Chapter 2

STOCK TAKING: RANGELAND AND LIVESTOCK RESOURCES

2.1 The Rangelands, Land Degradation and Black Beach

A REVIEW OF RESEARCH REPORTS AND DISCUSSIONS

EDITED BY DENNIS SHEEHY

Rangeland importance

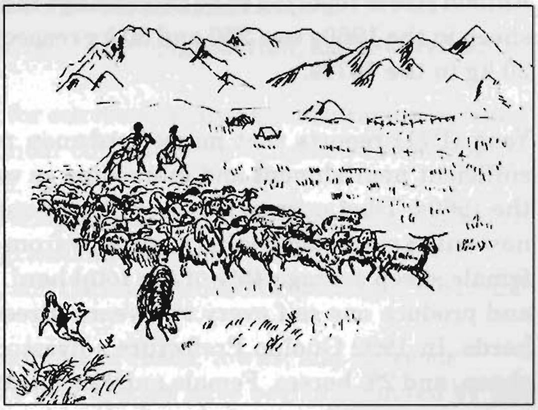
The Qinghai-Tibetan Plateau stretches over Qinghai, Sichuan, and Gansu provinces and the Tibetan autonomous region of China (Liu P33), (Table 2.1). Throughout the plateau, the dominant land type is rangeland which is used for livestock production. The main rangeland areas of Qinghai Province are alpine meadow vegetation around Qinghai Lake and south-eastern Qinghai. The total area of rangeland in Qinghai is approximately 36.5 million hectares.

Table 2.1: Distribution and area of degraded grassland in the Qinghai-Tibetan Plateau

Province	Grassland area (million ha)	% Degraded	
		1980s	1990s
Tibet	66.4	18	30
Qinghai	31.7	29	31
Sichuan	14.2	27	33
Gansu	16.1	44	49
Total	128.4	21	33

(Adapted by Liu and Zhou from Wang et al.)

The south-eastern monsoon and the high pressure of Siberia dominate the plateau's climate and have important implications for livestock production and rangeland management. The climate is divided into warm and cool seasons and the mean annual temperature is between 5.9 and 0 °C Precipitation increases from the northwest region (<300 mm/year) to the southeast region (>500 mm/year) (Wang et al. P63).



Desertification is reported to be a serious problem that is increasing in Qinghai Province. Annual precipitation is reported to have decreased by 10 mm in most areas of the province per decade since 1961 although use of 'cloud-seeding' techniques increased annual precipitation during the 1990s. Between 1960 and 2000 ambient air temperature is reported to have increased by between 0.2 and 0.3°C per decade, whilst the incidence and duration of winds at speeds sufficient to cause erosion and sand storms have also been increasing. The human population of Qinghai Province increased from 1.48 million in 1949 to 5.12 million in 1999 (Wang P62).

Although each factor unilaterally affects stability of the topo-edaphic-vegetation complex that has developed over millennia to form current ecosystems, the interaction among factors is having a significant and accelerating negative impact on ecosystem stability (Wang P62).

Rangeland Livestock Production

Total livestock numbers in Qinghai Province reportedly increased by 118% between 1987 and 1997. Meat production increased over the same period from 113,800 tonnes to 198,400 tonnes (Liu P33). Wang et al. (P63) consider livestock production to be traditional, backward, and monotonous. They report that the Plateau rangelands are overstocked; with, for example, the Yushu area of the plateau being 35% overstocked.

Li (P27) identified three classes of herder households in Qinghai Province's Guoluo Prefecture. The three classes were: poor households with 20 or less livestock per capita (mostly yak); middle level households with between 20 and 120 livestock (mixed sheep and yaks); and wealthy families with more than 120 livestock. Many families suffered labour shortages, which was identified as a primary cause of poverty. The same paper points out that wealthy households have tended to participate fully in the rehabilitation of pasture and in improving the feed resource. However, middle income families wish to participate in government programmes but often lack sufficient funds, whilst poor families receive welfare and generate most of their income from activities other than livestock production. According to Yang (P71), poor herders wish to have more animals while wealthy herders wish to increase the proportion of females in their herds.

Impact of rangeland degradation on livestock production

There are some indications that degradation of the rangeland resource base is beginning to seriously impact livestock production. Herders on the plateau believe that the area of rangeland has contracted and is now inadequate to sustain their animals. Although the herders know that the deterioration of the grassland in general is due to too large a number of livestock, they view pest infestation as an additional, important cause.

Animal size is reported to be decreasing (Yang P71). The average weight of yak and Tibetan sheep in the 1960s was 250 and 30 kg respectively, compared to average weights of 125 and 20 kg in the 1970s.

Yang (P71) reports that many herdsmen relate increased livestock mortality to lack of sufficient nourishment and inbreeding as well as to increased amounts of winter snow. In the 1960s, Tibetan ewes matured at 48 months and produced two lambs per year; whereas now only a single lamb is born and only from ewes in the best condition. Currently, breeding female sheep average 45% of the total herd. Female yaks currently mature at seven years and produce one calf every two years. Breeding female yaks account for only 30% of the herds. In 1999 Guoluo Prefecture's livestock herd consisted of 35% cattle and yak, 53% sheep, and 2% horses. Female animals made up 49.6% of the total herd.

A survey of 1,643 demonstration households in Guoluo Prefecture indicated that: 1) both poor and wealthy herders wanted to build fences, 2) a lack of seeds and cultivating skills prevented herders from planting forage and fodder, 3) most herders did not want to spend money on animal shelters or else thought shelters would decrease animals' resistance to cold, 4) herders were interested in building houses after receiving grassland contracts, 5) most herders did not view animal disease as the main limiting factor of livestock production, and 6) most herders were poor and said they needed a loan to be able to improve their livelihoods (Yang P71).

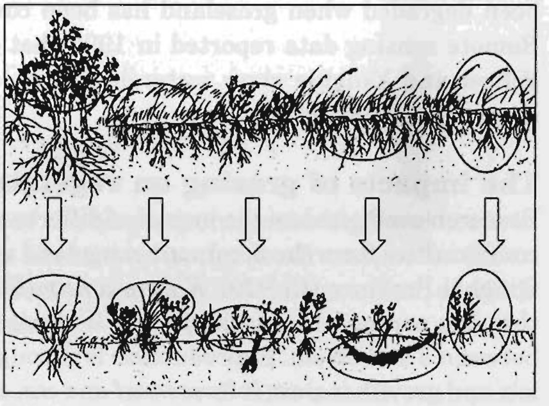
Rangeland condition

Liu (P33) report that 27% of the total grassland area had become degraded by the 1980s. During the 1990s, the total degraded grassland area had increased to 33% (Table 2.1).

Wang et al. (P63) report that over 16% or seven million hectares of the Qinghai-Tibetan Plateau is 'barren' land. This type of land has become known as 'black beach'. In Qinghai Province humus and nitrogen loss was reported as 310 and 7,121 kg/ha in soils lightly impacted by rodents, 915 and 21,365 kg/ha/yr in moderately impacted soils, and 1,759 and 40,357 kg/ha in heavily impacted soils.

The causes of degradation

Liu (P33) report that the ecological quality of the rangeland environment has degraded due to causes which include: herders' ignorance of the situation; poor management of the rangeland resources; snow disasters; persistent over-grazing; desertification; and rodent damage. These factors are preventing sustainable livestock development.



Human activities other than livestock grazing that have had a major impact on rangeland degradation.

- The extensive harvesting of fuelwood from Cypress, Diversiform Poplar, and Rose Willow forest). This has significantly increased sand dune formation and forest degradation, and lowered water tables.
- The destruction of extensive areas of forest for conversion into agricultural use. Around 0.66 million ha of grassland was brought under cultivation in Qinghai Province in the 1950s. Most of it has since been abandoned.
- Exploitative utilisation of grassland to develop livestock production. This has led to overgrazing and extensive degradation of grassland resources[1].
- Other human activities such as gold mining, and the uncontrolled harvesting of medicinal herbs.
- Infrastructural development such as the building of roads, towns, and railroads.
- Natural checks to the population growth of pest species have been eliminated by the killing and capturing of their natural predators[2] (Wang et al. P63).

[1] Livestock numbers have increased to over 20.9 million; 2.7 times more than in 1949.
[2] Reportedly, 15 to 20 % of animal species in Qinghai Province are in the 'threatened' category.

Erosion from wind and water and frost heaving further degraded the rangelands and have created a favourable rodent habitat.

Degradation impacts

A major impact of degradation on rangeland has been the loss of species diversity. Wang et al. (P63) indicate the three degrees of degradation not only by ground cover, but also by the number of different species found. The degree of degradation was considered small, if 86% of the soil was covered, in which case 18 species were found. Moderate degradation occurred at 46% coverage with 9 species, and serious degradation at 1% coverage by 5 species.

The grass yields of Dari, Maduo, Maqin, Quemalai, and other counties are reported to have decreased by between 50 and 80% between the 1980s and the 1990s. This decrease is believed to have been caused by over-stocking (Wang P62).

The vegetative production of 'black soil' type rangeland averages 400.5 (FW) kg/ha. Plants poisonous to livestock now comprise between 60 and 80% of the species found in black soil areas (Ma et al. P43).

In Maduo and Maqin counties, degraded grassland covers 1,266 sq.km of which 80% has been degraded when grassland has been covered by sand from destabilised sand dunes. Remote sensing data reported in 1995 that desert expansion in the source region of the Yellow and Yangtze river watersheds was expanding at annual rates of 20 and 2.2%, respectively (Wang P62).

The impacts of grazing on vegetation

Research conducted on the impact of different livestock stocking rates showed that *Kobresia* communities form the dominant rangeland vegetation type in the southeastern counties of Qinghai Province (Li P29). *Kobresia humilis* is a grasslike (*Cyperaceae*) herbaceous plant that is a perennial tussock species. It starts to grow in late April and grows to heights of between 3 and 15 cm. Reproduction is through vegetative multiplication. Although yield is low and growth is slow, it forms turf and can endure intensive grazing pressure, and usually becomes the dominant species.

In QLDP grazing trials, several different stocking intensities (0, 2, 4, and 8 SU/hm^2) were used to determine the response of *K. humilis* ramets to different grazing intensities. Plots were grazed between October and December and again in May of the following year. Results indicated the following.

- Tillers and aboveground biomass decreased with an increase in stocking rates. This indicated that grazing in the autumn reduced nutrient storage and spring grazing on the same plants reduced nutrients further, especially at stocking intensities of over 2 SU/hm^2.
- The number of flowering tillers/ramets decreased as grazing intensity increased while vegetative tillers initially increased under light stocking, decreased under moderate stocking, and then increased under heavy stocking intensity.

- As the number of clonal ramets increased, vegetative tiller numbers decreased and reproductive tillers increased
- This indicated that under heavy grazing pressure the plant tends toward vegetative reproduction rather than reproduction from seed as a way of competing with other plants and withstanding high grazing intensities (Li P29).

Dong et al. (P13) studied the impact of three stocking intensities of yak on frequency and cover of plants in an alpine meadow above 4,000m elevation. The three different treatments were light, moderate, and heavy grazing by four yaks. The results from these plots were compared with a non-grazed control area. The frequency and cover of plants were measured in 1998 and 1999. The study area was a fenced off area of degraded grassland. It was found that the stocking intensity had a notable effect on plant frequency and cover. Although the plant cover increased under the three stocking rates, the type of herbage present increased in different proportions. Light grazing (less than normal grazing intensity) increased plant cover (of the soil) in the first year. Under moderate and heavy grazing intensities, the plant cover increased only after the second year of controlled grazing. Under light and moderate grazing intensities, the cover of grasses and weeds decreased while the cover of sedges increased. Under heavy grazing the cover of grasses and sedges decreased while the cover of weeds increased. The study indicated that controlled grazing at light and moderate stocking rates would maintain grass and sedge composition and the yield of alpine grasslands.

2.2 The Climate

A REVIEW OF PAPERS AND OF DISCUSSIONS OF THE WORKGROUP ON RANGELAND BY NICK HODGSON

The Qinghai-Xizang (Tibetan) Plateau is one of the largest contiguous highland areas in the world. It extends over 2,000 km from the Himalayas in the southwest to the Qilian Mountains in the north-east. The plateau covers a total area of 2.5 million sq.km, of which Qinghai Province occupies about 720,000 sq.km.

Most of Qinghai Province is at an altitude of between 3,000 and 4,000 metres, with peaks reaching 6,800 metres. The province can be subdivided into the Qilian Mountains in the north-east, which have reasonable levels of rainfall and fertile cultivated valleys; the Qaidam Basin, an enclosed arid basin at an altitude of between 2,600 and 3,200 metres within the main plateau structure; and the Qingnan Plateau where the main area of alpine rangeland occurs.

Climate variability and climate change

The natural rangeland of the high plateau is characterised by a cold dry climate with long winters. Typical annual average temperatures range from -5°C to around zero, reaching a maximum of 10°C in July and a low of -15°C in January.

The length of the growing season ranges from a maximum of 200 days to a low of 150 days. Low water availability is a serious constraint to plant growth.

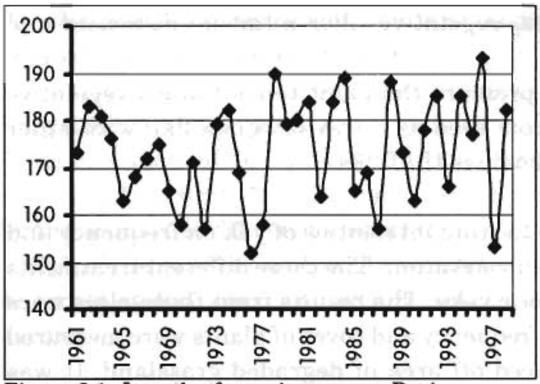


Figure 2.1: Length of growing season Dari meteorological station – Jimei

Land use in this harsh climate is further constrained by wide variability in the length of the growing season (Figure 2.1). An extreme example of this can be seen from Dari where in 1996 there were 193 growing days whereas in 1997 there were only 153; a difference of around 30% over two consecutive seasons.

Rainfall and temperature are also extremely variable. These factors, together with wind speed, cloud cover, and radiation, all affect plant growth.

The clearest index of potential growth conditions is actual evapotranspiration (ETa). The cumulative evapotranspiration for a growing season can serve as an index to measure the plant growth over a particular year. The loss of water through transpiration relates to water intake and growth in a plant. For example, the transpiration ratio denotes the amount of water used to produce one pound of dry matter on a plant.

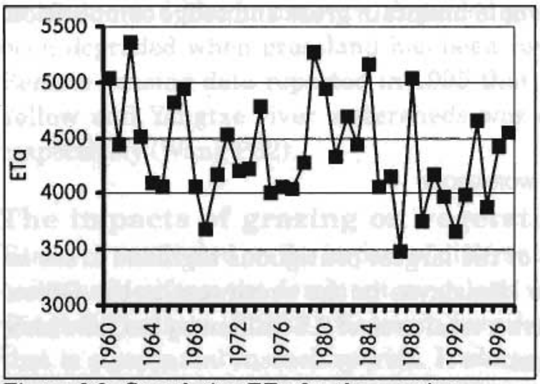


Figure 2.2: Cumulative ETa for the growing season, Dari meterological station

An evaluation was carried out by the Qinghai Bureau of Meteorology using data on evapotranspiration and rainfall to give actual evapotranspiration. Examination of the data that covered the period from 1960 to 1998 showed that the variability of average evapotranspiration had been at the high level of 30% (Figure 2.2).

There has been considerable discussion within the project about the impact of climate change on the plateau environment. There are some indications that annual average temperatures have been rising at about 1°C every fifty years, with the mean summer temperature rising at a rate of 1°C every hundred years.

Zhang Guosheng et al. (P77), in their paper on the effect of climate change on grassland degradation have stated that the annual mean temperature is increasing year by year in the source area of the Yellow River (Maduo County), with a particularly significant rise in summer temperatures.

Total precipitation is also increasing at a rate of 1.3 mm per year. However most of this is as winter snow, rather than growing-period summer rains. The impact of increasing winter precipitation is reflected in the increasing human toll of winter blizzards.

The same authors also considered that there has been a 14-year cycle of summer precipitation with climax years falling in 1961, 1975, and 1989. The figures showed low precipitation periods between the climax years, with the year 2000 as a low summer precipitation period. The authors developed a drought index, based on temperature and precipitation, that indicates a cycle of higher and lower precipitation years.

The authors also cite as supporting evidence the drying up of lake systems in the upper catchments. Water levels have dropped by up to two metres in some lakes and "up to one thousand lakes have disappeared completely." There is concern of the possible impacts of this on the Yellow River system and the downstream cycle of droughts and floods.

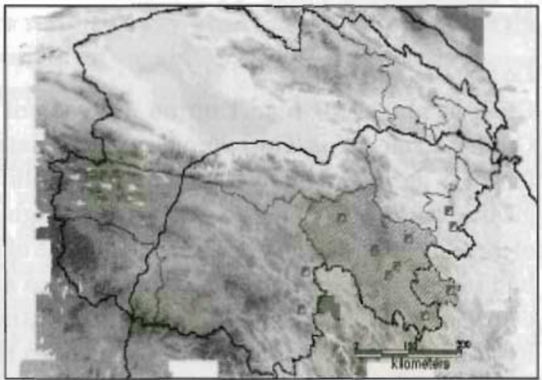


Figure 2.3: Project area – meterological stations

A similar conclusion is reached by Zhang et al. (P77) in their discussions on the effects of climate change on rangeland ecology. They looked at precipitation and other factors for each of the seasons and the flood season.

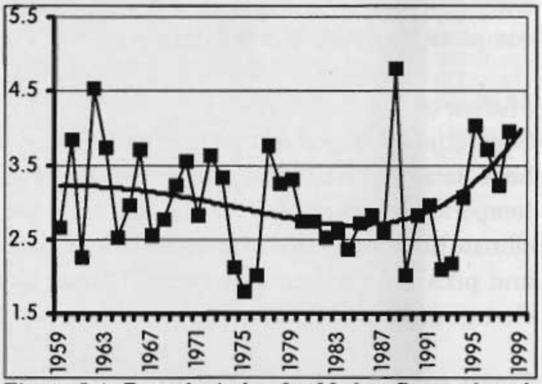


Figure 2.4: Drought index for Maduo County based on temperature and precipitation

The increase in dry season (winter and spring) precipitation and the decrease in wet season (summer) precipitation is considered to be leading to a situation of summer droughts and winter snow disasters. The authors say the trend is a move from "a large disaster every ten years, a middling one every 5 years and a small one every three years" to "a large disaster every 5 years, a middling one in every three years and a small one every year."

In the short and medium term it is the annual variability of climate that is most significant to the development of rangeland systems. If livestock systems are able to cope with the annual variability, then they are also likely to have the resilience and flexibility to adapt to long-term changes.

2.3 Changes in Vegetation Index, 1982-1999

SUMMARY OF A STUDY BY ANITA PERRYMAN

Introduction

Any policy and research concerned with rangeland improvement requires a good understanding of the dynamics of rangeland productivity. There is growing concern that in south-east Qinghai changed land-use practices and changes in climatic conditions are increasing land degradation, reducing the productivity of the rangelands and threatening the livelihoods of its inhabitants. However, no study had directly assessed the dynamics of vegetation in this area. QLDP and the Meteorological Bureau of Qinghai undertook such a study, which was executed by Anita Perryman, Yang Yinglian, and Xu Weixin. A more detailed report of its analyses is available from QLDP.

Previous studies

Land degradation

Chen et al. (1998) report on an assessment of the condition of the land in Dari County, Guoluo Prefecture. They compared 1985 data on rangeland grade and type maps with data for 1997 derived from NOAA and TM satellite images, which had been calibrated against a ground survey. They noted a decrease in high grade pasture and also concluded that the area of usable pasture had decreased, as the area of black beach land (eroded and degraded patches) had increased. By analysing stocking rates and carrying capacity data they concluded that overgrazing had not been the main contributing factor to pasture degradation. They hypothesised that global warming had been the key factor causing land degradation in Dari. However, their study was based on only two years of data, and so these years could be unrepresentative years when exceptional conditions occurred. The study reported here was carried out partly to build on the study carried out by Chen et al. by using a more historically complete, remotely-sensed data set.

Meteorology

Some studies suggested that land degradation had been caused by climatic change, whilst others have disagreed with this conclusion. Xu et al. (2000) suggested that there has been a rise in temperature and rainfall for Qinghai since the mid-1980s. Zhang et al. (1998) say that the drier climate has contributed to grassland degradation by compounding the problems of overgrazing and pika infestation. However, Thomas (2000) found that there had been no significant change in annual or seasonal potential evapotranspiration for Maduo in Guoluo Prefecture.

Data and methods

Normalised Difference Vegetation Index (NDVI) images often serve as a good indicator of vegetation dynamics. The aim of this study was to interpret a set of satellite images spanning the period from 1982 to 1999 to assess whether the productivity of rangeland had decreased or if falls in productivity were due to other factors, principally shorter growing seasons. These indicators were interpreted in conjunction with meteorological data to assess the impact of climatic and weather effects.

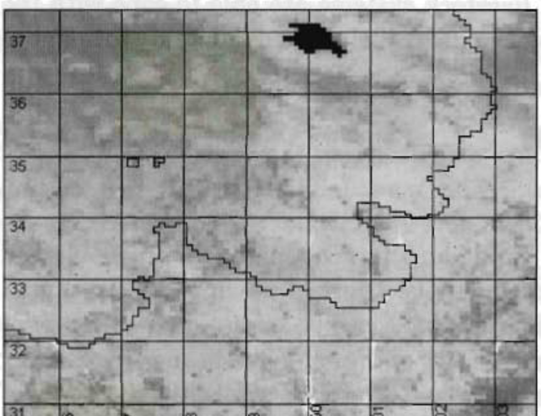


Figure 2.5: Pathfinder NDVI image for the end of July 1984

NDVI images

The image sets used in this study were ten-day vegetation images from the NOAA satellites (the Pathfinder AVHRR land data series), for the period from July 1981 to September 1994 and January 1995 to June 2000. These were downloaded from the internet (daac.gsfc.nasa.gov). Their spatial resolution is 8 by 8 km. Figure 2.5 is the Pathfinder NDVI image for the end of July 1984.

The Pathfinder data set includes Normalised Difference Vegetation Index (NDVI) images. Vegetation absorbs red light strongly for photosynthesis, whilst the plant cell structure reflects away near infrared radiation. This dual reflectance response is uniquely characteristic of vegetation. The NDVI method uses this response to discriminate and describe vegetation.

NDVI values range from –1 to 1. Values above about 0.05 indicate the presence of vegetation, and the higher the index the more vigorous the photosynthetic activity. Water and bare soils give lower index values and so can be distinguished from vegetation. Topographic and cloud shadows (which reduce the reflectance values) are partially compensated for as the normalised difference is used. Diseased, dead, dying, and dormant vegetation are not detected. This makes NDVI a good indicator for the examination of growing seasons and production.

Figure 2.6 shows a region of about 800 sq.km and shows the boundary of the study area — Qinghai Province. Qinghai Lake is the dark area. The vegetation index values are shaded from black (NDVI value of -1) to white (NDVI value of 1). In Figure 9 active vegetation takes values from about 0.1 upwards increasing with the vigour of the vegetation growth. Lighter areas indicate higher NDVI values where vegetation is growing more vigorously. The darker area in the north-east of the image (Figure 2.6) is the Qaidam Basin desert area. This area clearly has less growing vegetation than the south-east of Qinghai.

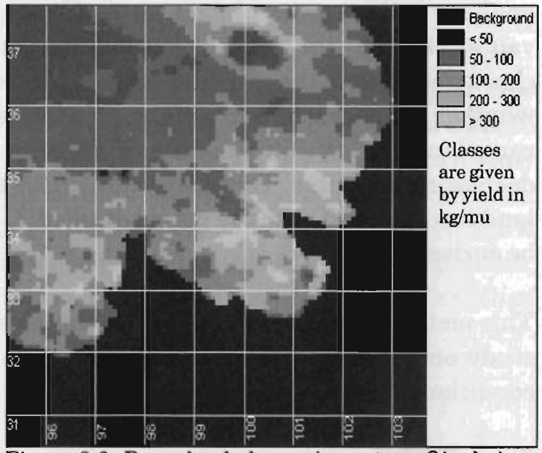


Figure 2.6: Rangeland classes in eastern Qinghai

Area covered

The region examined in this study covers parts of south and east Qinghai Province, bounded to the north by latitude 37.6 N and to the west by longitude 95.1 E, covering an area of approximately 350,000 sq.km or just over half of the province. The average annual precipitation of this area is about 500 mm, with the majority occurring in the summer. Precipitation varies from less than 50 mm in the Qaidam Basin area to about 700 mm in the eastern river valleys. Annual average temperature ranges from –6 to 4°C. The growing season usually runs from mid-May/late June to late September.

The area ranges from 3,000 to 5,500m in elevation. There is a band of lower land at 3,000m in altitude across the northern part of this area through the Qinghai Lake area, but generally the terrain slopes from west to south-east. The southern area is pastoral whilst the north-east is more agricultural.

Rangeland classification

A classification of rangeland was developed according to the information on the basic productivity of grasslands which can be picked out from satellite data. A rangeland grade map was produced for 1993 to 1995 using NOAA AVHRR data which were available at the

Bureau of Meteorology's Remote Sensing Centre in Xining. This map was derived from daily vegetation index images produced at a spatial resolution of one km. These data were composited to remove cloud contamination and were accumulated through the season. Five main sites and several seasonal sampling sites, chosen to represent the different vegetation type across south and east Qinghai, were used to collect field data. At each site five to ten 1m² samples were selected from within the 10 km² main sampling sites. The vegetation in these squares was harvested and weighed every ten days during the growing season. From this data the output yield in kilogrammes per mu (1 km² = 1,500 mu) was calculated and the rangeland grade map calibrated.

Basic approach

The methodology used was similar to that used by Tieszen et al. (1997b). This method analyses a time series of data for each rangeland class to determine the profile of NDVI values through the season. Various measurements are then extracted to measure the characteristics of the growing season. These measurements are then examined to assess whether the characteristics of the growing season have changed over time for each class of rangeland, to test, for example, if growing seasons are getting shorter or production is decreasing over time. This allows any trends to be identified to see if an increase in degraded land has occurred over the period studied. If this is found, then the rate of change can also be derived.

This methodology does not allow for the causes of degradation to be established. A parallel study on the meteorological conditions was carried out to assess the impact of weather conditions on rangeland vegetation.

Time series analysis

Six hundred and seventy-one Pathfinder NDVI images were uncompressed and re-projected. The study region was extracted and the real NDVI values retrieved.

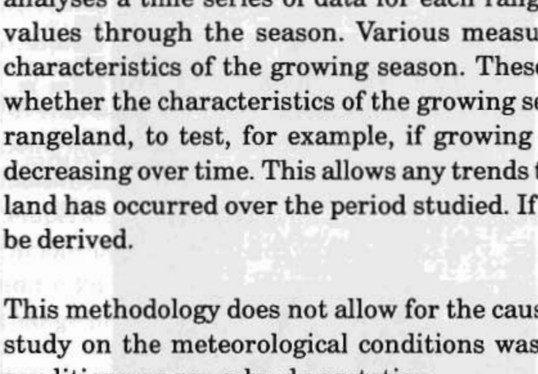


Figure 2.7: Temporal profile showing NDVI Metrics for 1983. The raw, smoothed and running mean profiles are shown. Various NDVI metrics are labelled

Time series' profiles were generated for each year of data for the rangeland classes showing NDVI values through the year. The green season or rather the growing season can clearly be seen by the rise and fall in NDVI values. It was only possible to extract full sets of measurements for years with complete data. Incomplete years (1981, 1994, and 2000) were excluded. The timing and NDVI values at both ends of the season were recorded (Figure 2.7).

The maximum NDVI over baseline and the timing of this peak in greenness were recorded. The maximum range in NDVI values was also extracted. The rate at which the green-up[3] and green-down occurred was calculated in

[3] The rate of green-up is the amount of change of DNVI per month between the onset of the green season and the season peak NDVI.

NDVI units per month. The time-integrated NDVI (accumulated NDVI over baseline for the growing season) was calculated. This quantity was taken as an indicator of seasonal productivity.

The measurements were tabulated for each rangeland class for each year. Graphs of the evolution of measurements from 1982 to 1999 were generated. Trend lines were fitted to data and the significance of trends was determined. The level of correlation between measurements was examined.

The measurements metrics for length of green season and accumulated NDVI (productivity) were considered most likely to reveal overall rangeland condition. Significant decreases in these two measurements over time would indicate progressive rangeland degradation.

Meteorological study

The Bureau of Meteorology carried out a study on climatic change to investigate how changing climatic patterns may have influenced rangeland vegetation. This was done to complement the remote sensing study. It reviewed the normal variability and looked for any changes in climatic and annual growing conditions in the project area, based on the evaluation of actual evapotranspiration rates using data from 1960 (where available) to 1998. While it was found that there has been considerable variation of precipitation and evapotranspiration, however, the study found that there have been no significant trends in either the length of the growing season or in actual evapotranspiration. This information was used to help evaluate the results of the remote sensing study.

Results and discussion

Results and discussion of time series' analysis

Temporal profiles and NDVI measurements were extracted from the time series for each rangeland class.

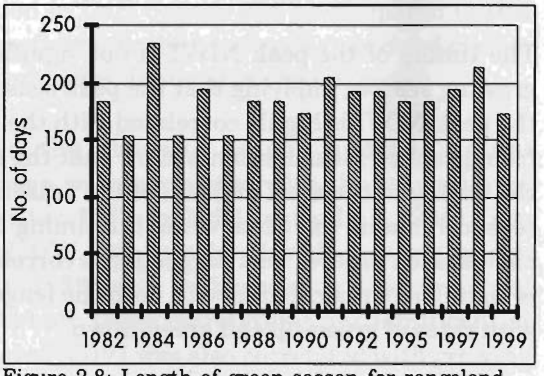


Figure 2.8: Length of green season for rangeland class 200 – 300 kg/mu

Graphs showing the evolution of measurements from 1982 to 1999 for length of green season and accumulated NDVI (productivity) are shown in Figures 2.8 and 2.9.

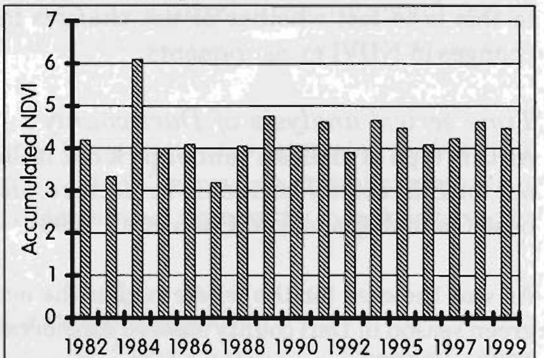


Figure 2.9: Accumulated NDVI (related to productivity) for rangeland class 200 – 300 kg/mu

These graphs show that there has been considerable variability between years. However, no significant trends are evident for any rangeland class for either the length of green season or accumulated NDVI.

The other NDVI measurements were also examined. These also showed variability

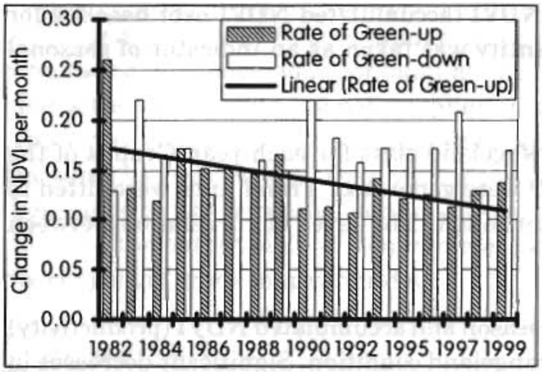


Figure 2.10: Rate of green-up and green-down in class 200 – 300 kg/mu

between years, but for most measurements no significant trends were found. The exception was the rate of green-up which showed a decrease in later years for all rangeland classes (Figure 2.10). This trend was significant at the 0.05 level. However, it appears that, for all rangeland classes, this trend is heavily influenced by the particularly rapid green-up in 1982, a year when the season started particularly late. When this year is removed the significance of the trend disappears from each class. The correlation between the timing of the onset of greenness and the rate of green-up was examined. The correlation coefficient for rangeland class > 300 kg/mu was 0.7823, which is significant at 0.001. This correlation indicates that when the season starts later the greening up occurs faster.

These data indicate that, although there is a lot of variability between years, there are no significant trends to indicate an increasing amount of degraded land in eastern Qinghai. This analysis was conducted using rangeland classes that are widely distributed across the eastern half of Qinghai. The results show that, on average across each of these classes, there has been no significant change in the amount of degraded land.

The timing of the peak NDVI is not significantly correlated with timing of onset of the growing season, implying that the peak season is not delayed by a late start. The timing of the peak NDVI is highly correlated with the rates of green-up and green-down (while data from graphed measurements show that the timing of the peak NDVI is less variable than the timing of the start and end of the season). This may imply that the basic shape of the season remains the same while the timing of the start and end effectively truncates the basic season profile. This suggestion is corroborated by the fact that the accumulated NDVI is significantly correlated with both the length of season and the maximum NDVI, but not with rates of green-up and green-down.

No reasons for any changes or lack of changes can be tested with this analysis. The exception to this is to test whether or not changes in the meteorological data are correlated with changes in NDVI measurements.

Time series' analysis of Dari county

As this type of analysis cannot pick out isolated areas of degraded land it was also carried out for Dari county in Guoluo Prefecture, an area identified as particularly subject to black beach land degradation (Chen et al. 1998).

As was the case for the whole region the accumulated NDVI (productivity) and length of green season in Dari county showed considerable variability but no significant trends between 1982 and 1999.

Comparison to previous study
A comparison was made with the results of Chen et al. (1998) on decreases in high grade pasture.

The NDVI time series was examined for changes between and around 1985 and 1997, the dates used in the study by Chen et al. The accumulated NDVI values show a clear drop in accumulated NDVI for each class from 1985 to 1997. However, when the accumulated NDVI for each year in the Pathfinder time series is examined, the conclusion of Chen et al. that land has become degraded is not supported. Figure 2.11 shows the accumulated NDVI for each year of the time series for Dari County. It can be seen that 1985 was an extreme year within these seventeen years, while 1997 was more normal.

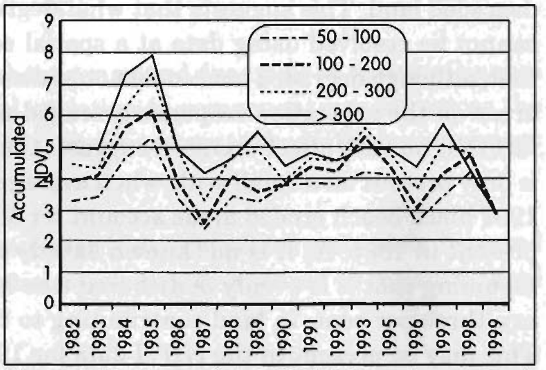


Figure 2.11: Accumulated NDVI for each rangeland class in Dari county

Incorporation of meteorological data
For future rangeland analysis vegetation data, derived through remote sensing, it is useful to increase the understanding of how meteorological data relate to the NDVI measurements. However, it is difficult to directly compare data derived for each rangeland class with the meteorological station data as the rangeland classes are dispersed across eastern Qinghai. However, the data for the meteorological station in Dari County can be compared in this way. Dari's meteorological station is located on the borderline between rangeland classes 200–300 and > 300 kg/mu, and so both of these classes are used in the analysis.

The amount of precipitation that fell in the growing season and the actual evapotranspiration (ETa) for the growing season were correlated with the accumulated NDVI (productivity) measurements for Dari for 1982 to 1998 (excluding 1994). The rangeland class 200-300 kg/mu accumulated NDVI was correlated with growing season precipitation (correlation coefficient, $r = 0.4586$) and with growing season actual evapotranspiration ($r = 0.4365$). With df = 14 both these correlations are significant at 0.1. For rangeland class >300 kg/mu accumulated NDVI was also correlated with growing season precipitation (correlation coefficient, $r = 0.6051$) and with growing season actual evapotranspiration ($r = 0.5730$). With df = 14 both these correlations are significant at 0.05. Hence there is a relationship between NDVI accumulated over the growing season and precipitation and ETa.

No in-depth statistical analysis has been performed to determine the interrelations between the NDVI measurements and the meteorological data. However, an initial examination suggests that these data sets are related although they are not necessarily measuring exactly the same quantities.

Limitations of analysis and suggestions for further work
This analysis has used rangeland classes based on yield. These classes were dispersed across eastern Qinghai. To better interpret the data and to compare it to other data sets it may be

necessary to use different regions for analysis. The analysis was duplicated for Dari County, an area subject to severe land degradation.

The Dari analysis still did not find evidence of a significant increase in the amount of degraded land. This suggests that what degraded land there is is in isolated patches which cannot be resolved using data at a spatial resolution of only 8 sq.km. It was anticipated that, although degraded land could not be directly seen in this data, the influence of degraded areas on the vegetation response averaged across each 8 sq.km area would be found. The fact that no such affect was seen suggests that any increase in the amount of degraded land is only present on a small scale when averaged over a county. Chen et al. (1998) say that in 1997 black beach eroded areas account for 5.52% of Dari county — more than double that present in 1985. As it is not known exactly how this is distributed across the county, and assuming that it is evenly distributed (the least detectable configuration) then a drop of, say, three per cent, in land contributing to the vegetation index value should be present. This may be present in the NDVI data for 1985 and 1997 but the overall variability of the seasonal growth obscures any identification of a change of this order.

To refine this, analysis data of higher spatial resolution should be considered. A spatial resolution of 1.1 sq.km. NOAA data is available daily. This data can be collected, calibrated, the NDVI calculated, co-registered, and composited to replicate the Pathfinder time series, but at a much higher spatial resolution. These one km data are very suitable for investigating rangeland dynamics. However, the archive for this type of data only extends back to 1992 in Xining. This could be analysed but a longer time series would be required. Data of a higher spatial resolution are usually not available frequently enough for investigating the dynamics of the growing season and coverage for Qinghai may be sporadic.

As an alternative strategy, some consideration should be given to which are the best regions for analysing time series' data. While rangeland yield classes define regions where the vegetation is expected to respond relatively homogeneously, counties are more useful for comparing other data determined on a county or point basis. A detailed classification of severely degraded areas could be used to pin-point the analysis, although minimum sizes of regions would have to be determined to ensure that the analysis is still valid.

The statistical analysis of data reported in this paper has been fairly basic, mostly owing to the lack of time to expand the analysis. More complete and sophisticated statistical analysis of the data could provide more useful results.

Conclusions

The analysis of the Pathfinder data indicated that, although there is much variability between years, there are no significant trends in land degradation over the east of Qinghai as a whole or in Dari county.

There are problems with basing conclusions on data from just a few dates, which will give only a snapshot view. The results can be rather different when data from a longer time series are examined.

Meteorological data for the same period showed similar variability and a lack of significant trends. No in-depth statistical analysis has been performed to determine the interrelations between the NDVI measurements and the meteorological data. However, initial examination suggests that these figures are related although they are not necessarily measuring the same quantities.

The PCA showed that different information about rangeland dynamics in eastern Qinghai can be derived from this data set. The spatial variation in component images across the region are particularly interesting and should be complementary to the NDVI measurement data.

The Pathfinder data are of insufficient spatial resolution to detect isolated and widely dispersed patches of black beach erosion. A higher spatial resolution is required to monitor these data.

2.4 Livestock Production

A REVIEW OF PAPERS AND OF DISCUSSIONS OF
THE ANIMAL PRODUCTION WORKGROUP BY JOHN DAVIS

The QLDP project area in southern Qinghai has a cold harsh environment with most of it lying over 3,500 metres above mean sea level (masl). Due to the harsh climate and short growing season it is not possible to produce food crops and the population are dependent on livestock for their survival. The two main livestock species are yak and sheep. Some horses are kept for riding. The herders practice a transhumance pastoral system moving their livestock to higher altitudes (>4,000 metres masl) in the summer and then returning to the lower areas (3,500-4,000 metres masl) with the onset of winter. In some townships there is an intermediate stop in the spring and autumn. The inhabitants of the six QLDP project townships typically follow these practices.

Trends

It is widely thought that the livestock productivity per animal has decreased markedly over the last 20-30 years. Yang (P74) indicates that the carcass weight has decreased from 250 kg to 125 kg for an adult male yak and from 30 kg to 20 kg for sheep. However, it is difficult to be sure whether or not these figures are accurate. The decline is attributed to the deterioration of the grasslands caused by overgrazing and, in the case of yaks, also to inbreeding. Conversely official statistics indicate that there has been little or no increase in livestock numbers over the period in question. Statistics from the Bureau of Animal Husbandry (BAH) show that the maximum livestock population was reached in the early 1970s with a slight decline in numbers since then. This applies to the province, prefecture and the project counties. Goldstein (R1996) argues that the rapid increases in livestock numbers reported from the 1950s through to the 1970s are likely to have been over-stated for political reasons. After the privatisation of farms in the 1980s, livestock numbers may have been under-reported. Livestock statistics for the project area need to be treated with caution.

The ratio of yak to sheep

The ratio of the number of yak to the number of sheep is an indication of the degree to which the system has become commercialised. The figures in Table 2.2 indicate that a

Table 2.2: Livestock statistics: prefecture, county and project area 1997

Area	Human population	Yak (Y)	Sheep (S)	Ratio Y:S
Qinghai Province		4,217,100	13,728,600	1 : 3.3
Guoluo Prefecture	121,900	1.179,600	1,334,900	1 : 1.1
Maqin County	31,200	211,600	377,500	1 : 1.8
Dari County	21,600	208,600	236,100	1 : 1.1

Statistics are from those of the Bureau of Animal Husvandry (BAH)

higher proportion of yaks are kept in the project area than in the province as a whole. This is an indication of the project area's remoteness as the yak is more important for people's subsistence in remote areas. Dairy products are significant in the herders' diets. The yak also provides hair for making tents and is used as a pack animal for the move from winter to summer grazing. Because of the long interval between generations in the harsh environment, especially in Dari, yaks are more vulnerable to losses from snow disasters than sheep. The sheep population can be built up more quickly after such losses.

Grazing systems

Apart from the move from winter to summer pasture there are no formal grazing systems. However, families – and in the more remote areas, tent groups – follow definite grazing strategies. Areas are set aside for grazing in the late winter or late summer and often the flocks and herds are split up. The more vulnerable animals, such as especially lactating or pregnant females, are put on the better grazing land on fenced winter pastures and the stronger animals are taken to the far away and more difficult areas. During the winter the herders adopt an opportunistic approach. When the weather is fine the animals are taken to higher areas, and when it is bad they are kept closer to the homesteads.

Yak production

The yak is the foundation of the way of life of the people in the project area. It is well adapted to the harsh conditions of the Qinghai Tibetan plateau and is able to respond to the variability and scarcity in levels of available feed. The cows only produce a calf every second year in southern Qinghai, although in areas with a higher feed availability annual breeding is the norm.

The yak has many useful attributes. Its ability to survive the very cold conditions is partly due to the composition of the hair, which consists of a coarse outer coat and an inner coat of much finer hair. Both parts of the coat are useful to humans. An adult animal produces approximately one and a quarter kilogrammes of hair of which just over half is the fine inner down. The coarse hair is traditionally woven to make the tents in which the families live. The hair is harvested in early summer.

Because of its adaptation to high altitudes, it is the most useful pack animal in this environment and is used both for riding and carrying loads.

Calving interval and lactation

Within one lactation a cow is milked over two summers. In the intervening winter, milk production drops to a lower level and is only sufficient to feed the calf. This no-milking period is important for the survival and growth of the calf. In the second summer the cow responds to improved nutrition and the animals are again milked. Figure 2.12 shows that the milk yield, after feeding the calf, is just under one litre per day. In the second summer the calf gets less milk and is only given access to the mother's milk -- important to stimulate milk letdown. In the second summer the yield for human consumption is approximately 80% that of the first summer. The two year calving interval does not entail a large drop off in milk yield for human consumption.

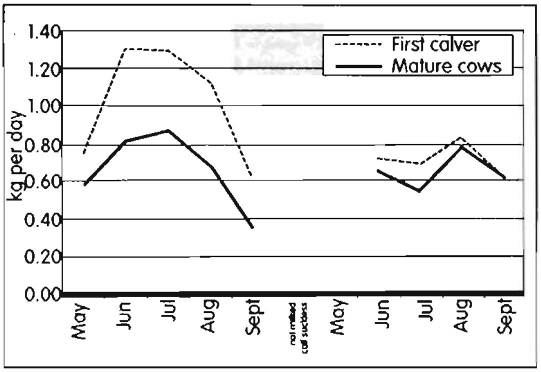


Figure 2.12: Milk yields after feeding the calf

Figure 2.13 shows the importance of the second summer when the cow is not feeding a calf. The animal is able to regain body condition before the next breeding cycle. If cows calve every year then the second calf is often born late in the calving season. This has its disadvantages.

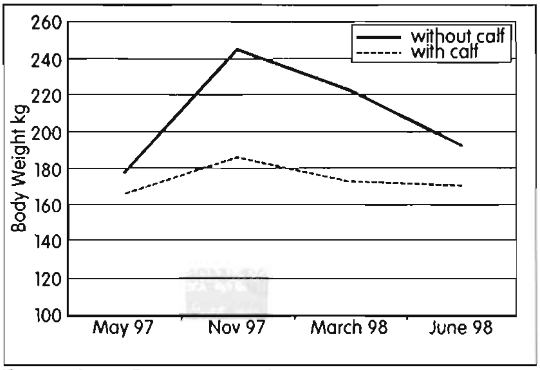


Figure 2.13: Live weight changes of yak cows over reproductive cycle

Weights at different ages are given in Figure 2.14. Growth rates are slow due to the poor nutritional status. The lack of sufficient and good winter grazing significantly reduces growth, and often live weight, in all winters except the third (which was between months 31 and 36). To examine weights at different ages, a limited number of yaks was slaughtered and dissected. A pack yak over 10 years weighed 370 kg with a carcass weight of 210 kg. Middle-aged animals, 5-7 years old only weighed 200 kg live weight and had a carcass weight of 110 kg.

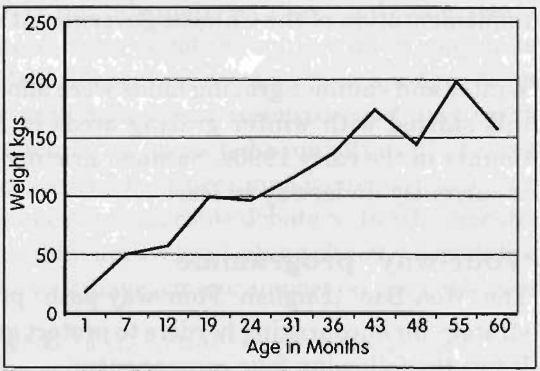


Figure 2.14: Live weights of different ages of yaks in Guoluo county

Sheep production

Sheep are kept for meat and wool. In the project area 45-48% of the flock are adult females. The lambing percentage is 75-80%. However, it is reported verbally by herders that only 70-80% of the lambs survive. Adult mortality rates are 6-8%. As with the yaks, the mortality is higher in the more remote Dari County. The sheep on average yield 1–1.5 kg of fairly coarse quality wool.

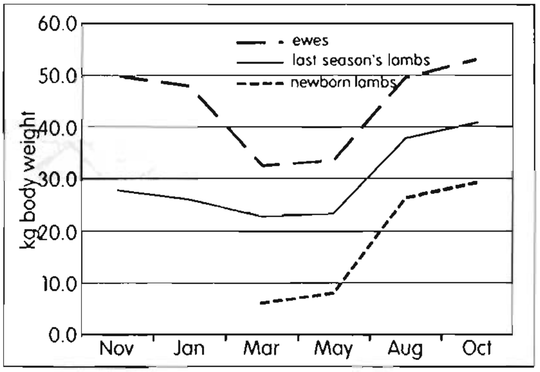


Figure 2.15: Live weight changes of sheep

Figure 2.15 shows the seasonal live weight changes of ewes, the previous year's lambs and the lambs born in the year of recording. The animals loose substantial weight over the winter, although when considering the figures for the ewes it must be remembered that by the end of the winter they will have given birth to their lambs.

Live weight at slaughter of males for mutton production is in the region of 45 kg with a carcass weight of approximately 20 kg.

The stress that yak and sheep face in winter because of insufficient feed is all the more dangerous if the animals have not been able, the preceding summer, to build up body reserves. Although insufficient winter feed is a serious constraint to production and survival, good summer grazing can mitigate the effects of winter.

2.5 Livestock Policies

A REVIEW OF PAPERS AND DISCUSSIONS OF THE ANIMAL PRODUCTION WORKGROUP BY JOHN DAVIS

Government livestock policy for the Qinghai rangelands has the twin objectives of protecting the environment and maximising livestock production. The principal method proposed to achieve this is for each herder household to become a small family ranch. This programme has a number of components.

Allocation of livestock and land

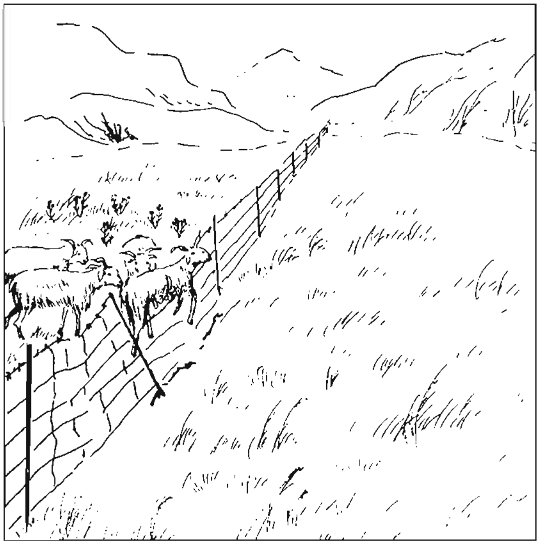
Livestock were allocated to individual families between 1983 and 1986 as part of the implementation of the Chinese government's 'family responsibility system'.

Winter and summer grazing lands were allocated to individual families. In the project area this started with winter grazing areas in Maqin County in the mid 1980s and in Dari County in the early 1990s. Summer grazing has only recently been allocated in Maqin and is currently underway in Dari.

'Four-way' programme

The 'Wen Bao' (English: Four-way path) programme is the Chinese government's major strategy for encouraging herders to protect grassland and intensify their production system. It has the following four components.

- Fencing[1] a 500 mu area for late winter feeding
- Making hay for supplementary winter feed by growing a plot of oats over 10 mu
- Building a 60 sq.m animal shelter for protection of livestock in winter, especially for the young lambs
- Construction of a permanent dwelling house on the winter pasture for the herder and their families.



Protection of the environment

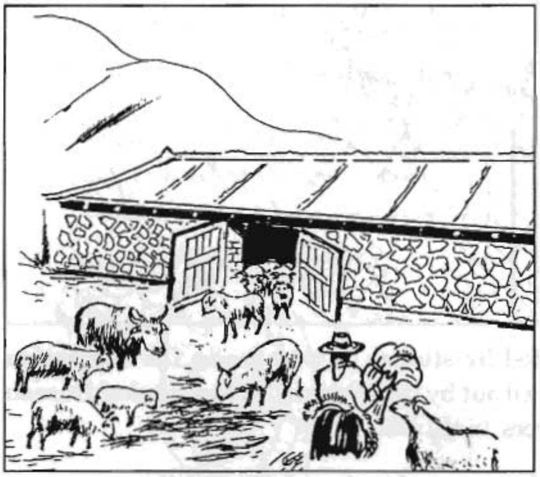
It is generally believed that the rangelands are degrading rapidly and that the principal cause of this is overgrazing by both large domesticated herbivores and by the pika and other rodents. This hypothesis has been tested by studies of changes in the vegetation index promoted by QLDP. These are being carried out by the Qinghai Meteorological Bureau in conjunction with the UK's Natural Resources Institute.

The rationalisation of stock numbers with the available feed resource is a principal aim of recent government policy along with poisoning campaigns against pika and *lagomorph* pest species. The availability of feed has been assessed by rangeland surveys which have been carried out by Qinghai Academy of Animal Science and Veterinary Medicine (QAASVM) approximately once every 10 years over a limited number of sites for each rangeland type. The productivity of each of these sites has been assessed. Recent climatic studies (Wang et al., P62) have shown that there are wide variations between years. The length of the growing season can vary by as much as 30% in different years. A study carried out on actual evapotranspiration (ETa) — the best measure of plant growth potential — has also shown variations from year to year of the same magnitude (Wang et al., P62).

It is crucial that livestock management systems take this annual variation and the dangers of snow disasters (every 5-10 years or so) into consideration. The possibility of losing large numbers of stock due to unusual weather conditions has to be taken into account when evaluating a rangeland's carrying capacity. It is not adequate to assess only one year's carrying capacity as the re-population of a herd, after a catastrophic winter, may take longer than regeneration of feed resources. Most herders do seem to take a longer term perspective, balancing animal numbers with anticipated feed resources and may carry excessive stock only for short-term reasons such as an expected acquisition of grazing rights. This is considered by some as proof of opportunism or poor management, but in fact it is a more realistic long-term view. There has been considerable debate as to whether the pasture areas of southern Qinghai are a 'non-equilibrium system' where climatic variability and extreme weather events, such as snow disasters, have a major impact on the growth in

[1] The initial fencing programme involved the enclosure of a 500 mu (33 hectares) area of winter grazing to leave as a strategic reserve until the late winter when animals are at their weakest and snow disasters are more likely to occur. In the second phase of the programme fences are used to demarcate each herder's grazing land.

livestock numbers and the type of vegetation. The project's consultants' opinions have differed on this point. Conditions do not show the very high degrees of variability found in the classical non-equilibrium systems in the arid tropics. However, the climatic variability and the occurrence of snow disasters indicate that the herder strategy of taking a long-term approach to the optimum number of livestock is substantially correct.



Maximising livestock production

The productivity of the rangelands is often only viewed in terms of meat production; and livestock are not seen in the wider context of supporting the people's way of life. Prices for meat changed very little over the five years of the project. Little account has been taken of the importance of butter and dried cheese in the herders' diet. The role of the yak in providing transport and in providing hair for making tents has also not been taken fully into account.

The government policy is to keep the same number of yaks, more sheep, and fewer horses. The herders are encouraged to have a higher proportion of productive females and to allocate the best grass to young males and more milk to the male yak calves to enable them to be marketed earlier to maximise meat production at the expense of other products.