Rangeland Resources and Conditions in Western Sichuan

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Introduction

Due to the high altitude and the harsh environment of the Tibetan Plateau, cropping is not possible in most areas. The only way the land can be used is for livestock grazing (Goldstein et al. 1990). At present, there are 167 million hectares of natural rangeland resources on the Plateau, comprising 42 per cent of China's total area of grassland. These areas form the basis for pastoral lifestyles and have been used for centuries. Even now, more than half of the population depends on range-livestock production systems for their livelihood.

In regions like the Tibetan Plateau that are classified primarily by high-frigid environments and a dependence upon livestock production, information about rangeland resources is essential for sustainable development. Over the centuries, the pastoralists of the Tibetan Plateau have been immensely successful not only in using vast rangelands but also in conserving the grazing capacity of these areas. Wildlife has also co-existed with nomadic populations on the Plateau (Schaller and Gu 1994; Miller 1995). These pastoral communities have evolved migratory, semi-sedentary, and deferred grazing practices to produce ample quantities of animal products for private consumption and for sale (Wu 1996). Today, however, numerous demographic and economic changes are triggering adaptive changes that will, most likely, significantly transform these systems. Economic progress has brought pressures on the environment, especially on rangeland ecosystems, and has also influenced infrastructure and daily nomadic lifestyle (Clarke 1987, Wu 1995).

Range Resources in Western Sichuan

Western Sichuan is located on the eastern Tibetan Plateau. Elevations range from 3,000 to 5,000m and the area is located between 97°26' - 104°27' E and 27°57' - 34°21'N. Western Sichuan is an impoverished plateau area in need of development and has a long history of pastoral development with pronounced local economic characteristics. The total area is about 236,000 sq. km. and includes 13.9 million hectares of rangeland. These range resources not only play an important role in the national economy and environment, but are also related to the improvement of local livelihoods.

Land classification figures clearly indicate the importance of rangelands in western Sichuan. Some 58.9 per cent of the land in western Sichuan is rangeland, accounting for 3.5 per cent of China's rangelands. Of the 13.9 million hectares of rangeland in western Sichuan, 12.18 million hectares are available for grazing. This means that about 7.5 hectares of pasture are available per person and about nine hectares are designated for each rural person.

A number of factors determines the natural occurrence and extent of high-frigid rangelands in their various physiognomic forms. The most significant of these are: geomorphology, precipitation, temperature, and grazing. It is important to understand that these factors rarely operate independently of the others. Most often, the joint impact of several of these factors may have a cumulative effect upon a given ecosystem; occasionally such factors, alone or in combination, may have an entirely different effect.

Rangelands are primarily divided by grass type. Although trees and bushes are found in some places as woodland and bush meadows, these trees or shrubs are relegated to a secondary position as habitat indicators compared to grasses. The high-frigid rangelands that support Tibetan pastoralists (such as those of western Sichuan) have been divided into four kinds, 12 groups, and 22 types (Ni et al. 1984, Table 1).

High-frigid Meadows

High-frigid meadows are mainly composed of perennial and medium (eumesophytic) herbaceous plants and are formed under the Alpine and cold-humid climate of the Plateau. These meadows account for about eight million hectares of available area in western Sichuan, or 62.28 per cent of the area's total rangelands. They are distributed between 2,800 and 4,700 metres and extend across the northern part of the Province through Hongyvan, Zoige, Aba, northern Zamtang, Serta, Serqu, Garze, and Litang counties.

This rangeland's sod layer is one of its most important characteristics. The tightness and thickness of sod layers only diverge with variations in hydro-thermal conditions from place to place. Generally speaking, the colder the climate, the tighter and thicker the sod layer becomes. In frigid climates, more biomass accumulate in the underground parts of plants than in the aerial parts, and the decomposition of organic matter is slower. In addition, high altitude, cold climates, long winters, short growing periods, and substantial day-night temperature differences give rise to apparent similarities between grass species and definite distribution laws.

Cold-tolerant and perennial plants are the primary flora, represented by *Kobresia,* which grow thickly in clumps and cover about 80-90 per cent of the high-frigid meadows. Secondly, creepers, such as *Potentilla,* grow in the form of lotus fruits such as *Polygonum* and *Primula*. Plants growing in clumps, such as *Festuca, Poa,* and *Elymus,* are the main dominators or companions of creepers. The proportions of these representative plants always change regularly and with variations in latitude and altitude. The more northern the latitude, the higher the altitude and the colder the climate, the more important *Kobresia* becomes. At lower altitudes with warmer, more southern climates, more *Graminae* grasses are found in the vegetation. The height and productivity are also negatively correlated with latitude and altitude. The further north the latitude and the higher the altitude, the lower the plant yield.

Since high-frigid meadows are distributed extensively across great vertical difference, the characteristics and properties vary. These regions were formerly divided into Alpine meadow and sub-Alpine meadow

Table 1: Classification of High-frigid Rangelands in Western Sichuan

Kinds	Sub-kinds	Groups	Types
High-frigid Meadow	Subalpine Meadow	Gramineal grasses on the plains	1. *Arundinella chenii* 2. *Elymus nutans, Roegneria nutans*
		Sedges on slopes	3. *Kobresia setchwanensis, K. Capillifolia*
		Forbs on plains or slopes	4. *Anemone rivularis, Potentilla answeina* 5. *Polygonum viviparum, P. Sphaerostachyum*
	Alpine Meadow	Gramineal grasses on the tops of hills	6. *Festuca ovina*
		Sedges on plains or ridges	7. *Kobresia pygmaea*
		Forbs on plains or slopes	8. *Spenceria ramalana* 9. *Anaphalis flavescens, Leontopodium longifolium*
	Moist Meadow	Sedges on low temperature lands	10. *Kobresia humilis, K. Tibetica* 11. *Carex spp., Deschampsia caespitosa*
Swamp Meadow		Sedge on accumulated	12. *Carex muliensis*
Alpine Shrub Meadow		Shrub meadows on shady slopes	13. *Salix ernestii* 14. *Sibiraea angustata, Dasiphora fruicosa* 15. *Leaflet Rhododendron* 16. *Caragana jubata, C. Erinacea*
		Shrub meadows on sunny slopes	17. *Quercus monimotricha* 18. *Sabina pingii var. Wilsonii*
Subalpine Woodland Meadow		Open woodland meadows on shady slopes	19. Fir, spruce, open woodland 20. Alpine Oak (*Quercus* spp) Woodland
		Open woodland meadow on sunny slopes	21. *Sabina* spp open woodland 22. Pinus *densata*, open woodland

Source: Wei and Dong, 1984

because they moved vertically across sub-frigid and cold-temperate zones.

In the sub-frigid plateau and Alpine areas at altitudes above 4,000 metres, the annual mean temperature is generally below 0°C; the mean temperature in January drops below - 10°C, while the mean temperature in July does not exceed 10°C, and grasses only grow 60-120 days of the year. There is never an absolutely frost-free season. The tight sod layer is 8-15cm thick and the vegetation cover is easily impacted by drought. Given these climatic conditions, the composition of plants is simple and the grass layer is tight and low. The main species of plants are varieties of *Kobresia*, such as *K. pygmaea, K setchwanensis, K capillifolia, K humilis,* and *K kansuensis. Polygonum* spp and some species of *Potentilla* are also included, as are species of *Carex, Festuca, Poa, Saussurea, Gentiana, Ranunculus,* etc.

Due to the heat deficit, grain crops cannot be grown in this area as it is always under stress from harmful frost and snow storms. Animal husbandry systems, particularly pastoral nomadism, meet the primary needs of the people of western Sichuan. Since solar radiation is strong and daily temperature range is great, the photosynthesis process is active and the ranges are highly productive. The utilization ratio, nutritive values, and palatibility remain high. This kind of rangeland is prime summer grazing land. It should be mentioned that this rangeland is extensive enough in many areas to be used as summer grazing pasture, but it can only be used for a short period of the year due to the harsh climate and inaccessibility.

In the cold-temperate zone between 3,000 and 4,000 metres, the annual mean temperature is 06°C; the mean temperature in January is -10°C, while the mean temperature in July can be as high as 12-15°C. Annual precipitation totals 600-700mm and the growing period lasts about 120-180 days. Due to these improved hydro-thermal conditions and rich organic matter in the soil, plants grow luxuriantly and grass cover is high. Different sub-layers of grass can be identified and species' composition is more complex. Besides *Cyperaceae*, which often dominates, more species are taking on a predominant role in plant communities. Grasses and forbs are also abundant, giving rise to apparent seasons and inspiring the name 'colourful meadow' to refer to these grasslands.

Rangelands in these lower regions are mainly used as grazing land in winter, but parts of some pastures are fenced off and the grass is later harvested and dried as hay to supply winter fodder. Since pastoralists spend up to six or seven months in these areas, and since these pastures are generally smaller than others, overstocking and degradation can be seen, despite the area's higher yields. The condition of these pastures, therefore, varies greatly.

Sub-Alpine Open-woodland Meadow

Sub-Alpine open-woodland meadow occurs in open, park-like stands in areas where forests are sparsely distributed such as the edge of forests, clear-cut plots, or the belt near the timberline. A woodland has a well-developed, dominant yet open tree layer with a canopy cover of less than 50 per cent. On average, less than one-third of the crown canopy is either distinct or touching, but crowns are predominantly not interlocking. Shrubs may be scattered in the undergrowth. The ground layer consists of grasses, herbs, and forbs and is well-developed but usually not very dense.

Sub-Alpine, open woodland meadows are always found at elevations between 3,000 and 4,200 metres and mainly occur on valley slopes, particularly the north-facing slopes of wide valleys. The major trees on the north-facing slopes or in the shady valleys are species of spruce and firs such as *Picea likiangensis, P. balfouriana, P. asperata, P. purpurea, P. wilsonfi, Abies fabri, A. faxoniana, A squamata,* and *A. georgei*. Some xerophilous species, such as *Sabina* spp and *Pinus densata*, are common on sunny slopes. Understorey shrubs are dominated by species of *Rosa, Rhododendron, Lonicera, Spiraea, Cotoneaster, Ribes*, etc. Grasses, such as species of *Elymus, Poa, Deyeuxia, Roegneria, Ptilagrostis*, and *Avena*, are relatively abundant and are commonly associated with different sedges and forbs.

These rangelands cover 1.13 million hectares of western Sichuan, comprising 8.1 per cent of the Province's total rangeland. Mean yield per hectare is less than 1,500 kg/ha, with grasses accounting for three to eight per cent of the yield, sedges cover six-10 per cent, while forbs are found on more than 80 per cent of the sub-alpine open woodland pastures. Legumes are rare and are always used as natural cutting pastures and grazing land in winter and spring. The belt near the timberline is used occasionally in summer and autumn when nomads alternate between seasonal pastures.

Shrub Meadow

Shrub vegetation is mainly distributed on south-facing slopes of mountainous areas or in plateau valleys, with a wide altitude range of from 2,500 - 4,500 metres. This range is analogous to the altitudinal range from the sub-Alpine conifer forest belt to the seasonal snowline. Shrubs cover between 30 and 80 per cent of these meadows, but if coverage exceeds 50 per cent, livestock have a difficult time grazing or browsing on these ranges. The area of this meadow covers 3.17 million hectares and accounts for about 24.9 per cent of the natural rangelands, with a mean forage yield of 2,250 - 3,750 kg/ha.

Major bushes include species of *Rhododendron*. These plants cover the north-facing slopes in large areas on the gentle plateau, but they are not of important grazing value. The herbaceous layer, on the other hand, is highly grazed. More than 65 per cent of this layer consists of edible forbs which are highly palatable and of high nutritional value. *Gramineae* and *Cyperaceae* grasses each account for about nine per cent of shrub meadows. This meadow is mainly used as summer-autumn pasture and natural cutting pasture; yet lower elevation meadows are also used as winter-spring pasture.

Swamp Meadow

Swamp meadows are distributed in certain areas on the Plateau such as depression areas, areas with poor drainage or seasonal water accumulation, swamp margins, the bottoms of wide valleys, and foothills with springs. Most of them occur within the Hongyuan and Zoige counties of Aba Prefecture, at elevations of about 3,400 metres. The soil layer is composed of peat-grey soil and peat soil.

They are not many species in this meadow and they are mainly composed of moist-eumesophytic plants and moist plants, as well as a few swamp and aquatic plants. *Kobresia tibetica, K humilis, Carex atrofusca, C. moorcroftii,* and *G. muliensis* dominate. These plant communities cover an average of about 60-85 per cent of the ground cover with a height of about 20cm. The fresh grass yield is about 5,000 kg/ha, of which sedge yields account for 60-90 per cent, grasses comprise three per cent, and forbs cover seven-16 per cent.

As the grasses on swamp meadows become green very early, these ecosystems are important spring ranges. However, many parasites live on the water and on the surface of the soil, which means that animals that graze on these areas run the risk of disease. Generally speaking, the utilization ratio of this kind of pasture is low. Water accumulates easily during the rainy season; these meadows can only be used on the edges during summer.

Characteristics of Rangeland Ecosystems in Western Sichuan

Floral Composition and Quality of Rangelands

Given the short history of the formation of the Tibetan Plateau and the harsh ecological conditions under which it evolved, the development of the flora in this region has been restricted. According to Liu (1991), there are about 350 species of plants in these rangelands. Among these, grasses are extremely abundant. According to amount, yield, palatability, and feed value, grasses and sedges are the dominant plants. Restricted by natural conditions, the high-frigid rangelands produce a high quality of grass but low yields. In order to improve the development of animal husbandry, an estimation of the amount of primary production alone is insufficient, as livestock consume only a portion of this biomass. Another important factor is forage quality.

Grasses not only include a great number of species but are also widely distributed over the vast natural rangelands. Most species of grasses are plants with high permissible off-take because of their root structure or inferior propagation and, in addition, because of their rich foliage and soft texture. In comparison with other herbaceous plants, the nutrient values of grasses are lower, but they are still the main forage for domesticated animals due to their abundance, high palatability, and convenience in processing, carrying, and storing. These grasses are very important for fattening animals during autumn. They are also cut and dried as supplementary forage. However, the rangelands encompassing these grasses are small and their yields are lower than pastures dominated by sedges and forbs.

Species of sedges are not as numerous as those of the grasses, but they are very important for natural rangelands, especially species with low temperature resistance. *Kobresia* and *Carex* predominate most high-frigid meadows. In Garze and Aba Prefectures, pastures have a predominant abundance of species of *Cyperaceae*. These plants comprise 68 and 71 per cent of the total rangeland area; they have a high nutrient value and are also highly palatable, particularly for yaks. The species of *Kobresia* contain 13.49 per cent crude protein on average higher than that of other species in this family. This characteristic of *Kobresia* makes up for the deficit of legumes in the high-frigid meadows. Sedges have some shortcomings, such as high silicon content, changeable yields due to seasonal alternation, and their short bodies, which lead to yield disadvantages.

Legumes are also found throughout various rangelands of western Sichuan, but they are not as numerous as grasses. Since they contain more protein, minerals (especially in calcium), and vitamins, they are still very important for the growth of livestock. The mean nutrient contents in legumes such as *Medicago, Vicia, Hedysarum,* and *Astragalus* are as follow: crude protein, 20 per cent (varies from 10-20%); crude fat, 3.1 per cent, and calcium, 1.51 per cent. Among these, crude protein is the most important nutrient in all herbaceous plants. Because of the limits of natural conditions, large-scale introduction of improved species of legumes is difficult in this region. Therefore, initiatives to breed local wild species should be implemented.

In addition to grasses, sedges, and legumes, other forbs also are numerous and are widely distributed throughout the region. Their yields rank first among other herbage (usually above 50%). Edible forbs comprise one half or one third of the total forbs, some of which are palatable for animals. Thir crude protein content is always higher than that of grasses and sedges.

Seasonal Availability of Rangelands

<u>Growing Phases of Plants</u>

Within a single growing season, grasses show a fairly consistent growth pattern. Initiation of growth is largely determined by temperature and, in most cases, growth does not commence until air temperatures reach about 6 °C (Briggs and Courtney 1985). While temperatures are above that level, the rate of growth is closely related to the input of solar radiation.

1) Germination or Regrowth

Perennial plants, such as *Kobresia,* begin to grow at the end of April or the beginning of May when the daily mean temperature is about 4 - 5 °C. During this period, because of the low temperature, plants grow slowly and production is also low. For grasses reproducing by seeds, the herbaceous stratum which develops during the growing season is determined by the amount and distribution of rain at the beginning of the season, taking into account substration and seed supply. It is obvious that rainfall influences the nature of a germination flush by determining the period of wetness of the substration. The longer this period, the higher the proportion of slow-germinating species in the vegetation. On the highlands, germination is not successfully completed until the seedling is well established.

2) Vegetative Growth

Once growth begins, it tends to be rapid. Daily dry matter pasture production increases to a peak within six to eight weeks. Thus, this phase of vegetative growth sees an increase in both the mean height of the pasture and in its density. The total biomass produced during the growing season is determined by growth factors in short supply. For natural rangelands, this is first, soil fertility, and, secondly, water and heat availability. Tillering ability and plant establishment play an important role in the plant coverage by various species.

3) Reproductive Growth

Throughout the phase of vegetative growth, flowering stems of plants remain short and close to the ground; but, during late spring and early summer, vegetative growth gives way to reproductive growth and flowering stems extend and ultimately produce a flower. The beginning of the flowering phase varies from plant to plant. According to observation in Zamtang County (Wu 1996), *Kobresia setchwanensis, K. pygmaea,* and *Leontopodium nanum* begin to flower as early as June. These plants not only regreen and flower quickly, but also bear fruit and become dormant rapidly. Plants that flower in the middle of July include *Carex sp, Potentilla anserina,* and *Oxytropis kansuensis*. Others, such as *Elymus nutans, Festuca ovina, Poa sp,* etc, flower as late as the middle of August.

Reproductive growth is important for two reasons. First, the beginning of this phase (flowering) is the moment when growth rate decreases. Thus, flowering dates determine growing period length and, consequently, biomass production and its quality (dilution of nitrogen). Second, reproductive growth is the basis for each species for the following season. During vegetative growth, there is competition among species for light, nutrient elements, and water.

4) Senescence and Dormant Period

As the season progresses, senescence increases. Stresses upon the plants become greater due to lower radiation inputs and reduced ambient temperature. Plants cease to be able to compete as successfully, and new tillers fail to mature. In high altitude areas, various underground parts and seeds of plants are always dormant. Seeds and dead residues of plants undergo several processes. These processes, along with previous plant activity, determine the development of the quantity and quality of forage with time, thereby affecting the next season's growth. In northwestern Sichuan, grasses begin to wither and then become dormant in early November, though this can vary with climatic conditions.

Seasonal Pastoralism

Vertical climate changes caused by topographic variation lead to the formation of different seasonal pastures and seasonal grazing cycles. This implies that the seasonal variation of forage supplements is not of an equal proportion and pastoralists have to migrate in order to adapt to these variations. Meanwhile, since different grazing animals demand different fodder and ecological environments (e.g., temperature, water source) at various seasons, grazing practices and pasture resources are also seasonal. As seasons change, livestock often have to cover great distances in search of food and water. This strategy usually promotes sustained-yield resource exploitation whenever land becomes scarce and, in particular, when seasonal grazing sites are inaccessible by any other means.

In western Sichuan, the start of nomadic migration corresponds to the growth of grasses. Spring grazing only begins after grasses have been sprouting for between 12-18 days and have reached a height of 5-10 cm. This corresponds to late April for most semi-nomadic mountainous areas, where altitudes range from 2,500 to 3,500 metres, and from late May to the beginning of June in nomadic areas above 3,500 metres. This commencement of growth is marked by grass tillering and forbs dividing. Grass palability and nutrient value are both high at this time. Stored nutrients exhausted by the sprouting of regressing grasses have already recovered; consequently, grazing activity does not impact grass regrowth.

The time of autumn grazing termination will impact the coming year's grass yield. If termination occurs too late, the plants' pre-winter nutrient storage will not be sufficient and production will decrease. Therefore, autumn grazing usually stops 30 days before grasses stop growing. Nomads always drive their herds down to winter pastures from the end of September to the middle of October.

However, natural conditions, such as location and altitude, can restrict and alter the length of sprouting and withering periods. In northwestern Sichuan, where rangelands are usually located above 3,300m, the growing period only lasts about 100 days and never exceeds 170 days. The dormant period, however, can last as long as 250-270 days. This discrepancy leads to fodder shortages and high mortality rates among domestic animals. In more southern, lower altitude rangelands, the growing period lasts about five months, from May to September. In general, as altitude increases, growing seasons decrease, dormant periods become longer, and the utilization value of pasture also decreases.

Features of Rangeland Ecosystems

Rangeland ecosystems include three main components: vegetation, soil, and livestock. Each of these components interacts closely with the others. Soil fertility, for example, partially controls grass growth and herbage production, which, in turn, affects animal behaviour and development. Animal behaviour, in turn, influences pasture and soil. These three components of the ecosystem as a whole are also connected to external socioeconomic systems.

Vegetation is a central component of rangeland ecosystems. It receives inputs of energy from solar radiation, water, and nutrients from the soil. Vegetation provides energy and nutrients to livestock and, through the return of plant residues and the penetration of roots, has a marked effect on soil conditions. It also acts as a buffer between grazing animals and soil, absorbing some of the physical damage of grazing by propagatively regenerating. Pastures are, likewise, influenced by animal behaviour such as trampling, selective defoliation, and the return of faeces to the soil. All these processes affect the rate of growth and competitiveness of herbaceous plants, and thereby influence pasture composition. These, in turn, control rangeland productivity.

Under the natural conditions of western Sichuan, yaks and sheep act as the main consumers of rangeland vegetation. Grazing must be considered a natural influence in rangeland ecosystems. Rangelands grazed lightly or moderately by these animals remain stable and productive. Moderate grazing can stimulate productivity, with production of above-ground parts increasing to twice the size of ungrazed areas (Wu 1996). Furthermore, there are indications that light or moderate grazing can maintain the balance between plant species for very long periods (Pearse 1970). Total protection, on the other hand, leads to stagnation of growth and more or less complete dominance of a few species. Species' diversity decreases and productivity drops sharply (Singh and Misra 1969).

Whittaker (1977) drew similar conclusions based on fieldwork conducted in Israel. He suggested that grazing stress can prevent competitive exclusion and further suggested that many of the diminutive annuals which contributed a large portion of the species' richness in his study area coexist by inhabiting different micro-sites in the rocky, shallow-soil hillsides. More importantly, vegetation can adjust to long periods of stress, both through immigration of new species and evolutionary changes in those present. Thus, grazing should have a detrimental effect on communities with little history of grazing, whereas grazing might well be required to maintain species' density in communities with a long history of pastoral behaviour. The so-called 'sustainable development in pastoral society' means a rational use of rangelands rather than absolute protection.

The complex relationship between grazing animals and plant communities has long been recognised by rangeland workers. In most experimental work involving herbivores, it is virtually impossible to control more than a few variables at any one time. Grazing has three main effects on vegetation: a) the sward is defoliated; b) nutrients in the form of dung and urine are returned or removed from the rangeland ecosystem; and c) the plant life suffers physical damage from trampling.

The management of rangelands, in most cases, represents a loss of matter — and therefore energy — to the system. Under conditions of dynamic equilibrium, energy removed from rangelands as fodder or livestock is balanced by energy put into the system in the form of solar radiation. In the absence of management, matter accumulates in the system and tussocks are often produced, particularly by certain plants such as species of *Kobresia* and *Carex*. Under these circumstances, the nature of available plant material in the system changes from predominantly fresh, living foliage to old, dead material. The animal community changes from one consisting mainly of primary consumers to one in which saprophagous, decomposer species predominate. Even so, animals are unable to decompose all the plant litter. Dead plant material accumulates as succession proceeds.

The aim of the pastoral herdsmen is to control all three components - by migration, changing grazing routes, regulating the duration herds stay in one place, determining grazing seasons, and by controlling livestock. Thus, herders regulate inputs and outputs within the system, as well as its internal structure. It should also be remembered that herders are affected by this system — not always directly but through the economic implications of rangeland productivity.

While a certain amount of rangeland production is needed to maintain equilibrium, overuse is detrimental. Although there are various degrees of overuse, and although factors such as timing and duration are important, the destructive effects of overuse have been noted worldwide. Degradation proceeds faster than regeneration (Behnke 1992). Species that germinate slowly have resistant seeds, which are always present. The seeds of rapidly germinating species are less resistant to grazing pressures; they may survive in a viable form in the soil for a year. Seeds produced by these former species one year will determine the population of the following year. It takes a long time to build up a population of rapidly germinating species. If degradation has been caused by overgrazing, the regeneration process will be protracted, since the soil surface has been destroyed (Fig. 1).

Potentials and Constraints of Rangeland Ecosystems

Rangelands are fragile ecosystems. The basis of appropriate management lies in not exploiting their potential in the short term beyond their capacity to recover. The demand for increased production has to be carefully weighed against the need for preservation and balance in the natural environment. Available fodder resources have to be evaluated so that estimates of production potentials can be made.

Rangeland Degradation

Degradation of rangeland due to overgrazing is manifest in almost all pastoral areas (Scholtz 1995). No areas are found in which the current plant growth might be considered climax composition. What has been done so far to discover major causes of degradation, ways of combatting it, and producing an understanding of traditional pastoral systems of livestock and range management? Stiles (1981) reviewed the position usually espoused by social scientists (anthropologists, geographers, development experts, etc) that degradation or even desertification is caused by many factors: natural disasters such as long-term climatic deterioration, restriction of natural pastoral movement patterns, and artificial concentrations of high-density populations resulting from the creation of permanent dwellings. This position maintains that, under natural conditions, traditional pastoral practices are the most effective methods of exploiting and conserving marginal resources.

This position has gained popularity worldwide since the 1980s. Yet this author is of the opinion that, given the complexity of pastoral ecosystems, the causes of degradation should not be given such a simplistic explanation. Ecological factors, such as long-term climatic deterioration, global climatic change, and ecological fragility, are internal causes of degradation; artificial factors, such as overexploitation of environ-

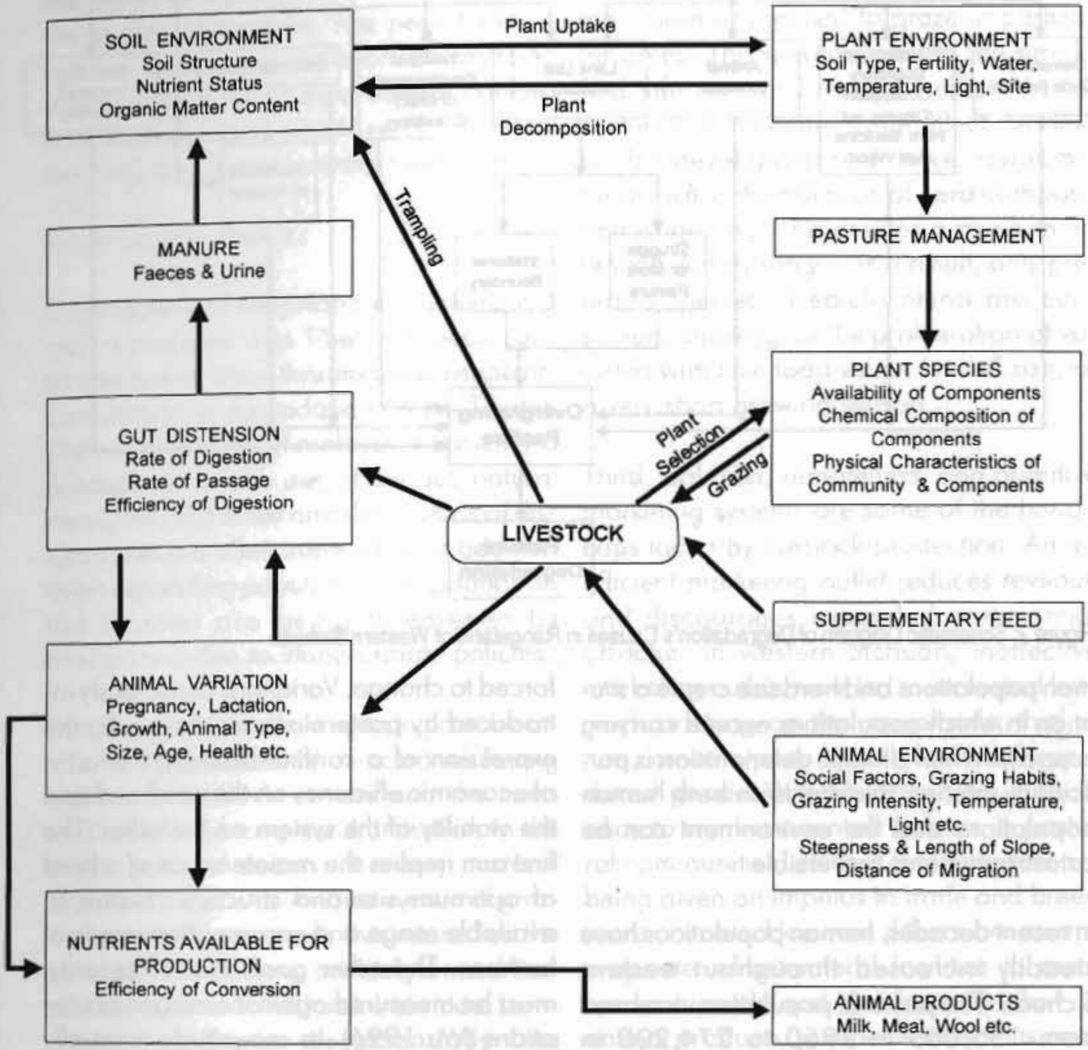

Figure 1: Schematic Complexity of Soil-Plant-Animal Relationships

mental resources by humans and their grazing animals, misjudgment of political decisions or economic policies, and so on, are external impetus for such depletion of grassland resources (Scholtz 1995; Wu 1996). To resolve this problem, data on the interrelationship of demographic, economic, and environmental change in relation to climatic change before and after the adoption of pastoralism as a subsistence base must be collected. It is not the author's intention, however, to give an overall explanation about the causes of degradation on rangelands. Such causes vary depending on location. Rather, this section has tried to simply outline and describe some forces affecting the study area (Fig. 2)

Pressures of Population

The principal causes of degradation derive from human beings' demands upon the environment that exceed the natural regenerative capacity of land. Increases in hu-

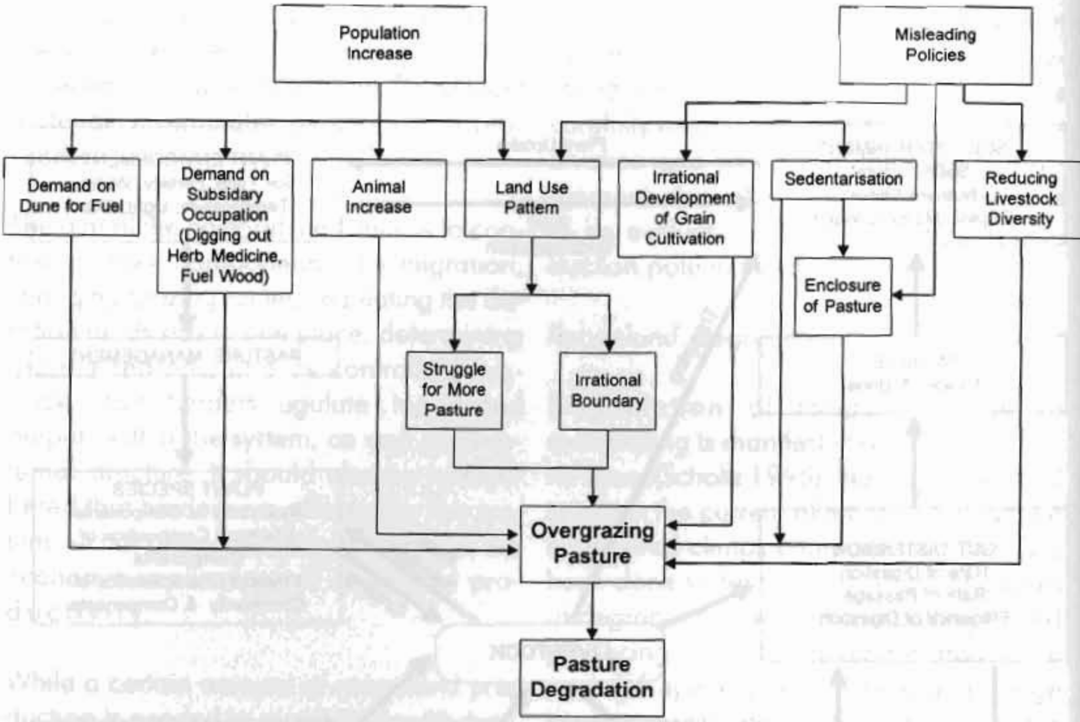

Figure 2: Schematic Diagram of Degradation's Causes in Rangeland of Western Sichuan

man populations and herd size create a situation in which populations exceed carrying capacity. When climatic deterioration is particularly intense, the effects on both human populations and the environment can be catastrophic and irreversible.

In recent decades, human populations have steadily increased throughout western Sichuan. The pastoral population increased from 155,085 in 1950 to 274,200 in 1990, an annual rise of 1.92 per cent. This indicates the population is no longer compatible with the land's capacity to support humans. In fact, most ranges that are used for extensive rearing of livestock already show many signs of degradation. In late autumn and early winter, rangelands are particularly denuded, giving forage grasses no chance to rehabilitate.

The availability of rangeland, together with the size of human populations, imposes limits within which livestock populations are forced to change. Variations consciously introduced by pastoralists are, as a rule, the expression of a conflict between the aims of economic efficiency on the one hand and the viability of the system on the other. The first aim implies the maintenance of a herd of optimum size and structure relative to available range and consumption needs of humans. The other goal, that of security, must be measured against emergency situations (Wu 1996). Its magnitude is usually based on vague empiricism, often revealing itself as a tendency to maximise animal populations.

Among pastoral nomads, the pattern which has emerged with modernisation is one of increasing pressure on pastures. As a result of successful attempts to reduce mortality rates, the human population is growing more quickly, as are livestock numbers. On the whole, efforts to increase the area of rangeland do not keep pace with changes in the two other variables.

Overgrazing in one area can be caused by an excessive density of livestock, which further leads to a progressive deterioration in the quality of pastures. This perpetuates a familiar cycle: accumulation of livestock; eventual decimation from natural causes; and accumulation which results in overstocking and, consequently, overgrazing.

Inappropriate Policies

Degradation of rangeland ecosystems is a global problem. The Tibetan Plateau constitutes one of these threatened ecosystems. Environmental degradation on the Tibetan Plateau and in the Himalayas is basically a product of human use of various natural resources. The scale and dimensions of disturbances are often irreversible. In addition to an expanding population, rangelands on the Plateau are being threatened by overgrazing due to inappropriate policies.

First, the problem of overgrazing can be attributed to a difference in incentives facing individual livestock owners and the costs and benefits of rangeland utilisation to the entire pastoral society. In many pastoral areas in China, a communal system of grazing is usually practised; this intensifies the contradiction between privately-owned livestock and communal land. Individual owners view pastures as essentially free comodities; if one person does not exploit the resource, then someone else will. This purportedly leads to a situation in which each herder maximises the number of animals grazed on the rangeland. Intense competition for the use of this scarce resource may ensue. This leads to deterioration and even rangeland destruction — consequences with many communal implications.

Second, many ecological changes occur in rangelands where extensive stock-rearing stems from low herd diversity. During periods of collective management, the composition of grazing animals was decided by the authorities concerned. Only certain animals were designated to graze in particular areas. This inevitably led to the simplified structure of livestock herds. Market preferences have the same effect, leading to the development of more economic herds, while the balance of herd composition is ignored. This creates a much more limited dietary range. As a result, only preferred species of edible plants are consumed, allowing for the proliferation of varieties with little food value, limited size, or a very short growing season.

Third, isolation, remoteness, and primitive marketing systems are some of the handicaps faced by livestock production. An inefficient marketing outlet reduces revenue and discourages expanded commercial off-take. In western Sichuan, ineffective marketing outlets have led to increased livestock stocking on the rangelands; this, in turn, creates price spirals for locally-produced goods. With changes from subsistence to market-oriented systems in pastoral communities, at least some herders are being given an impetus to trade and breed more animals. However, if there are no appropriate infrastructural facilities to meet herders' needs and distribute the flow of animal products, prospective benefits cannot be realised and overstocking is inevitable. This is the case in western Sichuan where the innovation of infrastructures has not yet been compatible with economic changes. Animal products have not become commodities; yet herders continue to increase herd size in the hope of benefiting from the sale of animal products. Without necessary infrastructure, however, pressure placed on grassland resources has intensified.

Finally, sedentarisation policies and initiatives aimed at enclosing large areas of rangeland have harmful effects on ecological conditions. Enclosed range areas, although their productive potentials are slightly higher than open range, are not immune to overgrazing. Stocking densities rarely match carrying capacity, but rather cater to the needs and demands of stock owners, and this often results in overstocking (Behnke, et al. 1993). Additionally, the changes from a long-ranging and highly mobile herding system to a short-range and sedentary or semi-sedentary one can have deleterious effects on range vegetation and soil. Grazing pressure on residual open range is increasing and migrations have to be rerouted. Some migration routes or water sources may be closed permanently, thus increasing pressure on others.

In addition to the factors mentioned above, it should be emphasised that there are also a number of other factors contributing to overstocking and degeneration of pastures, decline in livestock quality, and unstable productivity with poor economic returns. Yet these factors always exist in combination and affect the ecological situation of rangeland together. Under the *status quo* of rangeland management, productivity is decreasing, but excessive reclamation and grazing are continuing. In the mean time, numbers of grazing animals rise, but animal quality is not heeded. Thus, this problem of the relationship between livestock and forage is the basic contradiction of pastoral production in western Sichuan — a problem that is becoming more acute each year.

<u>Rangeland Ecosystems' Responses to Pressures</u>

Every ecosystem operates under the pressure of two kinds of factors, internal and external. Internal factors are due to the development of a plant community and associated changes in habitat conditions; external pressures are usually community-independent. Human population pressures are referred to as the anthropogenic factor and are also significant. The anthropogenic pressure acts as an internal factor when it predominates over a large landscape zone. This may be illustrated by pastoral ecosystems in which herding activities and exploitation are major agents in the system's economy.

High altitude rangeland ecosystems have developed in a climate displaying much seasonal variation. Therefore, fluctuations of a given environmental factor are much greater in an ecosystem associated with highland rather than lowland zones. Functioning under variable environmental conditions involves special ecological adaptations which permit ecosystems to survive through periods of strong pressure. Such adaptations are best known at the level of individual morphology and physiology. They are also found in the organization and management of ecosystems and are expressed both in terms of their structural properties and their response to environmental pressures.

Alongside the regular set of factors operating within a given geographical zone, there are also new agents which act upon ecosystems causing considerable deformations, both of the systems themselves and their surroundings. These agents will be referred to as *pressures*. It is not so easy to differentiate between pressures and normal environmental variations. It is assumed that pressures should be associated with the introduction of agents that have never before been encountered by ecosystems. Pressures cause so great a deformation of the requisites within an ecosystem that they begin to display a range of variations extending far beyond the regular limit. Anthropogenic pressure is a major type, affecting a system through a whole set of factors and fairly intense action. Thus, this pressure impedes the adaptive processes of the entire ecosystem.

To establish a new pattern of environmental relationships due to such a pressure usually entails a response of the ecosystem's components, i.e., rangeland, livestock, and pastoralists. This may evoke many concomitant reactions within a community, depending on the effect of a given pressure and a community's resistance to it. An obvious response is a change in the dominant structure of plant associations; species adjust to a new ecological situation resulting from different grazing pressures. Furthermore, community response also triggers ecological succession, thereby transforming the system so that it is better adapted to new environmental conditions.

Under strong pressure, some rangeland ecosystem components may be eliminated as a result of natural selection. Such pressures cause effective and directional natural selection in various species, producing changes in the genetic structure of populations. These phenomena have been found true of species on heavily overgrazed pastures. Changes in population structure are associated not only with diversity, but also with interspecific competition. Besides these changes in their genetic structure, populations display increased resistance to overstocked environments. The ways in which community organization respond to a given pressure must be determined. Its reaction to normal environmental factors chiefly consists of restructuring associations that compose different links of trophic chains. When pressures are strong, more profound changes in rangeland, in livestock, and in the related grazing system can be expected.

A plant community subject to heavy grazing pressure over a long period of time will undergo a process of change, eventually achieving a grazing climax which may be characterised as anti-pastoral. Plant adaptations to herbivores include escape in space and time as well as production of toxins, uncommon amino acids, and other digestibility-reducing substances (Nyerges 1979). Over time, dominant plant species will evolve toxicity specifically in response to new grazing pressure. In this case, toxicity is favoured in the plant community. Plant evolution occurs to such an extent that excessive foraging is prevented. Either plants and animals become closely co-adapted so that a sustained level of foraging is possible but overgrazing is prevented by toxicity or the relationship fluctuates in a cycle. At first, an increasing animal population overgrazes non-toxic species on the range until only toxic species remain. Animal starvation and poisoning ensue, causing a crash in the population of grazers. The eventual return of non-toxic species to the range follows.

The mediating role of stock in pastoralism depends largely on the evolved capacity of domesticated animals to forage successfully on available vegetation, which is generally scarce, of poor nutritive quality, and partly toxic. Thus, the capacity to forage must include adaptations to optimise nutrient intake and minimise or avoid consumption of toxins. Possible animal adaptations to plant poisons include detoxification of plant secondary compounds in the rumen and defensive foraging strategies essentially learned by individuals in infancy and specific to the local flora. In general, foraging by domesticated animals and control of foraging by humans are geared to optimise consumption; but these strategies must be understood in the context of plant adaptations to escape or minimise herbivore predation.

In addition, grazing impacts on the environment are strongly limited in space by the location of settlements and water sources. Grazing pressure approximates an inverse function of distance from the central water source or settlements. Vegetation response to grazing will, therefore, vary with distance from these sources, so that nearby vegetation is more strongly modified than vegetation further out. This is the reason why winter pastures experience uneven degradation. Optimisation strategies of rangeland ecosystem management are highly dependent on these factors. The study of pastoral ecology, therefore, becomes (at least partially) a study of spatial distribution and adaptive strategies adopted by pastoralists.

Perspectives and Conclusions

Rational utilisation of rangelands can retard degradation processes. Such rational utilisation of range could sustainably conserve rangeland resources. At the present stage of rangeland development, it is extremely necessary to collect more detailed regional and local information. This information base can serve as a starting point for detailed range management planning. The adaptation of animals to the natural environment and changes in seasonal fodder supply must be considered. Both of these factors may vary greatly within short distances as well as between different range or management units.

The aforementioned qualitative aspects of range utilisation should be taken into account for future development planning. The attraction of an increasing market economy has to be weighed against risks of land degradation. Today, systems of production in western Sichuan are more or less balanced; but ranges are already being used at close to their maximum intensity. These ecosystems are highly vulnerable. For this reason, rangelands should not be submitted to the uncontrolled and continually changing market interests arising from an increasing demand for animal products.

Rangeland developers should support the practice of mobility in traditional pastoral systems. As such, efforts to increase winter fodder resources should be encouraged, as this is the only way to use range resources adequately without immense financial investment. As a supporting measure, the re-establishment of degraded ranges and the establishment of protection areas for forage species should be prioritised.

At present, in pastoral areas of western Sichuan, the main development challenge is the articulation of a development strategy for nomadic areas that centres on rapid attainment of sustainability in all fields. Such a strategy must also consider regional, political, judicial, social, economic, and ecological circumstances. Pastoral economy or rangeland development cannot be treated as an isolated subject, but must be considered as an integrated part of a comprehensive regional development strategy based on basic needs and a 'self-help' philosophy.

It should be stressed that nomadism is the form of land use best adapted to these high-frigid ecosystems (Wu 1996). Various forms of nomadic living and economy, as described in the past, included - without question - optimal adaptation strategies. Furthermore, flexible, mobile stock- breeding based on the experiences of traditional nomadism and integrated into the entire regional economical, social, and ecologic system is the only way to use the poor and vast Tibetan Plateau adequately (Scholtz 1995).

The results of recent development trends cannot be clearly predicted. Nevertheless, a synthesis must be found between economic aspirations and environmental constraints. Traditions and new ideas have to be carefully combined to ensure the forther existence of rangeland production systems. In order to achieve all of these aims, projects should be comprehensive, employing experts from different disciplines. A component that solely addresses range conditions and the development of range resources should be considered imperative for projects dealing with rangelands. Both modern technical means as well as target groups' traditional knowledge should be considered basic to constructive development.

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