total. Losses in Nagchu Prefecture of the TAR alone were estimated at 1.03 million animals or about 15% of the Prefecture's total livestock population. It is estimated that in 1998 economic losses from livestock deaths alone reached 125 million US$ in the TAR (MILLER 1998).

In addition to their direct impact on animal mortality, snow and other disasters undermine rural development strategies, and are a major cause of rural and urban poverty. Rural development will have to start afresh every few years if such disasters are not better managed. Likewise poverty alleviation can only deal with symptoms until key risks are brought under control. For example, it is estimated that the total loss of meat resulting from the fat loss of animals in winter was as high as double the total actual output of animal meat in Aba Prefecture of Sichuan Province (WU 1997a). In Deqin County of northwestern Yunnan Province, heavy snowfalls every winter always lead to the blockage of highways. Local government must transport and store food, medicine and living necessities before every November. This alone increases this county's debt by as much as 250 million US$ and bank interest amounts to 0.3 million US$ (LINZIDUOJIE 1996). Meanwhile, snow blockage also prevents the export of timbers, mineral products and agricultural products from this county. The economic system of this county as a whole has to move into the situation of 'hibernation'.

3 Cold winters and the current development projects

Tibetan nomads, depending almost solely on livestock grazing and related activities for a livelihood, suffer greatly as a result of heavy snowfalls. Livestock losses on the Tibetan Plateau following winter's heavy snows are seen as one of the main proofs of the need to modernize nomadic pastoralism. It has been believed that in recent severe winters livestock were lost because traditional nomadism is unable to cope with harsh winters and the traditional migratory grazing practiced by nomads is an improper use of grasslands (LINZIDUOJIE 1996). It was argued that there is no incentive for individual nomads to manage the rangelands or invest in improvement since grazing is usually communal, which further indirectly leads to the loss of animals after serious snow disasters. Therefore, a widespread viewpoint is that only successful sedentarization would help prevent large livestock losses during snow disasters, improve rangeland management, increase productivity and raise overall living standards (LI a. YONG 1993).

From the 1980s onwards, the Chinese authorities started to replace the former programs of snow disaster relief with an investment program to prepare herders better for winter. A series of development programs was implemented in order to improve herders' ability to cope with snow disasters. The parcelization and allocation of former communally managed rangelands to individual households, then followed by fencing, cultivating forage, and building settlements, are the main methods adopted by the authorities in different pastoral areas (HUMPHREY a. SNEATH 1999; CHEN 1996; WILLIAMS 1996; WU a. RICHARD 1999; WU 1999). In 1995, there were 25 counties in western China selected as demonstration sites for an integrated development program. This development program, known as the 'Four Package Program' in some regions, is intended as a basic approach to combat snow disasters and includes the following four main categories:

– Stimulating herders' enthusiasm to practice scientific livestock management and sustainable rangeland conservation by individualizing the previously communally managed rangelands in order to prevent overgrazing and reduce animal loss in spring;

[6] The 'ecological carrying capacity' is the stocking rate determined by the limitations of available forage, and is considered more applicable to traditional pastoralism (see BEHNKE et. al. 1993).

Table 2: The most severe snow disasters in Yushu Prefecture of Qinghai Province
Die schlimmsten Schneekatastrophen in der Präfektur Yushu (Provinz Qinghai)

Time of snowstorm	No. of livestock deaths	Percentage of total livestock
1956 winter – 1957 spring	920	30.13%
1971 winter – 1972 spring	720	26.7%
1974 winter – 1975 spring	780	24.3%
1981 winter – 1982 spring	1,320,000	24.4%
1985 winter – 1986 spring	990	23%
1995 winter – 1996 spring	2,030,000	39%

Source: CHEN 1996; YANG a. HE 1987

– Building settlements for nomads in winter grazing areas to provide better conditions for human habitation during the cold winter and for infrastructural development;

– Building animal sheds at winter settlements for young and weak livestock to better cope with snowstorms; and

– Fencing winter pasture and developing artificial pasture for supplementary foodstuff in order to substantially increase livestock off-take and pastoral incomes through more intensive management.

In Qinghai Province, for example, the 'Four Package Program' started at the end of the 1980s, aimed at building up 11.1 ha of fenced pastures, 60 m^2 of animal stalls, 0.33 ha of artificial pasture and settlements for nomads in every target family. For the first three of these innovations the government supplied 60% of the required funds, the rest (40%) has to be afforded by the nomads themselves (CHEN 1996). The fourth, the construction of settlements, has to be entirely paid for by the nomads themselves. It was reported that the main purposes of this program are to increase the productivity of rangelands, especially on the winter pasture, to keep the balance of forage supply in different seasons, and to promote the ability to cope with snow disasters.

In western Sichuan, the development program starting in 1995 required that every settled household must construct a 70 m^2 house, a 80 m^2 shed for animals, and a 20 m^2 barn for storing hay. Every family in the program has to fence 500 mu (33.3 ha) of pasture, including 2 mu (0.66 ha) of artificial pastures (called 'improved pastures') and 8 mu (2.64 ha) of semi-artificial pastures (also called 'semi-improved pastures') (WU 1999). Fodder preparation by households is an important component of winter preparation. The artificial pastures are totally planted with oats or barley and intensively nurtured for hay production, but the fenced semi-artificial pastures are reserved for hay-making in autumn. The rest of the fenced pastures can be used for animal grazing during the forage deficit period in winter or spring. Use of supplementary foodstuff in pastoral Sichuan and Qinghai is becoming the norm during the winter season of low plant productivity and in cold-related disasters. In 1997, the allocation of rangelands was carried out practically in the demonstration counties and then quickly spread to other pastoral areas in the following years. A license for rangeland use, valid for 50 years, is given to every nomad family.

4 *Dilemma of the current program – discussion and suggestions*

4.1 Technical feasibility?

The key to improving livestock productivity is to provide animals with enough forage throughout the year. On the Tibetan Plateau, and even in the Winter Cold Zone as a whole, winter and spring are the main forage deficit periods. More attention thus needs to be directed towards providing more forage, either in the form of grazing or from hay that is made from native grass or artificial pasture. Growing artificial pasture for hay-making is a fairly simple technology that could provide additional food to improve livestock productivity and/or, in the event of heavy snowfall, help prevent large livestock losses (WU 1997a; WU a. RICHARD 1999). It has been found that these hay fields, primarily oats, produce five times more hay than does native grassland (ZHANG 1992) and this harvest can be stored for use during the critical forage period. Local officials and communities in many areas of the Plateau have also readily adopted this technology. However, not only in Qinghai but also in Sichuan only a few families can meet the government's requirements in the area of artificial pasture unless they cultivate the demonstration sites of development projects.

Probing into the reason in Qinghai and Sichuan, the feasibility of techniques to produce supplementary fodder is still in question. Firstly, the good artificial pastures in this region are generally located in the fenced corrals nearby winter houses. During the summer, while livestock migrate to summer pastures, annual grasses, such as oats or barley, are cultivated in these corrals. Before livestock are driven back from summer pastures, grasses must be mowed and the corral must be left empty for animals. The crops cultivated in these corrals may effectively utilize the manure (animal droppings) which was left during the last winter, but these annual plants can only be cultivated in the seasonal interval. The shortage of perennial plant cultivation inevitably adds extra working burdens to nomads who must be involved in the activities of crop cultivation and harvest every year. During the migration seasons, nomadic families have generally not enough human labour to deal with farm work in the fields instead of animal management.

Secondly, the shortage of skills and experience in crop cultivation among Tibetan nomads is one of the key problems facing these pastoral areas. In Sichuan, the artificial pastures for demonstration were mostly cultivated with the help of technicians. The transfer of cultivating skills to local pastoralists is a necessary step before this technique can be expanded. In addition, a large proportion of forages is stored as hay, but the practical conditions, such as high humidity, low temperature and high costs associated with labour, machinery and energy, are still the limiting factors for hay production in these remote areas.

4.2 Economic sustainability?

Fenced winter or spring pastures help to provide forage during lean times, while reducing pressure in nearby winter pastures that are beginning to green up at the onset of the growing season (WU a. RICHARD 1999). However, on the plateau the yield of fresh grass would only increase as much as 10% if pastures were only fenced without any further intensive management (CHEN 1996). Although over the long term these small fenced systems are relatively inexpensive to maintain, easily offset by the increased livestock production and income, they do involve relatively high initial costs. On the other hand, if the size of the fence is too small, the production of fodder from fenced pastures cannot provide enough supplementary feeding for animals' survival through snowstorms. If the scale of fencing is too large and even becomes boundary marks of allocated pastures, the investment is difficult to balance by any economic outputs of pastoral production. The balance point of cost-benefits for pasture enclosure, i.e. the suitable size of fence building, is not clear so far for both government authorities and project technicians.

The construction of settlements and animal sheds is also too expensive for local people. In Qinghai the financing source of this program, which costs about 2,500 US$ per household, is mixed: central and local government provide a grant of half of the costs, and the herders have to pay the rest (CHEN 1996). For a province with a GDP per capita of about 360 US$, this expense is not easy both for local people and governments[7]. Although low-interest and long-term credit is available to all herders, in fact only rich herders can afford the package, and the susceptibility of poor herders to snow risk, compared to richer ones, is increased. In Hongyuan of Sichuan, for example, the total investment in the project in 1995 was about 0.92 million US$, among which 40% was from the state government, 24% from provincial, 16% from prefecture and county levels and 20% were raised by nomads themselves (WU 1999). The high investment required for fencing and house construction implies the economic vulnerability of this program and cannot be sustained if there is no financial support from the government.

4.3 System flexibility?

Generally speaking, there have been two solutions to the recurring problem of forage limitations due to seasonal low productivity and climatic disasters. One solution is to supply additional foodstuff to livestock when their need is greatest. The other one, traditionally practiced by nomadic societies, is to adapt to the fluctuation in grazing resources by systematically moving around the landscape seeking for the most seasonally-productive grazing areas (MILLER 1998; SCHOLZ 1995; SNEATH 1998). These long-distance migrations to warmer latitudes or more sheltered areas sometimes avoided or reduced the loss of livestock due to heavy snowstorms.

During the cold season on the eastern Tibetan Plateau, for example, nomads' herds are at the low limit and as the temperature increases they are moved upwards to graze on new grass (WU 1997a; MANDERSCHEID 1999). Pastoralists seasonally exploit this spatial variability by moving livestock between altitudinal zones. In Sichuan and eastern TAR, traditional movements could be extended downwards to forest belts beyond the normal winter range in exceptionally snowy winters, allowing the animals to maximize feed supplies

[7] In Guoluo Prefecture of Qinghai Province, the costs of all these four innovations has varied markedly depending on the year, but in 1996, these four items could easily cost 3,600–4,800 US$ per household if they all were done at once.

which vary both predictably by season and location and unpredictably from year to year due to climatic events. In snow disasters, the ability of herders to move their animals away from the crisis becomes a more important strategy than at other times, but this flexible response to climatic fluctuation is possibly constrained due to the allocation of pastures. For rangelands used by mobile pastoralists, therefore, researchers presently tend to favor maintaining 'fuzzy boundaries' between pasture units (ELLIS a. SWIFT 1988; ELLIS et al. 1991). Flexible boundaries and communal control should permit the type of land use necessary in non-equilibrium conditions, in contrast to allowing rangeland ecosystems to be parceled out into private land holdings.

The main environmental risks, especially snow disaster and drought, may also be subject to global changes in climate. In the southern Qinghai the annual mean temperature has increased 0.2–0.5 °C every ten years since the 1960s (ZHANG et al. 1998). However, the mean temperature in May and September has decreased in the same period, which has actually shortened the growing period of grasses. As a consequence of the high sensitivity of alpine ecosystems to global warming, changes in alpine vegetation are likely to be more pronounced than in any of the other natural biomes (BOER a. KOSTER 1992). The combined effects of shrinking grazing lands due to potentially expanding timberline upwards, expanding agriculture, inflexible tenurial arrangements and increasing dependence on outside inputs, merely exacerbate the problem of social vulnerability responding to climatic variability.

4.4 Risk responsibility?

In China, following the implementation of the "Pasture Contract Responsibility System", formal organizations have a much less important role than formerly in production and disaster response (HO 1996). The privatization process in fact has caused the responsibility for risk to shift from government agencies to herders themselves, with assistance and coordination by government organizations. Traditionally and even presently, social networks and community self-help are very important and effective for nomadic communities to cope with natural disasters. Herders who belong to strong networks, or who belong to large multi-generational families or to cooperatives with good leadership, perceive and can react to risks differently from isolated households or those without such social capital (HO 1996; HUMPHREY a. SNEATH 1999; KERVEN a. LUNCH 1999; KERVEN a. ALIMAEV 1998).

In southern Qinghai and northwestern Sichuan, households still depend in the first place on other households in case of disaster, specially within a traditional tribe. Destitute herders can borrow or rent pasture or animals from neighbouring households. Generally speaking, herders with plentiful labour resources perceive and can react to risks in different ways from labour-scarce households. Therefore, while government cannot provide enough supports to these remote areas, collective operation in nomadic societies based on voluntary principles can also lighten government's burden during the coming period of harsh cold. Even more, at local levels, collective haymaking can benefit from the economies of scale possible during the late summer months when households are still grouped together in large camps, and a large labor force is available, before the dispersal which takes place in autumn as households move towards winter quarters. In Gannan Prefecture of Gansu Province it has been beneficial that some families cooperate together to produce hay in a big parcel of pasture, which lightens the problem of labour and investment to a certain degree, specially for small or poor families. Local government should encourage and support this new attempt with fixed funds for disaster relief. Direct governmental relief after snow disasters can be changed into an indirect approach, investing in the capacity improvement of community self-help.

4.5 Destocking possibility?

As an insurance against constraint events such as snowstorms nomads traditionally have to strive to increase stock numbers, in order to provide security in case of losses, to leave a remainder of feasible size, to rebuild their herds. Thus, the expansion of herd size in "normal" times, not stricken by cold, disease or unrest, is a survival strategy adopted by nomads worldwide (SCHOLZ 1991; WU 1997b). With the development of alternative sources of feed and veterinary facilities, the losses of animals during hard winters have been reduced. The increasing herds of livestock were widely perceived as having caused rangeland degradation in pastoral areas (LI a. YONG 1993). Therefore, it was always thought to be an active approach that the loss of livestock resulting from climatic hardship should be and can be turned into profit for herders, if good market outlets exist (ELLIS et al. 1991).

In the last two decades, a number of development strategies have been initiated by government or development agencies to force pastoralists to reduce their stock numbers and then to integrate subsistent pastoralism into the boosting marketing economics (LONGWORTH a. WILLIAMSON 1993; HUMPHREY a. SNEATH 1999; HO 1996). However, increasing human population has meant that an increasing number of families cannot agree to destock their already reduced holdings. Experience from other countries has also shown that compulsory destocking programs are difficult to implement even with supporting legislation (CHULUUN a. OJIMA 1999; HUMPHREY a. SNEATH 1999; KOOCHEKI 1993; WILLIAMS 1996). Moreover, the present supporting systems, such as the insurance system and government's disaster relief system, cannot sufficiently enhance nomads' confidence in destocking their livestock instead of their traditional insurance, not only in China but also in other countries of central or Inner Asia. When the snowstorm is over, the effect of winter's livestock losses will generally reverberate for years to come. It needs a considerable time for nomads to build their herds up again to the previous year's levels, and in the meantime thousands of families with fewer animals will face great difficulties in meeting their basic needs (MILLER 1998; SWIFT 1999).

Even so, it should be admitted that marketing still plays a key role in the rural economies of pastoral western China. The development of these pastoral economies is the key to poverty alleviation and to improving food security, as well as to the wider goal of the creation of sustainable livelihoods. ELLIS et al. (1991) also note that the most important development intervention for promoting pastoral survival may be that of reducing isolationism, and consolidating links between the pastoral ecosystem and external resources. This means encouraging the movement of goods and livestock through trade or marketing systems, and external economies which can consume and distribute products to and from pastoral areas as they become available. Hence, it is necessary for the government to consider improving a social and economic safeguard system, such as credit, insurance, relief funds and marketing outlets. "Rational" livestock management through rangeland intensification, which has been practiced in western China, requires an effectively operating market that facilitates the optimum destocking of livestock before the onset of winter. Without this market infrastructure, local herders will continue to follow subsistence strategies of herd maximization in order to reduce risk associated with winter livestock losses. Only if the confidence and capacity of nomads to cope with disaster can be increased will it be possible to implement destocking plans. Otherwise, rangeland degradation inevitably follows when livestock population increases, which is a common by-product after rangelands are allocated, because greater access to winter forage on privatized land has allowed more animals to be maintained through the winter[8] (LONGWORTH a. WILLIAMSON 1993; KOOCHEKI 1993; WU a. RICHARD 1999).

In order to guarantee the economic benefits from destocking, some alternative approaches of animal management could be considered. Diversification of herds is an approach to maximize resources and increase economic returns. This enables the exploitation of different microhabitats and the protection of rangeland biodiversity, as yak and sheep have different grazing requirements and play different roles in nomadic economics (WU 1997b). Another approach, which is economical and used more often in mountainous regions, is that animals are transported to an area beyond the disaster region, mostly to farming areas, where animals can feed on supplementary foodstuff (i.e. crop residues) or so that the surplus stock may be sold. Finally, an important consideration for pastoral development is that more ideal conditions of accessibility should be created for the remote pastoral areas. The development of more branches of major traffic lines could lighten the grazing pressures along the main accesses and lead to more sparse distribution of new settlements.

5 Conclusion

Privatization of rangeland has been regarded as a precondition for the protection of natural resources and the systems of common and collective pasture ownership as the primary cause of the degradation of rangelands (KOOCHEKI 1993; LI a. YONG 1993). But the real effects of pasture allocation are still vague because of the short time of implementation of this program. Attempts to create private, commercial ranges in some developing countries have not been successful (MUELLER 1999; JANZEN 2000; SCHOLZ 1995; WILLIAMS 1996). This reminds us to be vigilant for the potential negative results, and more careful tests should be done before any pilot experience is expanded to a large scale. Large-scale pasture allocation has raised a new set of issues regarding long-term sustainability in terms of cost and rangeland health. All options, there-

[8] Without the improvement of markets and socio-political conditions, herders always choose to utilize the extra supplies produced from the fenced artificial pastures to increase total animal numbers, rather than to increase the per animal feeding regime and thus the quality of the animal products produced (see LONGWORTH a. WILLIAMSON 1993). The increase in livestock numbers thus results in a higher stocking rate being applied to surrounding rangeland (in particular, the allocated winter pastures) and eventually leads to degradation (see WU a. RICHARD 1999).

fore, need to be evaluated on a site-specific basis, keeping in mind the socio-economic and ecological realities.

Traditional pastoral production systems are in dire need of assistance in developing response mechanisms to new forces affecting sustainability of the system. However, how to alleviate the negative effects of climatic variability and enhance the ability of the society as a whole to adapt to the harsh environment in the future is still a question for development planners and academics. In fact, Tibetan nomads and their livestock have dealt with snowstorms and severe winters for millennia in the highly dynamic ecosystem that exists on the Tibetan Plateau. Nomads learned to cope with the uncertainties of the environment by adopting a number of flexible production strategies that minimized risk and made optimal use of the resources available to them (GOLDSTEIN a. BEALL 1990; MANDERSCHEID 1999; SCHOLZ 1994; 1995; WU 1997b). Therefore, it is necessary for all activities financed by development programs to promote the use of local and regional expertise. Furthermore, forecasting the effects of climatic fluctuation or change on rangeland ecosystems in Winter Cold Zone is still an enormously complex and complicated problem. The interaction between climatic variability and socio-economic system is even more complicated than any single discipline can describe. More comprehensive understanding, therefore, should be encouraged before any blueprints of development plans are drawn up, and is also a prerequisite for proper insight into the complex response of ecosystems and socioeconomic systems to climatic change.

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