ABHANDLUNGEN - ANTHROPOGEOGRAPHIE
INSTITUT FÜR GEOGRAPHISCHE WISSENSCHAFTEN
FREIE UNIVERSITÄT BERLIN

BAND 55

WU NING

ECOLOGICAL SITUATION OF HIGH-FRIGID RANGELAND AND ITS SUSTAINABILITY

A Case Study on the Constraints and Approaches in Pastoral Western Sichuan/China

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PREFACE

The progressive degradation of many rangeland ecosystems, specially those of the Qinghai-Tibetan Plateau and the marginal areas around it, calls for thorough investigation if appropriate steps are to be taken to avert the catastrophes that ultimately threaten extensive areas on which pastoral nomads dependent. Of vital importance are studies of man-environment interaction that analyze the influence of pastoral economies on the different ecological zones.

Since the 1950s, all areas of the "Developing World" have experienced both a massive growth in human population and problems of resource use, economic and social pressures, and environmental degradation. The problems compound the fact that mismanagement at higher altitudes often impairs rich agricultural land below. Thus there is the urgent need for developing a fuller appreciation of the highland environment and its peoples, and for joining together all who depend on these lands for their livelihood, recreation, or scientific purposes; in short, all who rely on the high places of the World materially or spiritually.

The challenge to influence highland management by urging, and providing, a sound scientific base for decision making lies at the heart of our purpose – in seeking a better balance between environments, human welfare, and the development of resources. I hope that this study, can make a worthwhile start or at least a refocusing of concern and commitment. The damage already wrought may be irreversible and the onrush of population growth, deforestation, over-grazing, and sociological change beyond control. Yet there is widespread concern and a determined response. Many small pragmatic steps based on fuller understanding may reduce the present forces of degradation and, I hope, halt them altogether.

The preceding studies present a somewhat novel picture of the ecology of grazing systems on the Qinghai-Tibetan Plateau, and suggest a number of innovations in rangeland management. However, if the results of scientific research are to have any practical impact, they must be incorporated into government and donor development programs, and reflected in new policy objectives and implementation techniques. This integration between rangeland research and implementation was the focus of the author's deliberations.

The main theme of this dissertation is the ecological situation of rangelands and their development on the Qinghai-Tibetan Plateau, especially in the selected case studying area, western Sichuan. In terms of a wider approach some of the conclusions reached in this study may be applicable to other parts of the World, where similar conditions exist.

This paper is based on data collected during the summer of 1991 and the autumn and winter of 1992 in the nomadic area of western Sichuan. The fieldwork deals with pastoral nomads who have seldom been mentioned by western authors when researching the nomadism in Tibet or on the Plateau. Thus little fieldwork has yet been done. The main aim of this research project is to investigate the ecological situation of rangelands in relation to the socio-economic changes and pastoral development in recent decades, how nomadic people employ different strategies to different habitats, and how they or their governments react to the process of changes. This report is based on preliminary observations, and concentrates on the aspects of rangeland ecology in western Sichuan.

The joint expedition to the nomadic area, *Zamtang*, was organized by the Center for Development Studies (ZELF), Free University of Berlin (FU Berlin), and the Chengdu Institute of Biology (CIB), Chinese Academy of Science (CAS). In September 1990, Ms Angela Manderscheid, who brought a letter from Prof. Dr. Fred Scholz, visited Prof. Zhang Yong-di, former Director of the CIB and discussed whether it would be possible to conduct fieldwork in the nomadic area of western Sichuan. Following further talks after a pre-expedition to western Sichuan, the CIB and the ZELF signed an agreement, Prof. Dr. F. Scholz and the present Director, Prof. Liu Zhao-guang, representing both sides kindly assumed responsibility for the expedition. In the end of 1990, the CIB sent an official application to the CAS, requesting permission to carry out a Sino-German expedition to *Zamtang* County, a chosen area of study. Since the animal husbandry of nomads can hardly be studied without rangeland and its ecological background, the contents of the joint expedition included geography and biology. In the course of following discussions by letter the two institutes decided on the final route and schedule of the expedition, as well as the number of participants. The CIB assumed responsibility for organization and the German side formulated the scientific program of the expedition. After the *Volkswagen Stiftung* approved the financial application, all conditions were fulfilled.

The first expedition lasted 80 days, from 20 June to 30 August 1991. In spite of arduous conditions sometimes, we were fortunate that fieldwork proceeded more or less according to plan. After we finished the work in *Zamtang* County in August 5, we spent two weeks in *Hongyuan* County, another important pastoral county in western Sichuan, to compare pastoralism there.

To sum up the field material and study the detailed work, the participants of two institutes stayed in Berlin from November 1991 to June 1992, and made a plan for further fieldwork. The second expedition was conducted from 10 September to 4 November 1992. All of these works finally became the basis of my Ph D Dissertation. The following work is the result of two field compaigns and the study of literature and other documentation material in Berlin.

WU NING
BERLIN, December 1996

ACKNOWLEDGEMENTS

The successful completion of an empirical study of this nature was made possible by support from a number of individuals and institutions. In the first place, I would like to express my deepest gratitude and indebtedness to Prof. Dr. Fred Scholz, Centre for Development Studies (ZELF), Free University of Berlin, without his guidance and constant support, it would not have been possible for me to complete the work. Simultaneously, I would like to express my appreciation and thankfulness to all my colleagues and friends in this institute for their kind co-operation and support.

I am very much indebted to *Volkswagen Stiftung* for awarding me the scholarship to advance in my studies and for providing me with financial support to carry out the field investigation in China.

Without the sincere cooperation and help of several friends and colleagues at the Chengdu Institute of Biology (CIB), Chinese Academy of Science (CAS), it would have been difficult to carry out the field studies in western Sichuan. Among them, I wish to express my special thanks to Prof. Liu Zhao-guang, Director, Chengdu Institute of Biology, who offered me all necessary help during my studies. At the same time I would like to mention the name of Dr. Hu Xiao-hong, Dr. Chen Qing-hen, Dr. Qiu Fa-ying, Dr. Yin Kai-pu, Prof. Chen Ke-min, Prof. Yang Guang-hui and Prof. Wei Tai-chang, who helped me to identify the plant specimen collected from western Sichuan and provide enough information which are so useful for my research, and Mr. Qiao Yong-kang and Mr. Zhang Yu-cheng, who helped me so much in data analysis and computer's operation. In addition, specially cherishing the memory of Prof. Ni Bin-zhi must be expressed, who was an excellent expert in rangelands of western Sichuan, and who initiated the research in rangelands in western Sichuan in the 1960s and passed on so much his knowledge generously to me, but unfortunately died of a disease in 1992. I would particularly like to express my thanks to Mr. Chen Qian, who helped me sincerely and also devoted a lot of his time to help me in completing the drawings.

During my field investigation in the western Sichuan I received support and cooperation from several other friends. Among them I would particularly like to mention the name of Mr. Pu Xiang, Mr. Fong Bing and Mr. Gui Shi-hua for providing me with valuable information and help. Special thanks are due to the people in *Zamtang* for their cooperation during the interviews.

I am especially indebted to Dr. Jörg Janzen, who helped me sincerely and also devoted a lot of his valuable time to help me in completing the drawings and writings. I also express my deep gratitude to Dr. Franz-Volker Müller, Dr. Hans-Detlef Müller-Mahn, Dr. Hermann Kreutzmann, Dr. Marcus Nüsser and Mr. Daniel Winkler for their valuable suggestions as well as for plenty of help they have offered. I am most grateful to Ms. Angela Manderscheid for her assistance and suggestions both in China and in Germany. Particular thanks are specially due to Prof. Dr. Hartmut Ern for his generous help and suggestions in my writings and corrections.

Deepest gratitude must be expressed to my mother, Huang Guang-yu; my wife, Tian Min and my daughter, Wu Shuang for the encouragement and support they have offered throughout the whole period needed to accomplish this study. My father, Prof. Wu Wan-chen, read through my manuscript and gave me comments about the Tibetan history and English language as well. My younger brother, Wu Ping, also provided valuable material about the Tibetan history and the cultural development on the Qinghai-Tibet Plateau.

Last but not least, I am indebted to all my family members, friends and well wishers in Berlin as well as in Chengdu, who helped me directly or indirectly to complete my work.

WU NING
BERLIN, December 1996

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LIST OF ABBREVIATIONS

a.s.l	above sea level
CAS	Chinese Academy of Science (Academia Sinica)
CH	Chamaephytes
CIB	Chengdu Institute of Biology
DMI	Dry Matter Intake
DSE	Deutsche Stiftung für Internationale Entwicklung
FAO	Food and Agricultural Organization of the United Nations
FU Berlin	Freie Universität Berlin
GDP	Gross Domestic Product
GE	Geophytes
GIAS	Geography Institute of Academia Sinica
GOVA	Gross Output Value of Agriculture
GOVI	Gross Output Value of Industry
GOVIA	Gross Output Value of Industry and Agriculture
GTZ	Gesellschaft für Technische Zusammenarbeit GmbH
HE	Hemicryptophytes
HFM	High-Frigid Meadows
NFE	Nitrogen Free Extract
ICIMOD	International Center for Integrated Mountain Development
NGO	Non-Government Organization
POCC	Potential Carrying Capacity
PRCC	Practical Carrying Capacity
RRD	Regional Rural Development
RMB	Ren Min Bi (Chinese Currency)
SHM	Shrub Meadows
SU	Sheep Unit
SWM	Swamp Meadows
TAR	Tibet Autonomous Region
TH	Therophytes
THCC	Theoretical Carrying Capacity
TIST	Tibet Integrated Survey Team of Academia Sinica
UN, UNO	United Nations, United Nations Organization
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Program

UNESCO	United Nations Educational Scientific and Cultural Organization
WOM	Open-woodland Meadows
WIR	World Resource Institute
ZELF	Zentrum für Entwicklungsländer – Forschung

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ABSTRACT

Ecological Situation of High-frigid Rangeland and Its Sustainability - A Case Study on the Constraints and Approaches in Pastoral Western Sichuan (China) -

Since the early 1970s, the degradation of rangelands that affected the Old World Dry Belt, where pastoral nomads mainly distribute, and the large-scale impoverishment which affected millions of people, makes one aware of the possibility of such disasters elsewhere. It also highlights the most tragic aspects of the world ecological crisis and exposes our inability to prevent such situations from arising in the absence of adequate research and planning.

On the Qinghai-Tibetan Plateau, the ecological crisis appears in every physical and social aspect, and typically affects the rangelands on which most local people depend for their livelihood. Until today, however, changes in land use and vegetation cover on this Plateau have not yet been adequately and practically treated in studying the framework of sustainability.

Combined ecological and anthropo-geographical theories and methods, the following discussions are presented. This thesis deals first with the basic ecological influences and interactions before reviewing their implications for development. The limitations of an ecological perspective is recognized, but this stems mainly from the misapplication of perspective and should not detract from its value. Ecology is undoubtedly the most basic and pervasive of the many determinants of the pastoral production systems of the high-frigid land. To ignore ecology or to fail to take it into account is to court disaster. The amount of literature reflects the importance of the subject but is not reviewed here in any detail; rather the aim is simply to set the scene for later discussions.

<u>The Geography of the Study Area</u>: Western Sichuan is located on the eastern fringe of the Qinghai-Tibetan Plateau and fulfills the most important role in the connection between the Plateau and the hinterland of China economically and ecologically. Today it is at the transitional stage between a self-sufficient subsistence economy and a market economy. Economic progress has brought not only heavy pressures on the environment, but also great influence on the infrastructure and the daily life-style of the nomads. Meanwhile, the land-use system and the environment in the region, on the one hand, have become very fragile,

and on the other the degraded rangeland has become the barrier for local economic development.

Rangeland Resources : In western Sichuan there are 13.9 million hectares of rangeland, accounting to 59 percent of total land area, of which 12.18 million hectares are given over to available area. Consequently, pastoralism with its own unique identity becomes the representative economy on the Plateau. Here, altitude and temperature are the major factors that separate grazing lands from arable lands, and even differentiate seasonal pastures. This text mainly concentrates in the high-frigid ranges, such as high-frigid meadow, swamp meadow, alpine shrub meadow and subalpine woodland meadow, which is the main body to support the living-system of pastoralists in the study area and even on all of the eastern Qinghai-Tibetan Plateau. In addition, the floristic composition of high-frigid meadows, qualitative characters of natural pastures, ecological characteristics of the range ecosystem have been discussed, and the carrying capacity has been assessed.

Degradation of Rangelands: In the past 40 years, profound changes have taken place on the rangelands of the Qinghai-Tibetan plateau with implications for the future of the rangeland resources, the pastoralists, and their production systems. These changes include the modernization process itself which has brought improved access and services to previously remote nomad areas; the expansion of agriculture on the grasslands; the transformation of the traditional pastoral system in western Sichuan, first to collectivized agriculture and recently towards privatization under the "responsibility system" for land and livestock and general settlement of nomads with a corresponding reduction in the spatial mobility of livestock herds. These political, social, ecological, and economic transformations have altered previous stable relationships between pastoralism and the range environment, and eventually resulted in the rangelands falling into a state of social, economic, and environmental transition.

Changes in Utilization: Pastoralism on the Qinghai-Tibetan Plateau has evolved through long-term persistence under generally inhospitable conditions. Over the centuries, pastoralists have been successful in using multiple species and traditional rotational grazing systems to maintain the productivity of the range resources and to prevent overgrazing. Their goal – a common goal for all people – is to survive and pass on to the next generation their culture and social organization. No matter how changed historically the management system in the nomadic area, seasonal pastoralism still characterizes the highland animal husbandry up to now.

The seasonal changes of environmental conditions on the Plateau lead to seasonal changes of range features and eventually to seasonal pastoralism. The traditional strategies adopted by local nomads extend directly to the adaptation of these features. It should be appreciated that ecology both influences the occurrence or choice of the production system and the manner in which the system is managed. This is specially true of subsistence pastoralism, which is a response to environment and, in its execution, a living exercise in applied ecology. Through case studying, it could be learned that exploiting environmental heterogeneity could be thought of as the ecological reason for nomadic movement. Maintaining many stocks could be considered as an ecological strategy selected by nomads. Parallel to this, mixed herds, rather than herds of only one type of animal, also insure against cold failure. This also means a traditional way of keeping plant species diversity based on the maintenance of animal diversity. Furthermore, the survival today of nomadic pastoralism on the Plateau also provides proof of the rationality and efficiency of traditional Tibetan livestock production practices as a means of converting forage from cold, arid grasslands into useable animal products.

To prevent the degradation of rangeland, range managing techniques were introduced. But numerous demographic and economic changes of a long-term nature occur which trigger adaptive changes likely to transform the production system significantly. The most salient features are the emerging precedence of market-oriented production and modernization over the traditional subsistence production. This work has analyzed the positive and negative effects of modernized development within the area studied.

<u>Necessity of Sustainable Development</u>: The basis of the appropriate management of rangelands lies in not exploiting their use potential in the short term beyond their capacity to recover. The reasons for a range's degradation are population increase, inapproriate policies and man-made direct destruction. The degradation is inevitably expressed in different aspects, such as botanical characteristics of pasture, productivity of range and livestock, degenerated environments and low economic returns on pastoralism.

The rational utilization of range in a sense is an important agricultural measure, which could conserve the resource in a sustainable way. In order to meet the requirements of sustainability, this thesis has analyzed the indicators of unsustainability in the range ecosystem. Finally, in view of political, socio-economic and ecological sustainability, the constraints, potentials and approaches for pastoral development on the Plateau have been examined.

ZUSAMMENFASSUNG

Die Ökologie des hochalpinen Graslandes und seine Belastbarkeit - Eine Fallstudie über Probleme und Lösungsansätze in den Weidegebieten von Westsichuan (China)-

Als in den siebziger Jahren große Areale der natürlichen Weidegebiete v.a. in den afrikanischen und westasiatischen Teilen des altweltlichen Trockengürtels einer raschen Degradierung unterlagen, betraf das Millionen von Nomaden. Die Gefahr ähnlicher Katastrophen besteht auch andernorts. Neben der lokalen Verarmung gefährdet die Graslandzerstörung auch das globale ökologische Gleichgewicht.

Auch auf dem Qinghai-Tibet-Plateau gibt es Anzeichen von beginnender Graslandzerstörung, die Natur und Gesellschaft irreversibel aus dem Gleichgewicht zu bringen drohten. Allerdings wurden bisher die Wechselwirkungen zwischen Landnutzung und Vegetation im Hinblick auf die Belastbarkeit des Graslandes noch nicht genau untersucht.

Daher erfolgt mit ökologischen und anthropogeographischen Methoden eine Darstellung der Besonderheiten dieses Ökosystems. Weiterhin werden einige Ursachen und Folgen der Verschlechterung untersucht, der Wandel in Gesellschaft und Wirtschaft analysiert, sowie Vor- und Nachteile der traditionellen und modernen Bewirtschaftung diskutiert. Im letzten Teil werden einige mögliche Lösungswege für Westsichuan vorgestellt.

Inhalte der einzelnen Kapitel:

Nach einer <u>methodologischen Einleitung</u> (1) folgt die Darstellung der <u>Geographie</u> (2): Westsichuan bildet den östlichen Rand des Qinghai-Tibet-Plateaus. Es verbindet das Hochland ökologisch wie ökonomisch mit dem dicht bevölkerten chinesischen Hinterland. Heute wird die Selbstversorgungswirtschaft von der Marktwirtschaft verdrängt. Dieser wirtschaftliche Fortschritt beeinflusst aber nicht nur die Ökologie, sondern in sehr starkem Masse auch das tägliche Leben der Nomaden. Die mit den ökonomischen Veränderungen einhergehende Zerstörung von Grasland erschwert auch direkt die Bewirtschaftung.

<u>Weideressourcen</u> (3): In Westsichuan gibt es 13,9 Mill. ha Grasland (59% der Gesamtfläche), davon werden 12,18 Mill. ha als nutzbar klassifiziert, was 7,55 ha an nutzbarem Grasland pro Person entspricht. Es ist wenig verwunderlich, daß hier die

Weidewirtschaft dominiert. Die Einteilung in Weide- und Ackerland, ebenso wie die jahreszeitliche Nutzung, werden hauptsächlich von der Höhe und damit der Temperatur bestimmt. Es werden typische lokale Vegetationen wie die hochalpine Wiese, die Feuchtwiese, die alpine Buschwiese und die subalpine Waldweide vorgestellt. Erläutert werden jeweils die floristische Zusammensetzung, ihr Futterwert und andere ökologische Besonderheiten; das Kapitel endet mit einer Einschätzung der Belastungskapazität.

Degradation des Graslandes (4): Unter den einschneidenden Veränderungen, die in den letzten 40 Jahren für das Grasland und seine Bewohner eingetreten sind, dominieren die Modernisierung der Infrastrukur (z.B.: bessere Verkehrswege); die Propagierung des Ackerbaus; die Umwandlung der traditionellen Nomadengesellschaft zunächst in eine Form kollektivier Landwirtschaft und dann die Reprivatisierung unter dem "Haushaltsverantwortungsystem", wobei den Nomaden feste Weideflächen zugewiesen wurden, was zu einer geringen Bewegungsfreiheit für einzelne Herden geführt hat. Diese politische, gesellschaftliche, ökologische und wirtschaftliche Dynamik hat die einst stabilen Beziehungen zwischen Weidenutzung und -ressourcen verändert, so daß der Zustand der Grasländer jetzt diese gesellschaftliche, wirtschaftliche und ökologische Übergangsphase widerspiegelt.

Wandel der Nutzung (5): Die traditionelle Weidewirtschaft auf dem Qinghai-Tibet-Plateau hat sich unter extrem schwierigen Umweltbedingungen entwickelt. Jahrhundertelang haben die Viehhalter erfolgreich unterschiedliche Vieharten gehalten und verschiedene Weidewechselsysteme entwickelt, um Überweidung zu vermeiden. Ihr Ziel - wie für alle anderen Menschen auch – war es, zu überleben und ihre Kultur und Gesellschaft an die nächste Generation weiterzugeben. Ungeachtet der heutigen Veränderung des Weidemanagements besteht die Tradition und Notwendigkeit des jahreszeitlichen Weidewechsels fort.

Die Weiderotation spiegelt die klimatischen Veränderungen auf dem Plateau im jahreszeitlichen Rhythmus wider. Damit steht die Nomadenviehwirtschaft exemplarisch für den Einfluß der Ökologie auf ein Bewirtschaftungssystem. Besonders die Selbstversorgungsweidewirtschaft ist eine sehr direkte Antwort auf die Umweltbedingungen und kann als lebendiges Beispiel in angewandter Ökologie betrachtet werden. Fallstudien zeigen, daß die Nomaden wandern, um die Verschiedenheit der Umwelt zu nutzen. Außerdem beweist das Überleben der nomadischen Wirtschaft bis zum heutigen Tage, wie rationell und effizient die traditionelle tibetische Viehhaltung die Gräser der kalten und trockenen Grasländer in nutzbare Viehprodukte verwandelt.

Um der Graslandzerstörung entgegenzuwirken, wurden Weideverwaltungstechniken eingeführt. Allerdings fragt sich, ob diese Produktionsweisen den zahlreichen langfristigen demographischen und ökonomischen Veränderungen gewachsen sind. Die deutlichsten Trends sind die beginnende Dominanz der Marktwirtschaft und der zunehmende Anteil moderner Produktionsweisen (bei zurückgehender Selbstversorgungswirtschaft). Am Beispiel des Fallstudiengebietes untersucht diese Arbeit Vor- und Nachteile der Modernisierung.

Die Notwendigkeit verträglicher Entwicklung (6): Die Grundlage adäquater Weidenutzung ist sicherlich nicht allein der kurzfristige Nutzen. Die Gründe für die Weidezerstörung sind anthropogen: sie liegen im Bevölkerungswachstum, in irreführenden Entwicklungsstrategien und direkter Zerstörung. Das Scheitern allzu ausbeuterischer Strategien schlägt sich in der veränderten botanischen Weidezusammensetzung, der niedrigen Produktivität von Weide und Vieh, degenerierter Umwelt und geringen Erträgen für die Wirtschaftenden nieder.

Ein vernünftiges Weidemanagement stellt eine Maßnahme dar, mit der die Resourcen umweltverträglich bewahrt werden können. Um Grundlagen für ein solches Konzept zu schaffen, hat der Autor die Anzeichen der Unverträglichkeit untersucht. Zuletzt werden im Hinblick auf die politische, gesellschaftliche und ökologische Verträglichkeit die limitierenden Faktoren und Potentiale für eine Weidewirtschaftsentwicklung auf dem Plateau untersucht.

1. INTRODUCTION

1.1 Problem Identification

In the decades ahead, every effort will be made to redress the current alarming trend toward world instability stemming from the convergence of the natural resources crisis – the crisis of needs – on the one hand, and the ecological crisis – the crisis of behavior results – on the other.

For rangeland resources, the base of pastoralism, the crisis is worldwide (SCHOLZ, 1991;1995). In global development of nations and of people, livestock-dependent peoples everywhere are losing ground. For some decades, development planners, academics, and pastoralists have tried to bolster, modernize, or fundamentally transform the pastoral way of life with diverse motives and aims. Individual pastoralists have sought to cope with pressures by such adaptive mechanisms as labor migration, the increase of herd sizes, the diversification of craft production, or the pursuit of education. Large sectors even entire pastoral societies have been involved in planned development programs and projects coordinated by national governments, with the collaboration of administrators, planners, technicians, and extension officers. Consequently, the crisis derives inevitably from the unsustainable "modernization"[1], such as the simultaneous increase of pressures to absorb pastoralists into the non-pastoral economy (through settlement programs, wage policies favoring migrant labor, forced commercialization, a relative drop of the value of pastoral products, and the like), and of measures that directly deprive pastoralists of their former share of economic and political life (by the expansion of farming, destocking programs, and the destruction of traditional systems of land tenure). The result of these powerful forces is that pastoralism is increasingly being relegated to people too old to change, too poor in alternative skills to leave, or too far away from centers of power for anyone to care, as states by SCHOLZ:

> "*The land development plans of the various states show that the concepts deal with the settled population only. The mostly peripheral regions formerly frequented by nomads are no longer considered as economically important. ... Apart from a few specific measures, the vast areas are not taken into consideration.*" (1991:79)

[1] "Modernization" is the process of becoming modern, which refers to the overall process of social change that accompanies economic development (LARKIN, R.P. and G.L. PETERS, 1983). Here it implies the process of westernization.

Generally speaking, the major problem confronting pastoral peoples does not require emphasis: It is environmental degradation and, in its final stages, desertification. Of these degradations, the topic of rangeland degradation, particularly under the utilization of nomadism in the Third World[2] countries, has gained the special attention of researchers. This has led contemporary researchers to examine its exact nature, its significance in nomadic life-style and its interrelation with the "development process". This problem has been dealt with at length elsewhere. However, two main questions related to this problem have not yet to be satisfactorily answered. They are: 1) What are the causes of degradation? and 2) How can the process be halted and even reversed? Degradation, if it is allowed to continue, will result in the destruction of many pastoral societies and in the disappearance of this mode of production in environmentally marginal areas of the world. To be more precise, the emphasis on rangeland degradation may be attributed to the following facts:

- During the last few decades the Third World countries have been faced with the problem of a large increase of population in pastoral areas.
- Amongst other factors, "modernization" in the pastoral sector encouraged by governments, including the improvement of health facilities and infrastructure, has been contributing substantially to the growth of population and decline of nomadism.
- With the decrease of pastoral mobility, the insecurity of rangeland tenure, and the overstock of grazing animals, rangeland degradation has played a very decisive role in the socio-economic changes.
- It has been shown repeatedly that a comprehensive framework for analysis is lacking despite the growing body of literature on rangeland ecology and nomadic anthropology.
- The complex nature of the interrelationship between rangeland degradation and sustainable development in pastoral area has not yet been sufficiently identified.

Since the early 1970s, the degradation of rangelands that affected the Old World Dry Belt[3], where the pastoral nomads are mainly distributed, and the large-scale impoverishment which struck millions of people, makes one aware of the possibility of such disasters elsewhere (FRANTZ, 1978; CRONZE and GWYNNE 1981; and MARK, 1978). It also highlights the most tragic aspects of the world ecological crisis and exposes our inability to prevent such situations from arising in the absence of adequate researching.

It is a sign of the frustration of all who witness the plight of the pastoralists, that social scientists, livestock specialists, planners, and development bureaucrats have, within the last

[2] "Third World" refers to the poor countries of Asia, Africa and Latin America with low per capita income, which is employed in general sense and no strict index of per-capita income has been fixed.

[3] The term "Old World Dry Belt" is used for the huge arid and semi-arid zone stretching from the Atlantic Ocean in the west to the eastern border of Mongolia in the east.

two decades, begun to come together to search collaboratively for solutions to the profound problems that have eluded all their individual disciplines. The failure of traditional economic theory and policy to prevent or to solve environmental degradation led to the appearance of a "doomsday view" of the environmental problem. Zero (or even negative) growth was advocated to avoid the disastrous consequences of transgressing the physical limits of resources. Another pessimistic "conservationist" view focused on the preservation of ecosystems to the neglect of socio-economic conditions and consequences. These policies could not be accepted by countries or regions that were still in the early stages of socio-economic development.

Today, anthropo-geographers stress the rationality of local-level systems of livestock production and the links between the local-level processes and larger regional, national, and even international contexts (ZESSIN and FARAH, 1993; SCHOLZ, 1995). Rather than being seen as an irrational religious commitment, "pastoral culture" has been viewed as a set of symbolic and ideological assertions about the economic, political, and ecological processes in which pastoralists are rationally engaged. The emerging paradigm emphasizes the study of the degrees of relative autonomy and systematic links between the various levels, from micro to macro. It views the pastoralist as one who interacts not only with familiar objects of the pastoral neighborhood but with a range of institutions, influences, and offices that derive from regional, national, or international sources. In short, this perspective has opened the way for anthropo-geographers to look upward and outward from the local system they knew so intimately, in an attempt to understand the pastoral point of view of the world. Increasingly, this "view from below" sees that development programs, projects, planners, and practitioners are an inevitable part of the pastoral equation, as are regional markets, national governments, and international commodity markets – that is, part of the total set of factors "out there" to which pastoralists must respond (SCHOLZ, 1991; JANZEN, 1995).

The relationship between ecology and economy is of great theoretical important in an understanding of environment and development in pastoral societies. Yet, as illustrated by CROZE and GWYNNE (1981), it is difficult to reconcile the approach of the biological ecologist, which focuses on environmental constraints, with that the economic and ecological anthropologist, which focuses on individual human activities and motivations. However, as an outgrowth of recent developments in evolutionary and ecological theory, ecologists are increasingly recognizing that, to understand the ecology of a species, it is not enough to determine the distribution and abundance of aggregate populations in space and time. The behavior of groups is the result of the sum of individual actions based on individual decisions. The interests of each individual are different.

The great arid belt of the Old World, from the Atlantic shores of the Sahara to steppes of Mongolia, has been occupied by oasis farmers and pastoral nomads for at least 3,000 years (GRIGG, 1974), and pastoral nomads still occupy very large parts of the Old World Dry Belt, amounting to about 13 million square kilometers of the earth's surface, nearly twice the world's cultivated area (SCHOLZ, 1991) (Fig. 1.1).

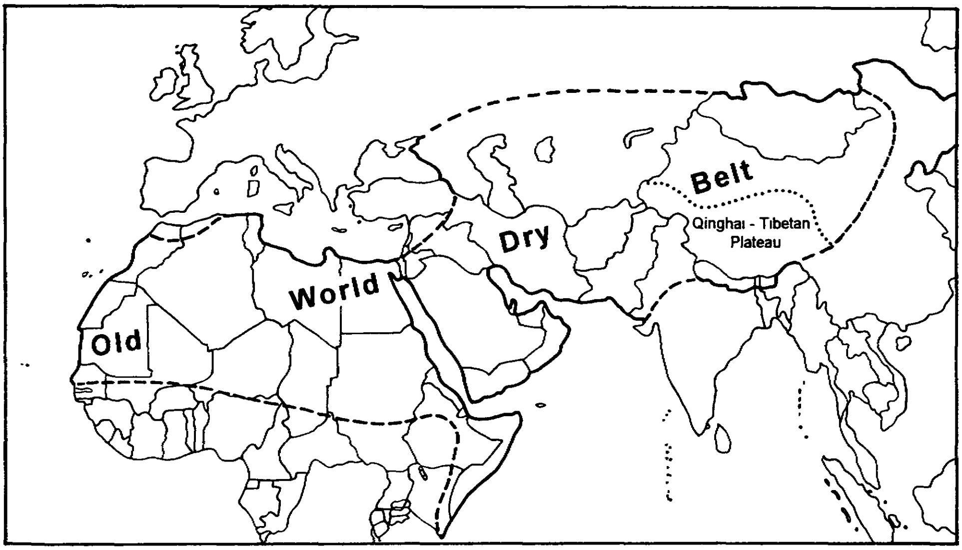

Fig. 1.1 Distribution of Nomadism in the World
Source: SCHOLZ, 1992

In additions, the ecological crisis of rangeland occurs in another geographical scale, – highlands – ,which including high mountains and plateaus. These are environments of special concern because of our demonstrated inability to ensure a better balance between potentially unstable ecosystems, development of their resources, and the welfare of their peoples. In line with the definition given by MANI (1980), the highland means areas with the altitude above 3,000 m a.s.l. He further point out:

> "*...a high altitude region, which is basically an area of relatively low atmospheric pressure. The reduced atmospheric pressure of high altitude is associated with atmospheric cold and aridity, deficiency of oxygen and carbon dioxide, intense insulation and rapid radiation, high ultraviolet and other effects as chain reactions.*" (MANI, 1980:1)

These effects become significant and the general environment, vegetation and animal life become markedly different from those of lowland areas. In addition, not only will highlands be among the first casualties of the requirement-behavior result nexus, but this in turn will exacerbate the already formidable problems of the neighboring, heavily populated lowlands through downstream effects. Inappropriate use of lands on highlands, including agrarian and grazing lands, will produce enormous environmental losses difficult to reverse and will have cultural, social, economic, and physical costs reaching far beyond their points of origin.

The Qinghai-Tibetan Plateau fortunately locates in both geographical scales, with the famous name, "Roof of the World", and the easternmost living space of pastoral nomads in the same latitude. The crisis appears in every physical and social aspect, typically reflected in rangelands on which most local people depend for their livelihood. Because of these attributes, many scientists were attracted to the multi-disciplinary problems of the Plateau, such as GOLDSTEIN and BEALL (1990) on nomadism, CLARKE (1987) and GOLDSTEIN (1991) on pastoral development, MILLER (1995) and Chinese scientists on rangeland resources (e.g., the publication of "The Exploitation and Utilization of Rangeland Resources in Northwestern Sichuan" in 1984, "Rangelands in Xizang" in 1992 and "Rangeland Resources in Xizang Autonomous Region" in 1994).

Pastoralism, the representative economy on the Plateau, is an economic activity in which man and the herds of domesticated animals live in a symbiotic relationship. However, what was always neglected by people in this relationship is the "bridge", rangeland, which connects two sides, man and animal, in a complete ecosystem.

> "*The present range situation could be compared to a house were the ground floor is represented by grass, the first floor by animals, the second by people. Only the first and second floors are catered for but the ground is neglected with the result that the house crumbles.*" (FAO, 1991:3)

It is a matter of fact that man-made changes in land-use and vegetation cover are major driving forces of environmental change. Consequently, in the period before the 1980s

"development" of pastoralism and "conservation" of rangeland resources became the subject of a contradiction. Only for last two decades has there been a slow but sure marshaling of concern over both developments and its ecological effects.
For thousands of years, the hardy pastoralists on the Qinghai-Tibetan Plateau (mainly Tibetan pastoralists) have been immensely successful not only in utilizing the vast ranges and pastures but also in conserving the grazing capacity of these high-frigid lands. The pastoral communities evolved a system employing migratory, semi-sedentary and deferred grazing practices to produce ample quantities of milk, meat, fiber and leather for their own families and for sale in the form of live animals, dried meat, cheese and handicrafts. The communal discipline demanded by the system was established through strict adherence to a set of traditions and values. (QURESHI, 1991)

Nomadic yak breeding sprang up on the Qinghai-Tibetan Plateau as a result of the adaptation of the communities with an economy producing specific ecological niches created by the simultaneous effects of various natural geographic, socio-economic, and historical factors. As an economic, cultural, and social phenomenon, it can only arise on the basis of certain conditions, such as an appropriate environment; a species structure of the livestock best adapted to the conditions of a given region; a certain degree of property differentiation involving private yak ownership; and an opportunity for the division of labor.

Irrespective of their long-term consequences, significant socio-economic and environmental changes are currently taking place throughout the entire pastoral area of the Qinghai-Tibetan Plateau, as well as throughout other nomadic areas reaching even the remotest areas. These changes have come about because of a number of different factors, for example, the penetration of market forces, innovations by nomads, and development programs launched by local, national, and international agencies. In China, the experiences in the nomadic areas of western Sichuan, Qinghai and Tibet clearly suggest that efforts to develop high-frigid pastoralism have been very limited. In addition to the physical difficulties already encountered by nomads, a variety of inappropriate development policies adversely affected pastoral areas. Prior to 1978 a general insensitivity of development strategies affected the needs and limitations of nomads and plateau environment. In spite of major achievements in capital construction, improvement in rural services, and enhanced equity following the revolution, the collectivization of communes reduced the incentives for livestock breeders to manage pastoral resources and the environment. Moreover, restriction on "subsidiary activities" (e.g., non-grazing and non-crop farm activities) and insistence on local-level food self-sufficiency reduced the scope for harnessing unique and diversified opportunities offered by the pastoral areas.

"Important social and economic reforms towards decollectivisation have taken place in China since 1978, with the introduction of what is generally referred to as the 'household contract', or the 'responsibility' system. Under these in effect a degree of property rights accrues to the household if not the individual, and open-market trade is under certain circumstances encouraged. In principle these changes are a step in a delinkage of the administration from production and consumption, with a corresponding shift from direct towards indirect controls in planning." (CLARKE, 1987:1)

The reforms in 1977 introduced the "Responsibility System"[4] that restored many of the incentives for herdsmen to increase pastoral output and productivity. However, in some areas the focus on private incentives has also encouraged degradation of rangelands. The immediate causes are: 1) reduced concern for collective management of assets such as pasture, and 2) the over-enthusiasm of herdsmen for increasing their incomes which also tend to increase resource extraction without corresponding conservation measures.

Based on the above statements, one can imagine that apart from influence of the harsh environments, the ecological situation of rangeland is mainly affected by the policies, i.e., the main causes of degradation are anthropological or sociological, but its appearances are ecological. Unfortunately such an important issue has remained neglected in China. With a few exceptions, published works on rangeland degradation and its conservation have seldom been studied in a comprehensive framework combined with natural and social science. Further, indigenous knowledge of nomads is negligible. The literature of rangeland degradation on the Qinghai-Tibetan Plateau reveal clearly that most of the studies have been done to analyze roughly range vegetation only from biological or physio-geographical view-points without giving sufficient emphasis to the complex interrelationship of degradation and pastoral development

[4] The full designation of "Responsibility System" is "The Contract Responsibility System of Socialist Collective Agriculture". It is a new concept of management that has evolved with the development of Socialist collective ownership and cooperative agriculture in China. A definition of the "Responsibility System" might be that it is a contract system that stimulates productive labour and agricultural management within the collectives. Within this contract system all items of agreement, responsibility, duty, benefits, and rights have to be clearly defined. The main concepts including: 1) Public ownership of land. The public ownership of land (e.g., rangeland in pastoral area) is the basic foundation of cooperative agriculture and collective ownership and is also a prerequisite for the System; 2) Agricultural producers' cooperatives. The cooperatives, on the one hand, and production teams and households on the other consititute the parties in the contract relationship. 3) Collective ownership of land. Land is owned collectively and the production inputs distributed among the households. Households are given State purchase quotas to fulfill and pay agricultural taxes (At present, in Tibetan pastoral area pastoralists do not need to fulfill the quotas and pay taxes.) 4) Household contracts. Households are given land on contract (In western Sichuan pasturelands are not distributed on contract, which still are kept in the Collective.), as well as other specialized inputs or machinery. Part of their produce is turned over to the Collective.

Much current academic and political interest from the international society has focused on processes of environmental degradation and rural development on the Qinghai-Tibetan Plateau or in the Himalayas, which can be exemplified by the publication of "The Himalayan Dilemma: reconciling development and conservation" in 1989 and "Himalayan Environment Pressure – Problems – Processes" in 1993. These works constitute a turning point in scientific consideration with highlands pointing out new ways of looking at problems, or new areas of research. Expanding upon these approaches, it is suggested that greater attention should be paid to the people involved and to their impact on the natural and socio-cultural environment: this appears to be an indispensable condition for the formulation of catalogues of measures of relevance to development for schemes of rural regional development in this area.

> "*The unanimously approved resolution stressed two points: first, that it is necessary to deepen and expand the knowledge of ecological and economic processes which are taking place in high mountains in order to arrive at a more exact understanding of environmental and marginal conditions affecting lasting development measures; secondly, that there is a need for actively promoting integrated regional development and the dissemination of alternative models for survival in high mountains.*" (KREUTZMANN, 1993: 39-40)

Traditionally, the degradation in rangelands is generally interpreted as the result of mismanagement of livestock and vegetation resources by traditional pastoralists in a spiral of overuse (overgrazing) leading to lower productivity, leading in turn to further overuse. Development programs typically respond to these problems by attempting to institute radical management changes, including curing livestock diseases, introducing domesticated animals, replanting ranges, sedentarizing nomads, and introducing new techniques of animal husbandry and veterinary care.

However, experience in last three decades showed that the inappropriate projects have run into problems and brought disappointments, and, in some cases, may have been the causes of deterioration on the Qinghai-Tibetan Plateau. For example, it is always ignored by man that the process of introducing domesticated animals to rangeland, whether rapid or gradual, constituted an invasion with major consequences for the ecosystem, including vegetation change and possible deterioration. In western Sichuan about 20 varieties of cattle of good quality were introduced from other regions or countries in last forty years for grazing on high-frigid rangelands or for crossbreeding with yak (ZHOU, 1982), but the results have been always disappointing. Even if the crossbreeding was successful, the crossbreed always displayed worse than yak in the present grazing system of the Plateau. One of the reasons is that, where regular grazing was eventually instituted around villages or along nomad migration routes, ramifying adaptive and coadaptive responses on the part of surviving species in the ecosystem would have emerged in time and continued developing in most areas to the present where they are still maintained by traditional systems of management.

Furthermore, to meet a rapid rise in demand for additional livestock products, in 1985 alone governments invested 21.35 million Yuan (RMB)[5] in attempts to improve pastoral systems in western Sichuan, among which 13.53 million Yuan came from the state government. After that, the yearly increasing rate of investment from governments is about 6% (LIU, 1991). Despite this large input, those results have in general been disappointing, largely due to an inadequate knowledge base on which development interventions were designed. For example, the rush to relieve or prevent death in spring among livestock led to attempts to transfer animal production technology without suitable pre-testing. Unless more linkages are established between biological and social changes in human welfare on the Plateau in the near future, there is a strong possibility that supports for livestock programs will wane.

Causally, in most cases development strategies for high-frigid pastoralism are simply extensions of generalized approaches that have been designed for non-plateau areas. This is so whether one looks at resource allocation and investment priorities, choice of technological and institutional measures, or inter-sectoral linkages and marketing. Thus, development efforts on the plateau area usually lack the plateau perspective.

Considering the researching work in Africa, BAKER (1975) argues that recent drought in Africa had disastrous consequences because uninformed manipulation of nomad societies (e.g., forced sedentarization) by colonial and national administrators had resulted in unpredicted and ramifying changes in the ecology of the rangelands. NYERGES also pointed out:

> "*Then, through not understanding that deterioration was largely the result of external changes rather than patterns of traditional management, development planners succeeded only in bringing about modifications that contributed to further destructive overstocking and overgrazing.*" (1979:1)

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[5] RMB is the abbreviation for "*Ren-min-bi*", which means people's currency. In June of 1995 its exchange rates are: 1) 1US$ = 8.37 Yuan (RMB); 2) 1DM = 5.87 Yuan (RMB).

In retrospect, massive intervention schemes based on the transfer of technology and the principles of range management suitable for ranching in the American West and Australia may not provide optimal solutions to the problems of African and Asian pastoralism, largely because of the significantly different ecological and cultural histories of Western and Eastern rangeland ecosystems. Rangelands in America and Australia have been ranched by capitalist entrepreneurs for a few hundred years at most, but traditional pastoralism constitutes an ancient subsistence adaptation to arid zones of Africa and Asia. Components of ecosystems under traditional management, including range vegetation, domesticated animals and human societies, have been subject to selective pressures and adaptive processes brought on by pastoral systems of production over substantial, if varying, periods of time. Therefore, ecological characteristics of organisms in these rangelands are the result of long-term and complex interactions among and within species and between species and the inorganic environment. Evolutionary processes and indigenous systems of knowledge are typically ignored in development projects. Yet the best solutions to the current problems of pastoralism may involve readjusting systems in conformity with patterns which have already proven to be adaptive.

Regarding the sustainable development perspective, the following may be noted. Notwithstanding the sectoral programs (directed at soil conservation, replanting pasture, and pastoral production), sustainable development, implying explicit concern for the long-term consequences of present-day development interventions, has not received sufficient attention. Consequently, development programs and policies in several parts of the Qinghai-Tibetan Plateau or all of the Himalayan region have continued on an ad hoc basis and have been short-term in their focus, resource extractive in nature, sectoral in orientation, and replicative of external development designs and experiences that are often untested and unsuited to the plateau situation. However, within this overall scenario there have been some exceptions where programs and policies, consciously or unconsciously, have been in keeping with specific local circumstances. The result, in such cases, has been developed either without degradation of range resources or with arrest of resource degradation processes.

Consequently, there are at least two basic dimensions to the knowledge of sustainable pastoralism. The first dimension relates to the perspectives, i.e., the understanding and incorporation of sustainbility as a policy and program goal. The second dimension relates actual decisions or actions in the pastoral sectors and their implications for the long-term sustainability of high-frigid pastoralism. (JOHDA et al., 1992)

The result of the degrading trend is seen today in the form of extremely degraded grazing areas, some of them irreversibly damaged and desertified. However, the vast rangelands of the region constitute a major land resource which must be utilized, and utilized in a sustainable manner. For this purpose, the dynamics of the pastoral ecosystem must be well understood and the development programs must be based on this understanding. Moreover, it is important to understand how categories of socio-economic driving forces, such as population growth, governance structures, level of economic development, trading associations, policies and the grazing behavior, have contributed or will potentially contribute to rangeland change. A focused effort on the degraded status and the sustainable development linking the socio-economic causes of environmental change with the natural science understanding in the rangelands of the Qinghai-Tibetan Plateau is urgently needed. The questions to which have to be given answers are:

- What characteristics of rangeland ecosystem in the Plateau can be described?
- What kind of degradation of the rangeland in the research area can be stated?
- What are the reasons for the environmental damage?
- In how far are changes in the land use practices of the rural population responsible for the deterioration?
- What kind of measures have been taken so far by the people and the government? and
- What sort of approaches is required in order to stop environmental damage and reach a sustainable development for the Plateau?

The challenge to influence rangeland management by urging, and providing, a sound scientific base for decision making lies at the heart of our purpose – to seek a better balance between environments, human welfare, and development of resources. I hope that this work, can make a worthwhile beginning or at least a refocusing of concern and commitment.

1.2 Selection of the Study Area

China is the third largest country in the world, with a land area of 9.6 million km², and located in the eastern continent of Eurasia, bordering the Pacific Ocean. Owing to its extending over 49°6' of latitude (from 4°5'N to 53°1'N), China thus lies mainly in the subtropical and temperate zones. With the western border at 73°3'E and the farthest eastern point at 135°E, a distance of 65°5' of longitude, China can also be divided into three natural regions which differ significantly from each other in physical features (XU and PEEL, 1991). They are the Eastern Monsoon Region, the Xinjiang-Inner Mongolia Arid Region, and the Qinghai-Tibetan Plateau Region. The pastoral areas in China are mainly distributed in the latter two regions (Fig. 1.2), which occupy about 52% of the total land surface area.

In line with the frame given by SHEN (1982), the agricultural-pastoral boundary crosses twelve provinces and autonomous regions and divides the whole country into two parts.

> "*It stretches from the western Song-nen Plain in Northeast China – the upper-middle reaches of the Liao River – Yin Mountain – the east part of Ordos Plateau – Qi-lian Mountain – and finally to the eastern margin of Qinghai-Xizang Plateau.*" (SHEN, 1982:2)

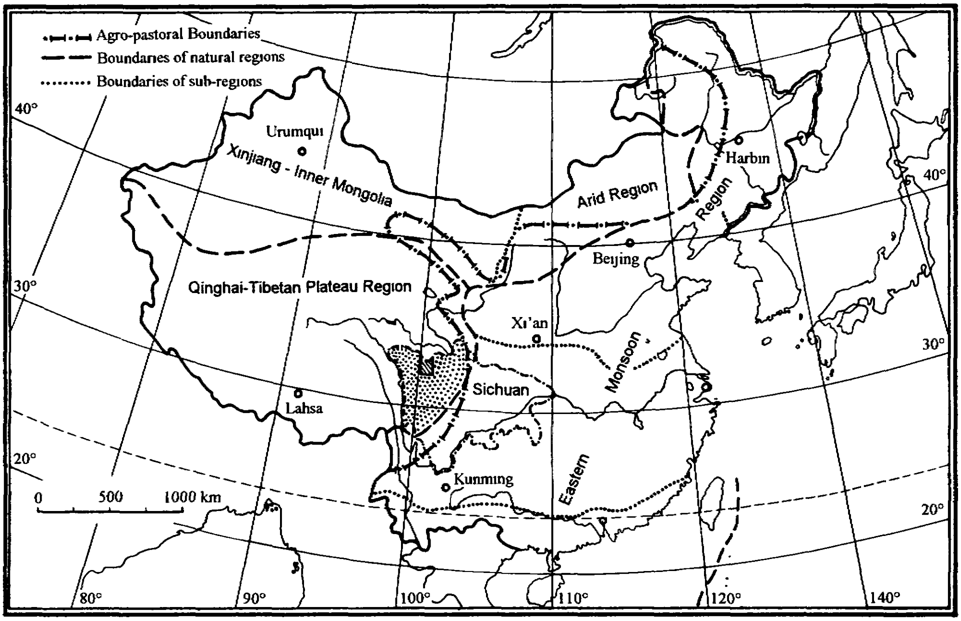

Fig. 1.2 Three Natural Geographic Regions and Pastoral Boundary of China
Source: 1) XU and PEEL, 1991; 2) SHEN, 1982

The northern and western parts of the line are mainly the pastoral areas; while the southern and eastern, are farming areas. Between these two parts, there is a transitionally crisscrossed belt, called "the semi-farming and semi-pastoral belt", or "agro-pastoralism mixed belt", which was also thought as a sensitive zone or an ecotone between the ecological systems in high Asia and that in eastern Asia. In the pastoral area, rangelands, which makes up to 88.3% of the total area of rangelands in China, are the main sources of fodder for grazing animals, where its chief characteristics are vast land with sparse population; many different nationalities; density of livestock and a minority of most livestock species and little farmland (Table 1.1)

Table 1.1 Distribution of some Items between the Pastoral Area and the Farming Area in China (in % of China Total)

Items	**Pastoral Area**	**Farming Area**
Total area of land	52.0	48.0
Total area of rangeland	88.3	11.7
Total area of farmland	10.4	89.6
Rural population	3.2	96.8
Horses	43.8	56.2
Asses and Donkeys	24.9	75.1
Mules	7.6	92.4
Cattle, yaks (cows and buffaloes)	25.1	74.9
Camels	73.1	26.9
Sheep	63.6	36.4
Goats	29.4	70.6
Swine	3.7	96.3
Total No. of animals	22.1	77.9

Source: SHEN, 1982.

It is not a mere coincidence that in China the economic significance of pastoralism is greatest on the periphery of central China, including Inner Mongolia, Gansu, Ningxia, Xingjiang, Qinghai, Xizang (Tibet)[6] and Sichuan, that have been identified as the less developed. Aridity or frigidness of the climate and scarcity of resources of these regions, constitute the most serious barrier to the development of their economies. At the same time, they also determine the nature of economic activity for the majority of the people. A mobile way of economy and living, scientifically known as **nomadism**, becomes the main source of livelihood for most of the rural people.

The Qinghai-Tibetan Plateau in this context means the vast area extending from Pamir in the west to Hengduan Mountains in the east, and bordering Kunlun Mountains and Qilian

[6] In this study "Tibet", "*Xizang*" and "Tibet Autonomous Region" refers to the same geographical region.

Mountains on the north and Himalayan Mountains on the south, which is the highest and largest plateau in the world and is known as the "Roof of the World". Its geographic location has been shown in Fig. 1.2. It lies in the south-western part of China and constitutes 23 per cent of the territory of China with the area of the region being 2.5 million km^2, though less than one per cent of the country's people live there. It embraces the whole of the Tibet Autonomous Region (Tibet), the major part of the province of Qinghai, western part of Sichuan Province and small parts of North-western Yunnan Province and North-eastern Gansu Province.

Two-thirds of the Qinghai-Tibetan Plateau is more than 4,500 m above sea level, and a number of peaks stand as high as 7,000-8,000 m. The remainder is at an altitude of 3,000-4,500 m, except for a few river valleys in the south and east which are below 3,000 m, and which occupy one-tenth of the region. The elevation leads to a very thin atmosphere, with widely distributed glaciers, intense exposure to solar radiation, and strong winds. According to the statement of XU and PEEL:

> "*Uplifting of this plateau began in the Mesozoic era, in the Tertiary period. Before this uplifting, China was basically a low flat peneplain and part of the present plateau was even submerged in the sea. By Neogene, in the Miocene or Pliocene, the eventual plateau area was elevated to 1,000 m or so above sea level. By the end of the Pliocene, a strong elevation made it rise to 3,000 m. Then a violent uplift occurred early in the Holocene which raised the plateau further to its present height of more than 4,000 m.*" (1991: 5)

The Gross Output Value of Industry and Agriculture (GOVIA) in 1986 is 5,851 million Yuan (calculated on the invaried value in 1980), among which the Gross Output Value of Agriculture (GOVA)[7] is 2,799 million Yuan, making up 47.83% of GOVIA, and the Gross Output Value of Industry (GOVI) is 3,053 million Yuan, accounting for 52.17% of GOVIA (Table 1.2).

According to the preliminary statistics, three quarters of the industrial production on the Qinghai-Tibetan Plateau is concentrated in Qinghai Province, where petroleum, metallurgy, machinery, mining, chemical, wool spinning and food industry systems have been built up. The energy industry, including petroleum, electricity and coal industries, developed rapidly

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[7] The term "Gross Output Value of Agriculture" (GOVA) refers to total volume of products of farming, forestry, animal husbandry, and fishery in value terms, which reflects the scale, of and the achievements made in agricultural production during a given period of time;

in recent years, which output value has taken up 14.94% of GOVI in 1988 in Qinghai Province. Machinery rank second in industry with the output value amounting to 14.26% of GOVI. The ratio between light and heavy industry is 37 : 63. The industry in Tibet is underdeveloped due to the restriction of natural resources and technical conditions. The GOVI only makes up 5.3% of the GOVIA. Mine, wool spinning and electricity are the main industrial productions in western Sichuan and northwestern Yunnan, where the GOVI can take 14.8% of the GOVIA.

Table 1.2 Composition of Gross Output Value on the Qinghai-Tibetan Plateau

Item	**Output Value (Million Yuan)**	**As Percentage of GOVIA**
Agriculture	2,799	47,83
Planting[8]	1,039	17,75
Animal Husbandry[9]	1,360	23,24
Forestry[10]	141	2,41
Others[11]	259	4,23
Industry	3,053	52,17

Source: LIU, 1992.

The area of cultivated land on the Qinghai-Tibetan Plateau is 1.2153 million hectares, which amounting to 0.49% of total area. The grain yield in 1986 is 2.2988 million tons, which means 235.25 kg per capita and accounts for 64.33% of the national level. On the Plateau cultivation only distributes in Hehuang Valley of eastern Qinghai, middle branches of Yalung Zangbo River in Tibet and valley area of Hengduan Mountains in Sichuan. However, the duration of sunshine in the region is 2,600-3,200 hours per year, and the sun shines 60-70 per cent of the time. This is a very good sunshine regime for crop growth, and as a result the yields of the crops which are grown in the region are often very high, such as the yield of wheat and barley per unit area created the highest records in China. The main

[8] The term "Planting" refers to cultivation of farm crops, which in Chinese statistics includes cultivation of grain crops, cotton, oil-bearing crops, sugar crops, bast-fiber plants, tobacco, vegetables, medicinal herbs, melon and gourd crops, and cultivation and management of tea plantations mulberry fields and orchards;

[9] "Animal Husbandry" in Chinese statistics refers to raising and grazing of all animals except fishing and cultivating, and hunting and raising of wild animals.

[10] "Forestry" refers to planting trees of various kinds (excluding tea plantations, mulberry fields and orchards), collection of forestry products, and cutting and felling of bamboo and trees by villages and other cooperative organizations under villages, which is different from forestry industry organized by state government.

[11] "Others" includes harvesting wild vegetation fruits, fiber, gum, resin, oil-bearing plants, grass, wild medicinal herbs, fungus plants, fishery and rural household commodity industries.

crops in this region are naked barley (Tibetan barley or called Qingke), wheat, peas, potatoes, and oil-seed rape, all of which are cold tolerant.
Vegetation on the alpine area is sparse and, in general, stunted. There has been hardly any impact of human activities on the landscape, except in strips of the small valleys in the northeast. Where the altitude is higher than 4,500m, the monthly mean temperature of the hottest month is below 10°C, and in some places lower than 6°C; and there is virtually no frost-free period. Cropping is not practicable, and the only way that the land can be used is for it to be grazed by animals tolerant of the cold.

Most of the places lower than 4,500 m are also unsuitable for cropping, except for the few river valleys in the south and east. Therefore, the extensive areas of rangeland are available for grazing. There are 167 million hectares natural rangeland resources on the Qinghai-Tibetan Plateau, making up 42% of total area of grassland in China. The quality of pasture and grass grove, specially in terms of high contents of crude protein and nitrogen free extract (NFE), is better than that in other areas of China (LI and YONG et.al, 1990), but the yield of grass is low, the annual yield of fresh grass per hectare is about 1,500 kg in average. The amount of large livestock (mainly yak, horse, cattle and cow) in 1986 was 17.2477 million, which took up 14.5% of national heads of big livestock. The amount of goat and sheep was 37.6981 million, making up 20.9% of national totals. Animal products coming from this region, such as wool, cashmere, hair, mutton and beef, account for 12.32 - 13.47 percent of the national production, and 29.2 sheep units per year are slaughtered per head of the agricultural population (XU and PEEL, 1991). Due to the geographical pattern the Qinghai-Tibetan rangelands have attracted pastoral societies for hundreds of years. Even nowadays, more than half of the regional populations living on the nomadic or semi-nomadic range-livestock production system (Fig. 1.3). The main domestic animals of the region are the altitude-tolerant yak, the Tibetan sheep, and the Tibetan goat.

Up to 1986, the population in this area is 9.75 million, among which there are 4 million Tibetans. The very low productivity of the grazing lands used by nomadic herders means of course that a very large area is needed to sustain the animals, varying with the natural conditions. One obvious consequence of this is that (human) population densities are very low in nomadic herding regions (Table 1.3).

In the southeast and east of the region abundant forests form the second largest forest area in China, with the area of 11.479 million hectares and amounting to 9.21% of the total forest area in China. The amount of growing stock is 2,697 million cubic meters, making up 25.51% of the national timber reserve.

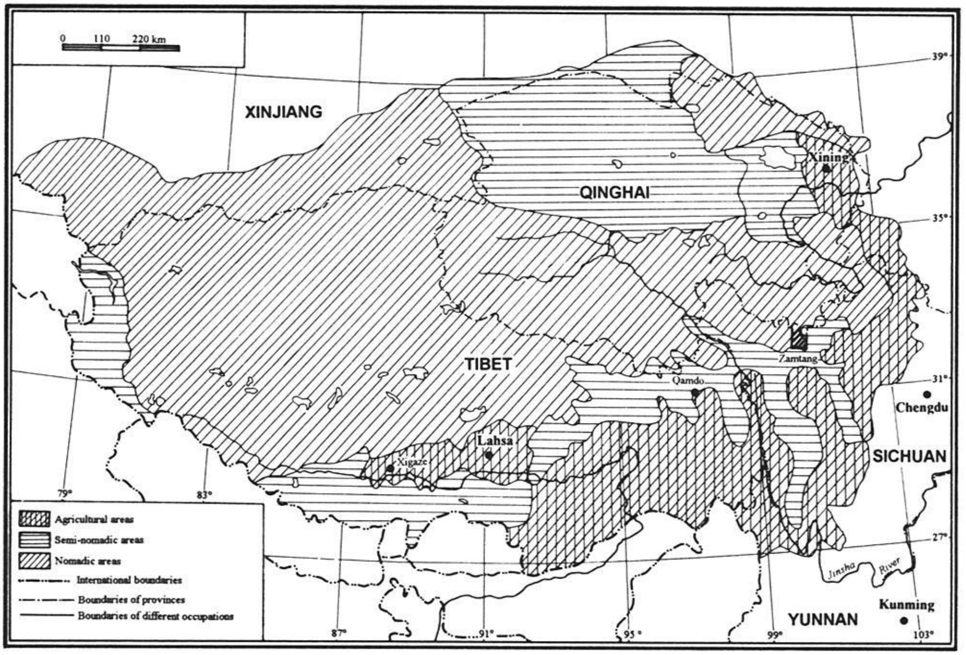

Fig. 1.3 Distribution of Nomadism on the Qinghai-Tibetan Plateau
Source: 1) GIAS, 1990; 2) TIST, 1992
Design: WU NING

In the chapters which follow interest is directed towards the eastern Qinghai-Tibetan Plateau, represented by western Sichuan, which situated in the heat-deficient zone, where the elevation is above 3,000 - 3,500 m a.s.l. Since the soil is not suited for any use other than grazing, and in the absence of alternative avenues of local employment of any significance, pastoralism remains the way most people earn their livelihood. This region, at present, is an impoverished plateau area in need of development and has a long history of pastoral development with pronounced local economic characteristics. Today it has been lying at the transitional stage between a self-sufficient subsistence economy and a market economy since the great changes took place in China in recent decades. Meanwhile, the economic progress brought pressures on the environment, specially on the rangeland ecosystem, as well as more influence on the infrastructure and the daily life-style of the nomads. Due to the population pressures; overuse of range; some misleading policies and related socio-economic activities, the changes of land use system and the environment in the region have become very fragile. The degraded rangeland has become the barrier for the local economic development.

Table 1.3 Population Density of Different Pastoral Areas in the World

Pastoral Area	**Average Density (per square kilometer)**
Mongolian steppes	0.5
Sahara*	0.5
Sahel*	3
Tibet Autonomous Region**	1.61
Inner Mongolia**	16
Xingjiang**	8
Qinghai**	5
Western Sichuan***	6.5
Qinghai-Tibetan Plateau****	<4

Source: * KONCZACKI, 1978;

** XU, 1986. (The number is based on the 2nd National Population Census.)

*** LIU, 1991.

**** LIU, 1992.

Western Sichuan distributes in the most eastward and takes the most important role in the connection between the Plateau and the hinterland of China economically and ecologically. Apart from influencing the environmental condition, nomadism is considered to have vital implications in the development process. Unfortunately such an important issue has remained neglected in western Sichuan, in spite of its immense significance. With a few exceptions, published works on indigenous nomadic knowledge are negligible in the country. Again, only a limited number of the studies have been completed by direct field survey. The nomadic literature in China clearly reveals that most of the studies have been done to compile and analyze historical data without giving sufficient emphasis to the complex interrelationship of traditional nomadism and development.

Considering the importance of rangeland development for Tibetan nomadism, the following study has been done, with the intention of examining the complex interrelation between the changes of grazing management, the ecological appearance of rangeland degradation, and the sustainable development of rangeland in this special environment. Thereby, emphasis has been given to the investigation and analysis of the causes of rangeland degradation and its ecological characters as well as socio-economic consequences, with examples from western Sichuan. Summing up, western Sichuan was selected as the study area for three reasons.

- Ecologically fragile region: This region is situated on the contact zone between Tibetan Plate and Yangtze Plate, and is the ecotone of highland's ecosystem and lowland's ecosystem, both of which lead to the fragility[12] of this region in ecosystem, geological structure and even traditionally local resource-centered economy. Any assessment of a complex system in terms of its ability to provide a sustained production of energy or resources for human consumption will depend upon the socio-economic level attained, or sought (WINIGER, 1983). Rangeland ecosystems are the complex systems where socio-economic systems mingle with natural ecosystems (see 1.3 of this book). Therefore, the fragility of the rangeland ecosystem in this region reflects centrally on the instability[13] of pastoral production and sensitivity of rangeland ecosystem.
- Transitional Region: Owing to the rapidly rise in topography, the altitude of this region, increases within a short distance, from 700 m a.s.l (e.g. Dujiangya City, 50 km away from Chengdu northwestwards) to above 3500 m a.s.l (e.g. Hongyuan County), with correspondingly leads to the increasing in biodiversity[14] (including genetic diversity, species diversity and ecosystem diversity[15]) and economic complexity or called cultural diversity (extending from agro-pastoralism, gradually through sedentary pastoralism and semi-nomadism into nomadism). In a way, the pastoral biodiversity is more fundamental than the conventionally known pastoral resources (e.g. herbage resources and livestock resources) and falls outside of a purely utilitarian and economic calculus. Pastoral biodiversity provides a fundamental base to pastoralism and to the overall economic

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[12] Fragility may be considered as the feature of a fragile ecosystem, which is situated always in an ecotone or geologically transitional belt, with the properties of sensitivity, very sensitive to the change of environmental factors, and instability, the weak sustaining capacity and fluctuating productivity (WINIGER, 1983; LIU, 1993).

[13] Instability can be defined in terms of falling revenue, or yield, resulting from a falling level of the input needed to achieve a specific level of production (WINIGER, 1983). Instability may take the form of physical damage, or destruction of an ecosystem through deterioration or loss of the substrate. In terms of the time-scale of such events damage to an ecosystem is defined as irreversible if it cannot be repaired within one generation. Stability and instability must also be considered in a spatial context: that is, a region as a whole may be in balance, or stable, while individual farms within the region may become unstable.

[14] Biodiversity means all species of plants, animals and micro-organisms and the agro-pastoral ecosystem and ecological processes of which they are parts, including both the number and frequency of ecosystems, species or genes.

[15] The three levels of pastoral biodiversity known to us are **Genetic Diversity, Species Diversity** and **Ecosystem Diversity**. While genetic diversity includes sum total of genetic information contained in the genes of individual forage plants, livestock and rangeland related micro-organisms. Species diversity would refer to the variety of living organisms, such as various types of plants and animals on the rangelands. Similarly, rangeland ecosystem diversity represents the variety of geoecological zones or habitats, grazing systems and ecological processes (DAHLBERG, 1987; DOVER, 1987; McNEELY et al., 1990).

systems. Thus, ensuring its availability today as well as to future generations is the necessary source of resiliency, regeneration and sustainability of pastoral systems.

- Interacting Region: Due to the geographical location, this region forms a very important channel for the flows of agricultural and livestock products, commodities and cultural value between pastoral nomadic societies on the Qinghai-Tibetan Plateau and agricultural societies in the hinterland of China, and even the external world. Socio-economically, the nomadic societies in this region could be affected by modernization process easier than that in the center of the Plateau. Geographically, this region also becomes a culturally mingling area, where various ethnic groups distribute and affect mutually. However, Tibetan civilization has dominated and developed here for thousands of years. Although the nomadic societies here are not totally the same as those in the center or west of the Plateau, they still represent a kind of Tibetan socio-culture, which is based on the special geo-ecological environments on the eastern Qinghai-Tibetan Plateau.

1.3 Applicability of General Theories

The problems identified above have clearly demonstrated the incompetence of general theories to restrain the rangeland degradation and its sustainability on the Plateau. At the same time it has emphasised the urgency of more empirical research permitting generalizations. Furthermore, it reveals some unique characteristics of the changes under the mixture of traditional and modern management.

> ***Development theory considers that development is a historically and socially specific process. It may involve evolutionary change within specific sets of social relations of production or the revolutionary transformation of the social relations and means of production.***

The success of a struggle to develop is by no means assured. The type of social change implied by a transformation of the relations of production may take decades, if not centuries, to achieve. Development is historical, diverse, complex and contradictory; it is the central feature of the human condition. Even if the state of development may be defined by some variables and by bringing them into quantitative or qualitative relationship with each other, the universal concept which has recently been formed is that development activities should be conceived in such a manner that economic growth as well as the living conditions of the population will undergo a sustained improvement. The development contributions initiated in bottleneck situations must ensure that regional development processes continue even after external contributions have been discontinued (GTZ, 1984). This new thought, namely **sustainable development**, include that development which meets the needs of the present should be without compromising the ability of future generations to meet their own needs.

In recent years the "**sustainability**" debate has created a great deal of concern. Besides the more publicized works, such as "Limits to Growth" by the Club of Rome in the 1970s, several significant contributions have been made to the subject and have been summarized by PEZZEY (1989) and BROODFIELD (1988). From the economic opinion the process was reviewed by MIKESELL:

> "*The integration of the environment into development economics dates at least from the 1960s, but environmental economics still does not play a major role in the leading economic development textbooks or other well-known treatises on the subject. In the late 1980s and early 1990s a few books featuring 'sustainable development' in their titles were published... . Sustainable development must be regarded as an important revolution in development objectives and policies.*" (1992: 4-5)

In fact, the concept of sustainable development, originally was set out in the World Conservation Strategy (1980) and popularized by the Brundtland Commission in the book "Our Common Future"(1987). Following the Stockholm Conference on Environment (especially following the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro from June 2nd-16th, 1992) a general consensus concerning future global development was reached within the framework of sustainability. Many organizations, institutions, and individuals, have drawn attention to the world-wide threat of runaway population growth, to unorganized use (even abuse) of renewable natural resources, and to the actual and potential impact of mismanagement in rural area and all of the so-called "Developing World".

However, despite all this, "sustainability" continues to be a much used metaphor, with only very little progress in making the concept operationally available. At present, it needs to be made more operational in terms of the criteria by which technical, social, economic and political interventions can be designed for sustainability. The problems stem from the futuristic nature of the concept and ist associated uncertainties (requiring specifications of contexts which can give operational meaning to the concept) and from the general neglect of the intra-generational aspects while focusing on the inter-generational issues as the sustainability debate (BROOKFIELD, 1988). However, various definitions of sustainability, which largely describe the situations rather than define the term, do highlight some broadly common elements. Especially in the developing countries, the heavy pressure of population, scant resources and deteriorated environment have formed a vicious circle. The less developed the economy is, the more over-exploited and abused the resources and environments are. The more the sustainability declines, the less developed the economy becomes. Though there are some natural, historical and external reasons for such problems, the main cause comes from the interior of socio-economical system. It is not difficult for us to find alarming waste in the use of resources, man power, currency and time, and the improper coupling of relation, institution and human behavior. The ultimate goal of sustainability research is to find the crucial reason of these problems according to the ecological relationships with limited external input through various technical, administrative and behavioral interventions; to enhance the ability of self-regulation, and to eventually realize sustainable development in accordance with local conditions.

As the definition of the Brundtland Commission suggests, sustainable development faces challenges from the interdependence of peoples and places throughout the globe. While environmental concerns threaten the "quality of life", the "pollution of poverty" may threaten life itself. Sustainable development encapsulates the realization that to achieve the goals of either conservation or development, the welfare needs of the poorest groups must be addressed. Meanwhile, it also identifies how and why future development patterns and processes must be sustainable on a global scale. From an examination of the historical origins of the concept, the text explores the current patterns and future challenges of resource use in plateau environment. According to the definitions given by GTZ (1984), sustainable development requires especially:

- that the long-term preservation and improvement of the natural environment should be taken into consideration; to this end the emphasis is on environment-oriented project planning, technology compatible with the local and financial situation, locally renewable energy sources and ecological systems designed for long-term utilization;
- that the population is willing and able to cope with the challenges of changing environmental conditions;
- that stable and self-sustaining circular flows within small geographical areas are created, directing the net product of a region into the increase of regional incomes and investments. These circular flows are also a prerequisite for reaching the poor and for increasing external relations with the economy as a whole;
- that the minimal prerequisites be fulfilled for the participation of the poorer population and for the abolition of under-privileged in the receiving country.

Conceptually speaking, the focus of sustainability is on the issues of inter-generational equity. This implies equal (or greater) availability of options, in term of human well-being or production prospects, to future generations as to the present one. Theoretical possibilities of such prospects, ensurable through accumulation of capital stock and technology for use by future generations, are constrained by the capabilities of the biophysical resource base. The latter cannot be stretched or manipulated indefinitely, without initiating processes of irreversible damage. This is especially so in the case of pastoralism where the dependence on biophysical variables is more direct and crucial.

The obligation to future generations is usually stated in terms of human welfare rather than the inheritance of physical resources. Since the quantity and composition of physical natural resources must inevitably change from generation to generation, what must be passed on is defined in terms of the social benefits, i.e. waht the resources are capable of producing when combined with labor and capital. The standard of welfare for future generations varies from a minimum standard of living necessary to perpetuate the human species to a growing level of per capita income expected to be achieved with the aid of technological progress. For many developing countries with high rates of population growth, not even the present low average per capita output could be maintained, given the world's present distribution of natural resources. Thus, some definitions of sustainable development suggest that not only must the value of the global stock of natural resources be maintained, but the resources must be redistributed to assure a certain level of consumption for all people regardless of population growth. Such definitions appear to move away from global resource conservation to an ethic of distributive equity. It appears to me that if global resource conservation is to remain the basic ingredient and rationale for sustainability, inter-generational responsibility should be based on maintaining the productivity of the natural resource base - not on some concept of inter-generational equity. (MIKESELL, 1992)

The above discussion calls for basic changes in the conventional development approach to suit plateau conditions. A related question is, can the new approach base on the plateau perspective ensure sustainable development in nomadic areas? By this logical structure, the new approach compared to the conventional approach is more conductive to sustainable development. This is more so because of its greater sensitivity to limitations and requirements of nomadic areas, built-in support (through diversified, interlinked activities) for regenerative processes, and recognition of the inseparability of sustainbility of the resource base and its use pattern and productivity.

Regarding the matter from the angles of evolutionary ecology and cultural ecology, traditional pastoralism is an intrinsic feature of rangeland ecosystems in an extremely harsh environment. Co-evolution in pastoral system implies that all socio-cultural sub-systems as well as organisms in the ecosystem are involved in a continuous process of adaptation[16] to optimize fitness in the face of selective pressures generated and maintained by the long tenure of traditional pastoral activity.

Pastoralism on the Qinghai-Tibetan Plateau is the main form of human adaptation to plateau environment. This is a kind of human culture derived from the primitive means of livelihood. In order to survive, man has to struggle with nature, to utilize natural resources and to obtain energy, food, and shelter from nature. Therefore, **culture**, as the way of human existence, is the effective means of human livelihood. Mankind improves its own condition with culture, and the level of cultural development may indicate the human condition in nature, and also the progress of the relationship between man and nature (SMITH, 1978). This theory indicates that the process of human adaptation to the environment should be studied on the base of cultural ecology, and that the main problem for a traditional pastoralism is to determine whether these adaptations would lead to internal changes within the society or ecosystem.

Important kinds of data are currently available on pastoralism from a number of sources, yet understanding of the interactions of species and human societies with natural environment in a rangeland ecosystem remains limited. Most studies conducted as parts of development projects are based on measurements of productivity. They stress questions of economics and range management. Such studies frequently indicate that human use substantially degrades natural vegetation and that traditional pastoral management typically fails to optimize herd productivity in market terms. However, they often neglect questions of the adaptive processes that modify plant-animal and human-environment relationships in rangelands, as well as the cultural factors which govern resources exploitation under traditional management systems.

Although there is a general impression that pastoralists are irrational in such matters as stocking rates and the management of grazing, recent observations indicate that within their economic and natural environment, they are as rational and productive as their counterparts

[16] Biologically speaking, adaptation of organisms refer to their interactions and adjustments with other organisms. There are nine known kinds of adaptation mechanisms adopted by all biological entities of the agricultural or pastoral systems (ODUM, 1984) viz. neutralism, competition of resources and mutual inhibition, amensalism, parasitism, predation, commensalism, protocooperation and mutualism or symbiosis. Understanding nomadic adaptation mechanisms between environment and man or his society will help strengthen the management of less understood forms of nomadism.

elsewhere (McDOWELL, 1984). Adaptive processes in rangelands brought on by pastoralism may have included the elimination of favored forage species and their replacement by species capable of preventing or escaping herbivore, or adaptation of plant species already prevalent to withstand a different, heavier grazing pressure. At the same time, carrying capacity was stressed for domesticated animals adapting to a new degree of competition and to compensate for anti-herbivore defenses in plants. Similarly, pastoralists developed new herding and husbanding strategies in order to occupy the range without causing frequent cases of rapid deterioration, and to maximize their fitness in competition with one another through optimization of herd size or productivity. Thus, my basic hypothesis with respect to the cultural ecology of pastoralism is that all sub-systems in a pastoral rangeland ecosystem adapt themselves in new directions in response to the ecological stresses and interactions generated by the permanent stability of domesticated herds. Except where recent disruption has occurred, these adaptations are reflected in the current ecological structure of rangelands under pastoral use.

Traditional patterns which emerge in analyses can be interpreted as the result of adaptive responses of organisms and societies to current pressures and specific historical processes. Before the advent of pastoralism, rangeland ecosystems had already existed for millennia (although they have apparently expanded since then under human use) (SCHOLZ, 1995). Archaeological evidence indicates that the earliest domestication of yak , sheep and goats occurred in various locations on the Qinghai-Tibetan Plateau at about 5,000 years ago (CAI, 1989). Originally an aspect of broad spectrum village subsistence, and then a specialization in its own right, this technology became prevalent in vast regions of the Qinghai-Tibetan Plateau, although its onset in any location is undetermined.

While the geographical extent of traditional pastoralism is presently diminishing in some regions in the face of the combined pressures of desertification, political action and agricultural expansion, this mode of production persists as the only feasible means of exploiting most rangelands (GALATY et.al, 1981; SEIFERT, 1988; SCHOLZ, 1991). Using criteria of longevity and size of the human and animal population supported, the resource exploitation strategies involved in traditional pastoralism, which include herd management practices as well as animal foraging patterns, approaches a long-term optimum for the environmental conditions faced.

However, even though pastoralists may operate in a practicable way, their systems are of concern to governments, as governments often view them as a mobile force with disruptive potential and as groups which contribute little to national productivity. To a large extent animal scientists and other technologists view pastoralism as a system with potential for larger outputs of animal products, but these scientists are at present frustrated on how to induce viable changes (SCHOLZ, 1986). There are also certain groups, such as some of ecologists and conservationists, who frequently consider the pastoral system a destructive force in a fragile environment. On the contrary, it is pastoralists who have selected a large number of animals now found due to their adaptive systems. In addition, pastoralists have focused management to meet their needs as, for example, their yak and sheep not only breed throughout the year, but are species of high fecundity.

Conceptually speaking, the human is the principal component of a given compound ecosystem on the one hand, which means a social, economic and natural complex system. On the other, the environment should be considered to be an integral part of development, because both of them are linked together so intricately that separate approaches to either environmental or developmental problems are piecemeal at best.

Developments of pastoralism need to be based on studies of the adaptive strategies of organisms in rangelands. Further, the complex social, economic and ecological problems that stem from hydro-thermal conditions and range deterioration depend on a host of variable local and external factors. As a result, planners need to understand the ecological and cultural contexts, and their interactions, for each system to be modified. Specifically, little information yet exists from any location concerning interrelationships between herds of domesticated animals and resources of vegetation on the one hand, or the relationship between foraging herds and the production strategies of herdsmen on the other. Domesticated animals, however, are the basic means by which pastoralists exploit natural vegetation, and information on their ecology and "ethno-" management should be crucial to planners in indicating precisely where and why a pastoral system of production has shortcomings and what possible avenues are open to change and improvement that take advantage of established relationships.

The aim of the pastoral system is to use animals to harvest limited amounts of vegetation scattered over large distances which cannot easily be gathered by any other method. In energy terms it is very inefficient as only a very small proportion of incoming solar radiation is converted into usable material, yet without the method no benefit at all would accrue (SCHOLZ, 1995). The low energy efficiency does, however, mean that only small human populations can be supported by this method of husbandry, even though very large areas of land may be involved. With the various nomadic groups follow a regular pattern of movement from one grazing ground to another at different times of year, so that they can always be where biological productivity is at its maximum (BEAUMONT, 1989). Of course, nomadic groups were never fully self-sufficient and depended on contact with sedentary agricultural groups for cereals to supplement their diets of milk, cheese, blood and meat.

Based on the above statements, one can imagine easily that pastoralism is a very complex system which has many interrelated components such as climate, soil, plants and obviously, animals operating with a high degree of interaction within a certain economic and social environment (SCHOLZ, 1995). Traditionally, these components have been studied separately by scientists in animal science sub-disciplines and other disciplines such as range, forage science, botany, health science and economics. Ecologists have long recognized that optimization of production efficiency requires these components to be synthesized and studied in an integrative form. This has usually been attempted in an informal, intuitive and unorganized fashion due to the lack of defined theory and methodology. However, with the emergence of system theory as a science during the last 30 to 40 years, the use of a system theory approach to the study of livestock production has received increased attention.

The production of rangelands is often expressed in the number of cattle, sheep, and goats per hectare, or in kilogram of meat and milk per animal. Although this production (secondary production) is the ultimate goal, we must accept that plant production (primary production) is the basis for this secondary production, since it nourishes the livestock (SCHOLZ, 1991b). This primary production can be natural vegetation, cultivated forage or agricultural by-products. The quantity and quality of primary production determine secondary production. Likewise, secondary production influences primary production. Primary production, in turn, depends on the environment, although man can intervene (for example, by fertilizing, enclosure, etc.). Climatic factors (rainfall, temperature, humidity, radiation, and photoperiod, etc.) and edaphic ones (texture, fertility and depth of the soil, and topography) determine the quantity and quality of forage produced in the first place, which in the end decided the base of pastoral system. Consequently, the inter-relationship between environment (e.g., the ecological situation of the rangeland) and economic process (e.g., pastoral development) has put new questions before us. Figure 1.4 indicates this relationship in pastoral system, which will be illustrated in following paragraphs.

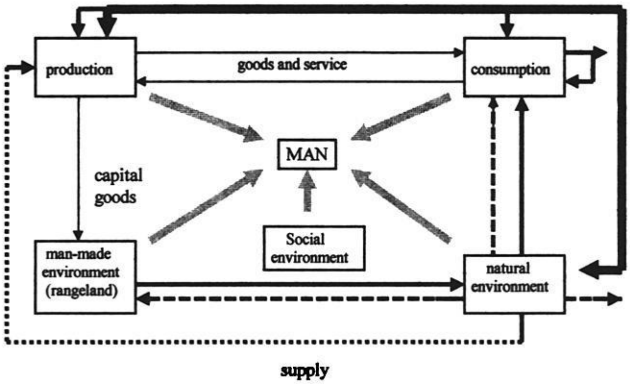

Fig. 1.4 Environmental - Economic System in Pastoralism
Source: 1) BARTELMUS, 1986.
2) ROSSI, and YOUNG, 1990.
Design: WU NING

A close connection between environment and development is implicit in the definitions of the environment (as the conditions and influences that interact with man) and of development (as a process to improve human welfare) just arrived at. The environment can be considered to be an integral part of development, since any impact on man's environment also influences his state of well-being or welfare.

The pastoral economic system comprises productive, consuming and accumulative activities which create flows of goods and services (including labor) between the systems components. The environmental system consists of natural, man-made and social components. The two systems are shown to overlap in the area of rangelands. Emissions of wastes (e.g., urine and dung) originating from production and consumption activities are indicated by bold black arrows. Flows of natural environment to rangelands and then to production and consumption are shown as broken arrows. These flows represent the two basic functions of the natural environment and rangeland: waste disposal from and resource supply to the economic system. This presentation is based on the principle of mass conservation, according to which resources may be used but are never consumed. All materials either return to the natural environment and rangeland or are recycled in the economic process, generally in a modified form. Recycling is, therefore, the only ecologically sound way of waste disposal. Recycling is indicated explicitly in the flow chart by feedback loops of emissions. Destructive ("disastrous") activities of the natural environment are symbolized as medium black flows from rangelands to the natural environment, and out of the natural environment.

Environmental and economic activities may affect human welfare either positively or negatively. This is indicated in the figure by bold gray arrows pointing from all economic and environmental components to the symbol for man. The consumption of "useful" goods and services provides individuals with what economists call "utility" or "well-being" (BARTELMUS, 1986). Active participation in the productive system may produce either positive or negative effects resulting from the carrying capacity. The impacts of aggressive and altruistic actions of individuals and social groups (e.g., controlling stock number and grazing routes based on the rangeland's conditions) are indicated as welfare effects of the social environment.

1.4 Approach and Scope of the Study

The subject of rangeland degradation and its sustainable development has, however, not been claimed by any particular discipline to belong solely to it. Sustainability itself is a broader concept and disciplinary bias should actually restrict the scope of research. Contrary to that, a multidisciplinary approach widens the visual angle and enables researchers to analyze the problem more pragmatically. It obviously overlaps the field of several disciplines, but nowadays it is widely agreed that common efforts are necessary to make the studies of sustainable development of rangeland more meaningful.

Keeping these in view, the following study attempts to analyze the characters of rangelands and pastoralism in western Sichuan, the changes of pastoral management and some socio-economic aspects of degradation. At the same time it evaluates the causal relation of degradation and development process on the Plateau. Besides, the study also sheds some light on the survival and adaptive mechanism of nomads in western Sichuan. In order to define the approaches and scope in this study, several constraints on pastoral development on the Plateau that influence range management efforts should be first clarified.

Ecological:

- Land production potential – there is an absolute upper limit.
- Disease, insects and parasites.
- Climatic variability – season, intensity and distribution of rainfall and thermotical conditions can have major effects on forage production.

Political/Economic:

- Boundary delineation – community, regional.
- Agricultural demands – the expansion of subsistence agriculture often results in the

exclusion of livestock from key grazing areas and/or the degradation of grazing land near agricultural areas due to concentration of livestock owned by sedentary agriculturists.

- Trade conditions – market restrictions.
- Bureaucracy – policy constraints and absence of precedent regulatory mechanisms.

Social:

- Customs concerning animal husbandry.
- Traditional land use.
- Prejudices among pastoral groups.
- Technological development.

Earlier literature on rangeland degradation or pastoral development indicates that compared to botanists and range management specialists, who tried to analyze and evaluate the change of vegetation cover under the grazing pressures, or anthropologists and sociologists who concerned themselves mainly with nomadic life-style and non-economic or ecological factors, the geographer's interest was mainly in the settlement and mobility of nomads. The scope and sphere of geography and ecology in rangeland development research have, however, notably increased with time. During the recent period, geographical and ecological research has gained new dimensions and proposals have come up to widen the scope of research in this discipline (SCHOLZ, 1991; 1995). In this regard it is worthwhile to hint at the discussion of sustainability in the "**development process**".

Unlike prior notions the process of development is understood not solely as a social science approach, but also as an natural science (SCHOLZ, 1995). To know what features in a degraded rangeland appear, what factors produce such changes and how they operate, one should proceed further and ask: – what is the sustainbility of rangeland in nomadic area and why should certain social, economic or ecological patterns be considered in the sustainable approaches? The above discussion demonstrates clearly that these questions could be best answered by applying the ecological and geographical development research approach, because:

- within this approach it is possible to analyze simultaneously the ecological causes and appearances, the socio-economic aspects of nomadic activities and;
- integration of development theories in this framework enables researchers to determine the complex correlation between development process and range degradation, the precise understanding of which is immensely important for sound interpretation.

The **ecological approach** has been employed increasingly in anthropology during the last quarter century, because some anthropologists and geographers believe that

> *"anthropology would gain considerably if anthropologists made a habit of always looking for explanations at the level of the economic base before turning to other types of explanations ... (and that) Taking an interest in ecology in one step toward this."* (DAHL, 1979:262)

In fact, ecology was of practical interest early in nomads history as well as in the whole human history (SMITH, 1978). The importance of the physical and biotic environment in influencing the spatial and social organization of pastoral societies has been widely recognized since EVANS-PRITCHARD's (1940) seminal book on the Nuer. During the 1950s and the 1960s, monographs on nomadic societies very often included sections describing important features of the environment such as climate, seasonality, vegetation, and water sources. During the 1970s, there has been a continued concern among anthropologists and others about the ecology of pastoral societies[17]. More recently, cultural ecologists interpret nomadic spatial and social behavior as adaptive responses to specific features of the natural environment (DYSON-HUDSON, 1980). SCHOLZ (1991) further confined the adaptive responses to two categories: "Time" and "Space"[18], and thought that the nomadic migrations between complementary grazing areas always aiming at the maintenance of resources were accompanied in the long run by a variety of adaptive measures both guaranteeing existence and sparing resources.

Generally speaking, before the 1970s, ecology was always viewed largely as a subdivision of biology and was sometimes used by geographers when they studied environment. Recently, it has diverged from biology as an essentially new integrative discipline that links physical and biological processes and forms a bridge between the natural sciences and the social sciences (ODUM, 1977). Using concepts borrowed from biology and geography, the socio-cultural approach to ecology views human societies as adapting or adjusting to environmental factors. Most ecological studies have focused on societies whose basic subsistence derives from hunting, gathering, fishing, shifting cultivation, or pastoralism. Regardless of the subsistence base, the general point of departure assumes that cultural patterns and social organization are always affected by ecological factors. Thus, it is

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[17] For a review of literature in the relationship between ecology and nomadic society see DYSON-HUDSON and DYSON-HUDSON 1980.

[18] In the traditional way of mobile livestock keeping, "Time" means course and periodicity, and "Space" means range and direction of wandering (SCHOLZ, 1991:83).

imperative to explore and sum up the "legacy" of traditional knowledge in nomadic society and further probe into the ecological essence (SCHOLZ, 1995). ODUM also stated:

> *"To survive in primitive society, all individuals needed to know their environment, i.e., the forces of nature and the plants and animals around them. Civilization, in fact, began coincidentally with the use of fire and other tools to modify the environment. Because of technological achievements, we seem to depend less on the natural environment for our daily needs; we forget our continuing dependence on nature."* (1983:2)

Actually, it is indisputable that ecology is the study of the totality or pattern of relations between organism and their environment (ODUM, 1983). The study of the environmental house includes all the organisms in it and all of the functional processes that make the house habitable. On the other hand, economics is translated as "the management of the household" (ODUM, 1983), and accordingly, ecology and economics should be companion disciplines. Owing to the close relationship between two disciplines, the views from two aspects will be adopted inevitably when man studies a complex ecosystem.

As the description mentioned in this Chapter, a rangeland ecosystem used by pastoralists is the base of pastoralism and most simply described as a plant-animal-human food chain. Crucial factors in this set of relationships include the cultural value of stock, the economics of husbandry, traditional patterns of herd management and migration, livestock production parameters, the grazing behavior, population dynamics, ecological impact of domesticated animals, the limits and spatio-temporal variability of water and vegetation sources and other defenses in range plants. Although protein - good grazing for the livestock – appears to be the primary determinant of nomadic movements, there are other factors in both the biotic and the social environment influencing movements of individual herders. The complexity of pastoralism presents in many interactions within and between trophic levels. One must study the differences between individuals, as well as the overall patterns of the groups, to understand the system of livestock management. With a sparsely settled, highly mobile population, actually observing the behavior of individuals and their herds will provide important, detailed information about individual actions and strategies that can be gained in no other way.

Owing to the properties of rangeland ecosystem, the interaction between human culture and the natural environment has been the topic of much academic debate. STEWARD (1955), in what he termed a **cultural ecological approach**, postulated the emergence of a core of institutions related to the fundamental processes of adaptation. Following his suggestions, many writers have paid special attention to the significance of natural resources, the techniques by which they are exploited, and the systems of production and exchange that develop. This cultural core is said to influence or largely determine such things as residential patterns, inheritance practices, the size and organization of local communities, and other economic, political, and religious institutions.

The new perspectives of cultural ecology[19] have helped to advance our understanding of the dynamic relations between physical environment, the use of domesticated food animals, and the organization of nomadic societies. The nonsocial factors in the ecosystem are often thought to affect the number and size of animals, the age and sex structure of herds, their rates of reproduction, morbidity, and mortality, the size of flocks, and their location during the year. In an ecosystem each species has peculiar capacities and requirements that facilitate survival in areas (or niches) where dependence on other species, or on kinds of subsistence activity, is less probable. In order to ascertain whether the adjustments of pastoral societies on the Qinghai-Tibetan Plateau to their environments require particular modes of behavior or whether they permit altitude for a certain range of possible grazing patterns, this study will adopt three procedures proposed by STEWARD (1955:40-41) for analysis:

- an analysis of the relationship between the environment and the subsistence system;
- an analysis of the relationship between a given subsistence technology and behavior patterns; and
- an evaluation of the extent to which other cultural aspects are affected by behavior patterns entailed in a given subsistence system.

It is undeniable that some ideas in this paper are drawn from **evolutionary ecology** to explain ecological patterns of traditional management practices and vegetation changes in the vicinity of pastoral camps and grazing routes. One of my basic positions is that traditional pastoralism is an intrinsic feature of the ecology of rangelands on the Qinghai-Tibetan Plateau as vegetation, domesticated animals, and human societies have co-evolved in these areas since the inception of pastoral technology. Thus, plant toxicity, browsing by domesticated animals, and exploitation strategies of humans are adaptations for survival on the part of different species of organisms, but these adaptations have provoked counter-adaptive responses on the part of affected species. Undisturbed pastoral systems, therefore,

[19] The concept "Cultural Ecology" means: "1) The study of the processes by which humans interact with the physical environment. 2) The analysis of the relationships existing between the natural environment and the distribution and activities of humans." (LARKIN and PETERS, 1983: 49)

are complexly interrelated to the adaptive strategies of all organisms in rangelands (NYERGES, 1979).

Other anthropo-geographers use the method of participant observation to analyze nomad cultures in terms of the ecological, economic, political and social pressures impinging on them (SCHOLZ, 1974; JANZEN, 1980; ZAROUG and OSMAN, 1991; BARRETT, 1992; ADAMS and DEVITT, 1992). In such analyses, features of nomad social organizations are interpreted as influenced by and responsive to a difficult environment and the herding technology. Anthropo-geographers, then, also have considered some traits of pastoral societies specifically in terms of ecological adaptations, but at the same time have tended to implicitly assume that the technology, the animals and the environment are unchanging givens in the system. As a result, these factors crucial to an understanding of rangeland ecology have not been given due consideration in terms of the future research.

The significance of the ecological history of pastoralism for development projects is generally clear – development strategies that disrupt previously established relationships can have disastrous, multiplying consequences because adaptive pressures on organisms are suddenly changed. The traditionally adaptive mechanism is and will be the approach or base for future development, if the internal and external conditions could not be totally changed. Research along the lines of that reported here from western Sichuan can eventually be used in formulating development strategies that are non-disruptive. In the end it is necessary to stress again that co-evolution in rangelands does not necessarily imply stability, but only that all organisms in the ecosystem are involved in a continuous process of adaptation to optimize fitness in the face of selective pressures generated and maintained by the long tenure of traditional pastoral activity in these areas.

As pastoralism at this point goes beyond its framework as a natural science, many problems can only be solved politically (SCHOLZ, 1991). It was argued that technicians should not take part in development procedure as long as they are only asked to correct the political mistakes as a sort of stop gap. Given strong public opinion, political difficulties can probably be overcome, but economic considerations remain the chief obstacle to any kind of comprehensive, long-range planning for environmental use. The problem derives from the sharp dichotomy between market and non-market values. Regardless of the political systems in different countries, manufactured market goods and services, are accorded high economic values, whereas the equally vital goods and services of nature, such as the conservation and rehabilitation of rangelands, remain mostly external to the economic system and are accorded little monetary value or at least in slow return. BROWN singles out four biological systems – fisheries, forests, grasslands, and croplands – as the foundation of the global economy and continues his commentary:

> "*The condition of the economy and of these biological system can not be separated. As the global economy expands, pressures on the earth's biological systems are mounting. In large areas of the world, human claims on these systems are reaching an unsustainable level, a point where their productivity is being impaired. When this happens, fisheries collapse, forests disappear, grasslands are converted into barren wastelands and croplands deteriorate along with quality of air, water and other life-support resources.*" (BROWN, 1981:433)

BROWN's scenario for "Building a Sustainable Society" (1981) calls for a systematic, government-backed, global conservation of resources, involving using less with greater efficiency. In reality, livestock production and pastoral development on the Plateau rest squarely on a combination of ecology, economics, biology and sociology. Ecology happens to be the most fundamental of influences, but to elevate one component above the rest is inherently dangerous. Ecology can provide a useful meeting point for other disciplines but, for most purposes, the more useful framework is that provided by livestock production systems. Ecology has a large part to play in molding production systems as well as in their evaluation, but it is the production system which is the summation of all determining factors. It is both neutral territory in the event of disciplinary conflict and, most important, it is the natural focus of the development process. For the most part problems arise only when the ecological perspective is pursued too far or too vigorously. To override ecology and cause pastoral settlement on the plateau is wrong, but to insist that an area of high ecological potential receive priority over one of low potential, irrespective of social benefit, is also wrong. The problem is accentuated when ecological priorities are seen in terms of conservation rather than development. It is good that there are ecologists whose principal concern is conservation, but those with regard for the Qinghai-Tibetan Plateau have somehow to tread a middle course which gives priority to the people and their perspectives while preventing ill-advised and destructive land use.

1.5 Definition of the Concept

Before the analysis begins, some concepts should be defined more precisely; because for any scientific research it is immensely important to define clearly the terminology, or at least the central concepts. Unless an event or a phenomenon is distinctly defined, it becomes difficult to identify the phenomenon, and it consequently complicates the discussion. In the following paragraphs discussion mainly concentrates on "sustainability" or "sustainable development", "nomadism" and "rangeland", other concepts mentioned in the context will be described separately in the chapter concerned.

1) "Sustainable Development" or "Sustainability"

Development is a process of becoming and a potential state of being (JOHNSTON et.al., 1986). The process of development is the means by which such conditions of human existence might be achieved. They, in turn, would necessarily involve people in a productive, crisis-free and non-exploitative set of relations with nature and in the struggle to remove oppression and exploitation from the relations between themselves. And yet the term is widely used to describe the state of particular societies and the processes of change experienced by them. Thus the term is commonly used to refer to an amalgam of characteristics (related to economic growth, welfare and modernization) ascribable to particular societies.

The discussion in the previous section has shown that **sustainable development** is a field of interest for a variety of disciplines and divergent theoretical approaches have been taken by various fields. As a result, a wide spectrum of definitions has emerged, emphasizing diversified perspectives. Until now, it is difficult to find one universally accepted and all encompassing definition of the term "sustainable development".

There are a number of concepts of sustainable development which reflect the values and objectives that adherents regard as important. Ecologists concentrate on the degradation of physical resources that sustain life in all its forms. Their objective is to preserve the global ecosystem for future generations and to minimize its current deterioration. Most environmentalists tend to view sustainable development in terms of the capacity of the natural resource base to maintain and increase human welfare measured in terms of both marketable and non-marketable goods and services. Perhaps the best-known definition is that given in the Brundtland Report, which advocated "*development that meets the needs of the present without compromising the ability of future generations to their own needs*" (World Commission on Environment and Development, 1987:43). The term "**sustainability**" is an abstract concept to describe this status of development process. The GTZ (1993) suggested sustainability that

Development activities should be conceived in such a manner that economic growth as well as the living conditions of the poorer population will undergo a sustained improvement. The development contributions initiated in bottleneck situations must ensure that regional rural development processes continue even after external impulses and contributions have been discontinued.

This could be further highlighted by the **operational meaning** of sustainability. The operational meaning of the term, as inferred from its definitions or descriptions provided by ecologists, environmentalists, economists, and other scientists (CONWAY, 1985; RAEBURN, 1984; TISDELL, 1988; CHAMBERS, 1987; 'FOOD-2000', 1987; and BROOKFIELD, 1988), which becomes clearer when related to specific situations, could be as follows:

Sustainability is the ability of a system (e.g. plateau pastoralism) to maintain a certain well-defined level of performance (output) over time and, if required, to enhance the same, including through linkages with other systems, without damaging what TISDELL (1988) calls the essential ecological integrity of the system.

Because of the time factor involved and the system's responsiveness to changing requirements, sustainability forms mere subsistence and is compatible with development. The definition of sustainability showed the different concepts of what is meant by this which is clear only at first glance. People found it rather difficult to find some detailed criteria for measurement in quantitative terms. By picking up the key threads from the mainstream debate on sustainability, we attempt to give operational content to some of the issues involved with reference to pastoralism (comprising all land-based activities) in plateau regions. Within the framework of this context sustainability means that *the long-term reproduction of the household as well as the long-term survival of the life-system, and that there are close interdependencies between these two.*

Instead of exact criteria of measurement, fields of sustainability were listed as a sort of reminder. Not only the classical **ecological-biological sustainability** (a) has to be taken into account but also the **socio-cultural sustainability** (b) and the **politico-economic sustainability** (c). The factors that influence the decrease or increase of this wider interpretation of sustainability are strongly interrelated (GTZ, 1993).

With respect to (a) the following were mentioned: – the diversity of ecological systems; – the climatic aspects with regard to sustainability; and – the different agro-ecological zones.

Regarding (b), it was agreed that the contrast between modern and traditional world views affects sustainability, and within this context labor-related aspects need special attention. Within the field of politico-economic sustainability (c), influencing factors depend, in particular, on the market in all its aspects. In the last sectors, negative processes are relatively easy to remedy by efforts to maintain sustainability. The close interrelation of all these aspects was once more exemplified by degradation related to land tenure. Social, economic, political and ecological factors combined to cause these effects. A difference depending on a short, medium or long-term point of view was mentioned, stating that, in most cases, it is the government that tends to have the short-term view and not the peasant household. But nomads are often not able to react in time to the defects they notice. It should be stressed again that sustainability is not a technical problem. Therefore, the linkages between natural and social sciences are an important field of research if one wants to understand the reactions of households to certain innovations or actions that take place.

2) "Pastoralism" and "Nomadism"

As a result of extreme climatic conditions in many regions of the world, the livestock industry (called "**animal husbandry**") represents the only possible kind of land use. It appears in various economic forms as sedentary livestock industry, as migratory livestock industry, and as stall-feeding.

The term "**pastoralism**" refers to the way of life of pastoralists[20], their socio-economic institutions, and land-use systems. In this context it ascribes to the description that *the practice of breeding and rearing certain herbivorous animals so that be these means alone it is possible to satisfy human needs with regard to food, clothing and shelter. Negatively it may be defined as the complete absence of agriculture* (JOHNSTON et. al, 1986). In fact, pastoralism could be defined as an animal husbandry excluding stall-feeding, i.e. keeping livestock in feedlots. At present, several types of pastoralism have been identified, notably **commercial pastoralism** - conducted on the large grasslands of the world and regularized for the efficient production of meat for world consumption – and **pastoral nomadism**[21] – a wandering subsistence economy now seen to be declining in the world (SCHOLZ, 1991a).

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[20] "Pastoralists" can be defined as people who derive most of their income or sustenance from keeping domestic livestock in conditions in which most of the feed eaten by their livestock is natural forage, not cultivated fodders and improved pastures (SANDFORD, 1983).

[21] "Nomadism" is valid in German and French speaking areas. In the English speaking world, other mobile life-style groups such as gypsies, hunters and collectors etc. are also described as 'nomads'. The real, livestock-keeping nomads are, as a rule, distinguished by means of the additional word 'pastoral'. In this context "pastoral nomadism" are used synonymously.

The **migratory livestock industry**, which was called "**mobile livestock keeping**" by JANZEN (1993, 1995), is that part of the industry in which livestock is driven from range to seasonal range throughout the year. The ranges cannot be used during the whole year and are situated too far away from a fixed station to allow direct management. Nomadism, semi-nomadism, transhumance, and other variations of a mobile way of animal husbandry belong to these traditional forms of the migratory livestock industry. Traditional forms exit not only between the migratory and sedentary livestock industry but also between the various forms of migratory livestock industry.

Highlighting and modifying the conceptions given by SCHOLZ (1982; 1991; 1992; 1995), JANZEN (1982; 1986) and other writers (GRIGG, 1974; JOHNSTON, 1986; RINSCHEDE, 1988), some terms concerned this context are explained below.

The term "**nomadism**" is taken as meaning *a life-style and economic system whereby the groups concerned (tribe, tribe-section, extended family etc.) carry out episodic and/or periodic migrations, together with their main source of income, livestock, in order to ensure their livelihood and on the basis of special physio-economic and/or even socio-political conditions in specific areas. They usually carry their housing accommodation with them on their travels and possibly also carry out other extra-pastoral activities on a temporary basis (arable farming, trade, transport services, wood/medicinal herbs collection, employment as agricultural laborers, etc.)*.

The expression "**semi-nomadism**" is used to describe *those life-styles and economic systems for which migration and livestock are still the most important economic factors, but where extra-pastoral activities -- in particular arable farming -- are also of great significance. Futher typical characteristics of semi-nomadism are shorter migration distances with greater frequency of small livestock-keeping and, apart from portable housing accommodation, the possession of permanently fixed huts/houses in long-term settlements around cultivated areas or other places of employment, where the groups or parts of them remain stationary for a large part of the year.*

Many writers have emphasized the differences between **true nomads**, who have no permanent dwellings and do not practice farming, and **semi-nomads**, who cultivate land for part of the year, and move with their herds during the dry or cold season. Others have emphasized the difference between **vertical nomadism** and **horizontal nomadism**, and the pattern and distance of migratory movements. **Mountain nomadism** is representative of vertical nomadism, and was considered as one variety of semi-nomadism adapted to orographic conditions (SCHOLZ, 1992), in which *nomads migrate seasonally with their livestock along the mountainous relief upwards from their base rangelands situated in the mountain valley or foreland partly over intermediate pasture stages to the highest mountain pastures and vice versa*. This seasonal movement is caused by the different characteristics of the pastures in terms of altitude, thermal or agro-economical conditions.

Whilst most writers have emphasized the differences based on the differently representative grazing animal[22], such as cattle nomads in West Africa, horse nomads in Turkestan, camel nomads in Arabia or Sahara, and yak nomads in Tibet.

Nomadic herders rely solely upon natural vegetation for their livestock's fodder, and they traditionally neither sow pastures nor store forage. As they live in areas whose cold precludes all-year grazing, they are forced to move their herds in search of new pastures. The migrations are not random, however, and are regularly employed by nomads as a survival strategy. Consequently, the primary reason for migration was thought that:

> *"The main factor is that the change of location was determined by the need for subsistence goods rather than marketing or economic plans. Also, various examples prove that change of location more or less consciously was a measure against over-use or exhaustion of the local fodder and water supply. Therefore, the recurring migration between various regions completing one another principally guaranteed the long-lasting use and maintenance of the scarce natural resources and prevented diseases."* (SCHOLZ, 1991:83)

On the eastern Qinghai-Tibetan Plateau, where nomadism is vertical rather than horizontal, each group of nomads follows a certain route each year, although perhaps stopping at different places on the route to graze from one year to another. The route, from the low altitude, such as broad valley, to alpine pastures, is so designed to maximize the optimum use of seasonal variations in grazing. With the contemporary decline of nomadism, the semi-nomadic characteristics are more common than pure nomadic characteristics nowadays throughout most of the Plateau and its fringes.

3) "Rangeland" and "Range Management"

Grasslands form an important part of the world's vegetation cover. Their importance is ecological as well as economic. Grasslands in good condition protect the soil against water

[22] For more detailed literature in different nomadism see SCHOLZ 1992.

and wind erosion and provide grazing for man's domesticated livestock as well as many species of wildlife. In this context **grassland** means *all kinds of land where vegetation constituted solely of one layer dominated by grasses and grass-like plants* generally. This layer may contain variably herbaceous plants, including graminoid plants, herb, forbs, and even weeds. I also adhere to that meaning and formation pointed out by WERGER:

> "*For a vegetation to qualify as a grassland there also can be another lower layer of small plants below the grass-dominated layer and, finally, even some emerging shrubs or trees may occur, but their cover should be less than 1% of the surface area, i.e. on average more than eight crown diameter apart.*" (1983: 107-108)

Conceptually, **rangelands**. are defined as '*those areas of the world, which by reason of physical limitations – low and erratic precipitation, rough topography, poor drainage, or cold temperatures – are unsuited for cultivation and which are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife*' (STODAR et al., 1975). This definition includes grasslands as well as shrublands and forest areas often used by grazed animals. The term '**range**' imples broad, open unfenced areas over which grazing animals roam; but as ranglands are more intensively managed, fences – once useful for distinguishing range from **pasture** lands – are to be found increasingly on rangelands. In western Sichuan, as well as in the Eastern Tibet, high-frigid **meadow** is the main body of rangeland, which is mainly compostеd by perennial and eumesophytic (in medium habitat) herbaceous plants, and the most frequent life-forms are hemicryptophytes and geophytes (see 3.4.1 in this text).

Four other definitions should be mentioned here. "**Natural pastures**" are considered to be the herbaceous complex if they have not been sown or planted by man and consist of plant species indigenous to the area in which the grasslands occur. "**Semi-natural pastures**", or namely "**semi-artificial pastures**", on the other hand, have been sown or planted by man, or greatly modified through inclusion of one or more exotic forage species – grasses or legumes – in the sward, but not intensively managed. Indigenous species have been allowed to establish or persist, and the grasslands are more or less in equilibrium with the natural vegetation in the area where they occur (HOLZNER, WERGER and KUSIMA, 1983). On the contrary, "**artificial pastures**" refer to the pastures consisting of artificially grown grass, normally established on land that has been plowed, and intensively managed through reseeding, fertilizing and controlled grazing. In general, artificial pastures contain more nutritious grasses in greater quantities and valuablly exotic species introduced to replace native grass forage. It should be mentioned, however, that in western Sichuan there are not real "artificial pastures" in this mean. The "artificial pastures" in western Sichuan means the pastures grown artificially for cutting grasses. In the end, "**cutting pastures**" or "**hay meadow**" are the pastures where plants are cut and prepared for hay or green fodder (silage).

Finally, **range management** is '*the science and art of optimising the returns from rangelands in those combinations most desired by and suitable to society through the manipulation of the range ecosystem.*' (STODAR et al., 1975). Range management combines the biological, physical, and social sciences. It is biological because it deals with vegetation and the responses of animals which harvest the vegetation. It is physical because climatic, topographic, and hydrologic factors affect range use. It is social because the needs of society determine how range resources are used. There is a tendency at present to emphasise the scientific aspects of range management, and, whereas science is vital, range management is more than a science. It is also an art, since range managers need to take the scientific information available and synthesise it into practical management plans. This requires the ability or perception to detect changes taking place on the rangelands and then the skill to adjust the plans to range use. This 'feel' for rangelands is what makes a good range manager and can only be acquired from spending considerable time in the rangelands, closely observing what is taking place (MILLER, 1990; 1995a).

4) Rangeland "Ecosystem" and some corresponding concepts

The ecosystem is the basic functional unit in ecology, since it includes both organisms and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth. This level of organization must be of primary concern for us if society is to begin implementing holistic solutions for the problems now emerging at the level of the biome and the biosphere (ODUM, 1983). In this text the author will adhere to the definition given by ODUM:

> "*Living organisms and their nonliving (abiotic) environment are inseparably interrelated and interact upon each other. Any unit (a biosystem) that includes all the organisms that function together (the biotic community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined biotic structures and cycling of materials between living and nonliving parts is an ecological system or* ***ecosystem****.*" (1983:13)

The term "ecosystem" implies a dynamic and functional approach to ecology. Such an approach is essential and appropriate, for ecology is a dynamic science. However, it may be helpful to discuss some static and classificatory concepts of ecology as they relate to rangeland, before considering its dynamics a functional system. **Populations** of both plants and animals are usually found to be grouped together, or mixed, in space and time; such assemblages are frequently called **communities**. Communities may be large or small, but the biosphere (all the plants and animals on earth) is conceived as comprising a small number of basic communities called **biome-types**, of which the vegetation component is often called a **formation**-types or type of vegetation (TANSLEY, 1946). Each biome-type is physiognomically distinct, although the species of which it is composed, including the dominant species, may not be the same in different parts of its range. The concept of **dominance** relates to the community structure of vegetation in particular; it is perhaps a less useful idea when considering animals. It is usual to classify as dominant those species in a community which most influence the other species (so-called companions) and are least influenced by them. The communities of a biome-type dominated by different species are the biomes which together comprise the different biome-types.

Although an ecosystem may be characterized in terms of synoptic terms, i.e. by inventory of its components, both biotic and physical, the essential features of the term are: (a) that it implies a functional and dynamic relation between the components, going beyond a frozen mosaic of species distribution; and (b) that it is holistic, implying that the whole possesses emergent qualities which are not predictable from our knowledge of the constituent parts.

The temporal dimensions of the system are also amenable to study, e.g. population numbers through time are often followed. For most species each ecosystem has a carrying capacity, i.e. an optimum level for a particular population, which may be a simple number or subject to fluctuations of various kinds. Again, the changes in species composition and physiognomy of an ecosystem through time may be studied, as in the secondary succession from a desertifized bare ground through various types of vegetation to a stable, self-reproducing grassland. When succession has apparently terminated at an ecosystem type which sustains itself and gives way, under natural conditions, to no other, then this is said to be a mature or climax ecosystem.

The applied side of the concept is evident in the idea of **productivity**, which is the rate of organic matter production per unit area per unit time by an ecosystem and which can be used to compare natural ecosystems with those affected by human activity and indeed with totally human-made ecosystems. The concept of **stability** is important in the human-biophysical interface because it related to the resilience of an ecosystem to perturbation. If there is a particular act of environmental manipulation, will an ecosystem recover its former state (given the cessation of the impact) or will it not? That a perturbation may be human-induced has led to the introduction of ecosystem-type thinking and practice into geography (STODDART, 1965). So geographers among others have studied ecosystems with a large human-induced and directed component such as agriculture (the term agro-ecosystems sometimes used) and pastoralism.

1.6 Materials and Methods

Data and literature used in this study were collected by the author mainly during two field trips for the purpose of this research in western Sichuan and during some field expeditions earlier which were organized by the Chinese Academy of Science on the Qinghai-Tibetan Plateau. The field trips were carried out together with Mrs. Manderscheid for the first time in 1991 (June to September) and then in 1992 (September to November). Altogether, seven months were spent in *Zamtang* and *Hongyuan* which are located in the mainly pastoral area of western Sichuan. The principal aim of these two trips was to collect primary data on ecological conditions of rangeland, traditional and modern management of rangeland and pastoral changes through direct field survey, as well as to gather other types of information useful for this study from different sources. The archive work carried out both in China and in Germany made it possible to examine a large amount of literature on rangeland degradation and sustainable development in pastoral areas of the Qinghai-Tibetan Plateau and in other Third World countries or underdeveloped areas. It also helped the author to investigate various other studies conducted previously and relevant for this study. The main methods employed in the course of fieldwork are as follows:

1.6.1 Reconnaissance Survey and Selection of Sample Areas

The purpose of reconnaissance survey was to identify the type of pastoralism in the western Sichuan. In this regard a few studies concerning the location of nomadism were consulted. Before drawing the sample, extensive tours throughout the western Sichuan, specially northwestern Sichuan were also undertaken by the author and colleagues in the autumn of 1990 to identify such areas. Identification of pastoral areas was done mainly on the basis of visual observation and introduction of local officials and analysis of published data.

1.6.2 Interviews and Observer Participation

In-depth interview schedules, participant observation, open-ended interviews, sample surveys, and socio-demographic questionnaires are the basic research tools used in this study for the analyses of development anthropological aspects. The detailed data on household size and composition, access to resources only exists for the pastoral nomadic groups in *Zamtang* and *Hongyuan*. This material is derived from the author's own fieldnotes (1991-1992).

Interviews were undertaken on the basis of a questionnaire prepared within the area under investigation. As the pastoralists are given to both under- and overstatement, answers to the questionnaire were subjected, whenever possible, to repeated checking. I gathered data by general discussions with officials and others in the context of daily observations, together with in-depth and open-ended interviews of households. Unless otherwise stated, the secondary source statistics have been gathered from locally administrative departments, or are from official publications of the State Statistical Bureau. Those presented here focus more on the situation today rather than on possible suspect longitudinal comparisons.

The more traditional anthropological field method of observer participation was constantly used when the author was staying with groups that showed distrust or were reluctant to provide information. In research conducted in 1991 and 1992, I spent seven months in contact with nomads and observed their movements with their herds during summer, autumn and winter. The backbone of empirical information, however, was collected by sample survey, in-depth interview schedules and socio-demographic questionnaires.

In October and November 1992, a second active period of field work was undertaken. During this short period of time the author traveled extensively visiting the alpine areas populated by the major pastoral nomads in *Zamtang*. Again, participant observation was used as a fundamental research tool. However, because of the brief nature of each visit, interview schedules, open-ended interviews and a pasture allocation questionnaire formed the core of data collection techniques. It was not possible to randomly sample the population as time was too short and the distances that needed to be covered too great. Work in each pastoral nomadic area required first a visit to the government appointed representative in the region who was then interviewed on the subject of traditional and modern pasture use and allocation. This visit was followed by one to the local leader. Here, a structured interview was conducted along with a pasture allocation questionnaire.

1.6.3 The Survey of Rangeland Ecology and Quadrat Methods

Information on vegetation and the ecological conditions at grazing areas is based on some plots (Quadrats). Among them, four series of twelve plots were conducted separately in winter and summer pastures; and with the gradient of altitude two series of eight plots were set out from winter to summer pastures at 1 km in distance intervals or 50 m in altitude intervals. Two series of plots proceeded in the radial line of settlement at the same altitude to detect the changing trends of pasturelands corresponding to human activities. The other two series of eight plots were set on two sides of fences.

Each 1×1 m² quadrat for herbaceous plants or 5×5 m² for shrubs was laid out in alpine area; ridge slopes and the frequent streambeds cutting through plains with their own characteristic vegetation associations, were avoided. At each plot following information are recorded:

- Identify of each species: The plant species occurring within each quadrat were listed. The specimens which can not identified by author are brought to different taxonomists in Chengdu Institute of Biology, Chinese Academy of Science (Academia Sinica), or Department of Biology, Sichuan University[23]. Greater parts of the collection have been given to the Herbarium of the Chengdu Institute of Biology, Chinese Academy of Science;
- Height of vegetation: Change in structure may be measured by simply placing a ruler vertically on the ground and reading of the height of the vegetation. It is usual to ignore inflorescence. Although a "mean height of vegetation" is largely fictional, very useful results about structure can be achieved by this very simple method;
- Abundance of herbaceous plants or number of shrub in the plots: The abundance of plant species in rangeland may be estimated using the "frequency symbols" familiar to all ecologists from the pages of TANSLEY (1953), which are listed in Table 1.4;
- Coverage of plants: Quadrats need not be used in assessing vegetation by means of frequency symbols, which record, rather imprecisely, the abundance of different plant species in the vegetation. It is often more helpful to record the cover of the species; quadrates were then be used. Cover is the area of ground which a species occupies, or the area of shadow cast by that species when illuminated directly from above. The BRAUN-BLANQUET scale (Table 1.5) of cover is used in this text, which is graded from 5 to 1 and a +;

[23] Taxonomic errors as evident in the specimens determined in various herbaria by different taxonomists could not be excluded by the author.

- Yield of fresh grasses (overground parts): The overground parts of fresh grasses in one square meter quadrat were cut down and their weights were measured at once; meanwhile, plants were measured separately according to the classification of *Graminae, Cyperaceae*, Legume, forbs and harmful plants; and
- Habitat: When record the vegetative characters, environmental conditions were written down at the same time.

Table 1.4 Frequency Symbols and Their Meaning

Symbol	*Meaning*	*Symbol*	*Meaning*
D	Dominant	occ	Occasional
co-d	Co-dominant	r	Rare
A	Abundant	vr	Very Rare
F	Frequent	l	Local, a suffix used to qualify other symbols

Source: CRONQUIST, 1982

Table 1.5 The Braun-Blanquent Scale of Coverage

Coverage	Symbol
76 - 100%	5
51 - 75%	4
26 - 50%	3
6 - 25%	2
1 - 5%	1
<1%	+

Source: DUFFEY et al., 1974.

1.6.4 Mapping

Mapping was used to record all typical instances of the traditional patterns of life and of seasonal movement. The main emphasis in this connection was put on the detailed illustration of patterns of settlement and mobility, as well as of land use.

These methods were then supplemented by the collection and evaluation of statistics, reports and old manuscripts. The most useful material in this connection was that provided by the official agencies involved in the investigation.

Some maps were drawn to illustrate the distribution of nomadism, animal husbandry or different livestock, and describe the changing rules of climatic factors. Finally, it should be declared that all of the international boundaries in the maps of this book are not necessarily authentic.

2. GEOGRAPHY OF STUDY AREA

2.1 Studying Frame - The Western Sichuan

2.1.1 Physical Conditions and Animal Husbandry of Sichuan Province

Sichuan Province is located in the hinterland of southwest China (Fig. 1.2). More than 111 million people in 1993 make their home on the province's 567,000 km². The population is comprised of people from 15 nationalities, such as *Han*, *Yi*, Tibetan, *Qiang*, *Miao*, *Tujia* and *Hui* etc.

Lying in the west of the subtropical zone of China, Sichuan is located in the transitional zone between the Qinghai-Tibetan Plateau and the plains in the middle and lower reaches of the Yangtze River (*Chang Jiang*). And with a tilted topography from northwest to southeast, it has numerous types of landform, clear vertical changes, and relatively great regional differentiation, thus forming distinct regional features. In general, if the *Longmen* Mountains, *Daxiangling* Mountains, *Daliangshan* and *Xiaoliangshan* mountains are taken as the limits, Chengdu Basin is situated to their east and high mountains and plateaus are to their west. So far as its geographic position is concerned, Sichuan crosses eight latitudes (26°2'-34°0'N) from north to south and thirteen longitudes (97°0'-110°0'E) from west to east, with a relative height difference of more than 7,000 meters (Fig. 2.1).

The high mountains and plateaus in Sichuan above 3,500 m a.s.l take up 35% of the total land surface of Sichuan, which is distinguished by a cold climate, strong solar radiation, and a population of Tibetan pastoral nomads. The mountains between 1,500 m and 3,500 m a.s.l make up 23%, with an apparent vertical climate which is suitable for the comprehensive development of farming, forestry and animal husbandry. The low mountains and hills below 1,500 m a.s.l amount to 39%, with warm, plentiful rainfall and a climate suitable for the production of grain and cash crops. Plains, i.e. Chengdu Basin, only occupy 3% of the total land in the Province (Fig. 2.2).

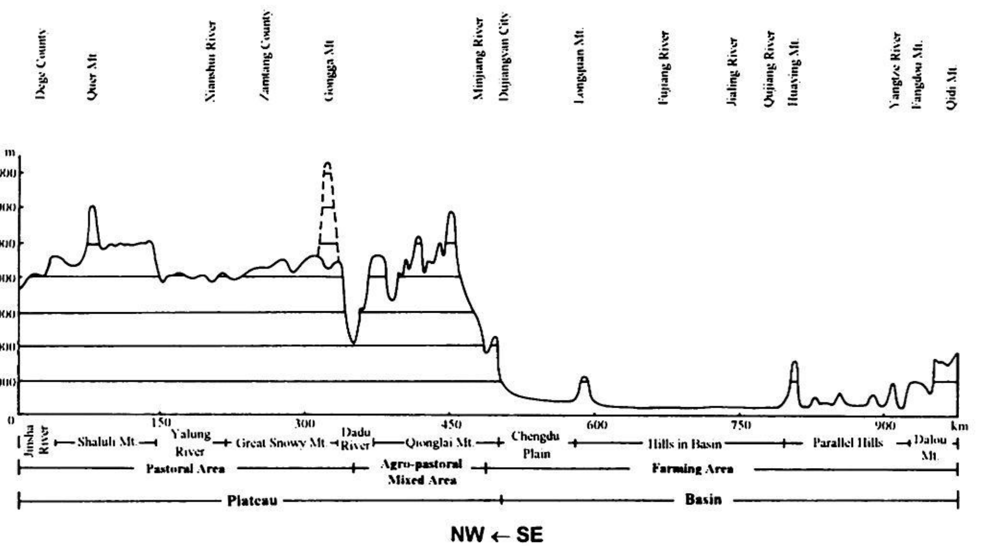

Fig. 2.1 Geomophological Profile of Sichuan
Source: SICHUAN ANIMAL HUSBANDRY BUREAU (ed.), 1989

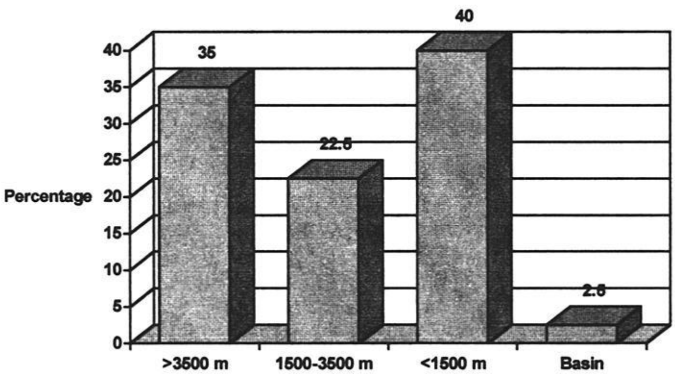

Fig. 2.2 Composition of Landforms in Sichuan
Source: Editorial Board of "Vegetation in Sichuan", 1980.

All these, along with its complex landforms, exert a great influence on its climate, soil and vegetation. As a result, these natural elements have an obvious horizontal and vertical zonalities. Broadly speaking, in landforms, Sichuan extends westwards from basins and hilly areas, gradually through low, medium and high mountains into plateaus (see Fig. 2.1). Its climate crosses warm and humid climate in the basin, semi-humid and cool mountainous climate, and cold and dry plateau climate. In its vegetation, one finds successively an evergreen broad-leaved forest zone, a dark coniferous forest zone and zones of shrubbery and meadow rangeland.

According to the survey of rangeland resources in Sichuan Province carried out during 1979-1987 (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989), there are 22.5 million hectares of natural rangeland in Sichuan, which make up 39.76% of the total land, of which there are 19.6 million hectares of available rangeland, accounting for 34.59% of the total land and three times the present tillage land. These range resources not only play an important role in national economic and environmental protection, but also are related to the development of livestock husbandry and the improvement of the living standard of local people. In relation to the geomorphologic features and the distribution of rangeland resources, the structure of animal husbandry in Sichuan differentiates in three regions (Fig. 2.3):

1) Pig-breeding in Basin (I)

Owing to the ideal hydro-thermal conditions and fertile soil, traditionally developed farming, and shortage of natural rangeland, pig-breeding has developed, which depended on the provision of fodder and grains, and form the basis of animal husbandry in the Basin, where the number of pigs make up 86.0% of the total numbers of livestock, besides which goat making up 5% and cattle 2.3%. This region is populated by *Han* farmers, who play the dominant role in rural societies. In additions, *Tujia*'s farmers are scattered mainly in the southeast of this region.

2) Cattle, goat and pig mixed-breeding on the periphery of the Basin (II)

Hill and low mountains are distributed around the Basin, accompanying the worst tillage land and popular pastures on slopes, which provide a fundamental condition to develop domesticated herbivores and pigs together. In this periphery cattle make up 33% of the total numbers of livestock in Sichuan and goats 17%. The domesticated herbivore amounts to almost 25.3% of the total livestock in this area. The numbers and proportions are more than that in the Basin and there is more potential to develop. Anthropologically, various ethnic groups are distributed in this region, such as *Qiang* (*Kiang*) and *Hui* in the northwest (upper reaches of *Minjiang* River), *Yi* in the southwest (*Daliangshan* and *Xiaoliangshan* Mountains), *Han* in the north (*Daba* Mountains) and Tibetan on the western fringe.

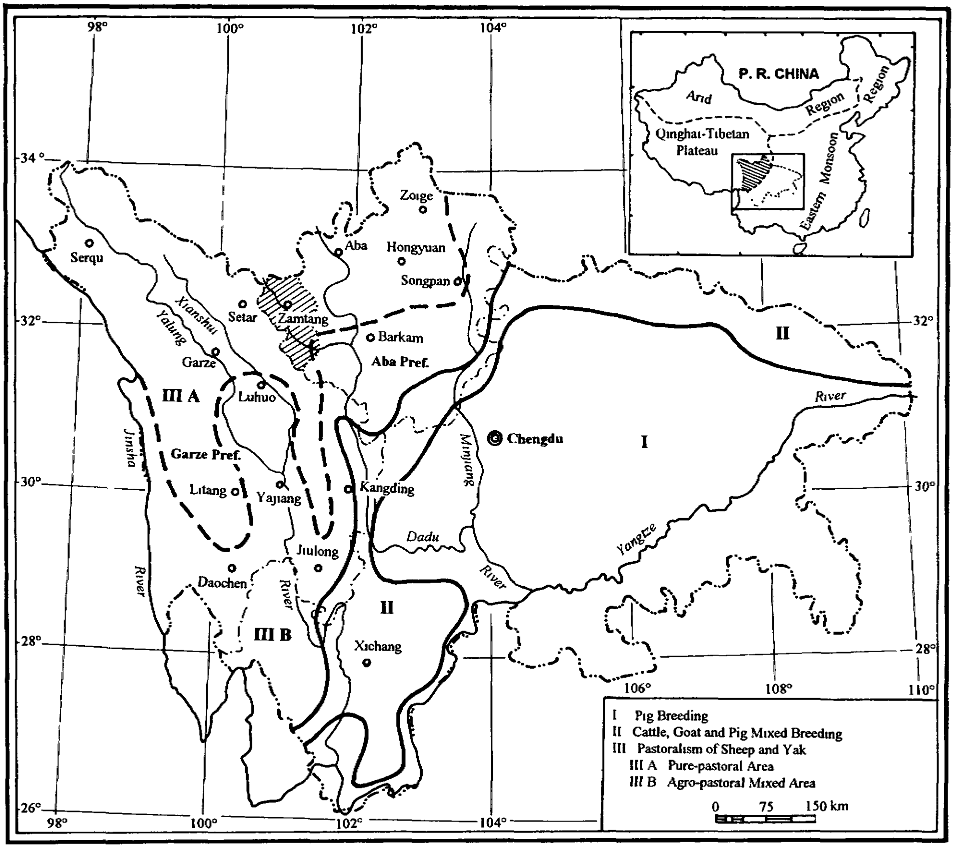

Fig. 2.3 Distribution of Different Animal Husbandry in Sichuan
Design: WU NING

3) Pastoralism of sheep and yak on the northwestern Plateau (III)

With the extensive rangelands, the northwestern plateau is the most important base for Sichuan to develop herbivore husbandry. The number of herbivores take up 76% of the total numbers of the Province, among which sheep and goats amount to the most, followed by yak, *Dzo*[24] and cattle. Yak and *zu* make up 80% of the total numbers of stock in the Province

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[24] "*Dzo*" (male), or "*Dzomo*" (female), is the crossbreed between yak and cattle (*Bos taurus*), which can date historically from 3,000 years ago when Qiang nationality had adopted this technique to reproduce animals. This word comes also from Qiang's language. When *Dzomo* crossbreeding with yak continually, after five generations atavism occures, i.e. the final result is yak. In Aba Prefecture the cross-breeding is only carried out for two generations. The F1 animals are called '*Pian Niu*' and F2 called '*Za Niu*'. '*Za Niu*' further canbe divided into two kinds: '*Mao Za*', the progeny between male yak and *Dzomo*; '*Huang Za*', the progeny between male cattle and *Dzomo*.

and 20% of them in China. Sheep and goats comprise 23% of them in the Province. In this area the yield of beef and mutton occupies 26% of the total production of the Province. Tibetans are the main ethnic group spread on the Plateau.

2.1.2 Ecological Potential and Constraints of Western Sichuan

The western Sichuan is the vast area between the line of *Longmen* Mountains - *Dadu* River and *Jinsha* River (the upper reaches of the Yangtze River) locating between 97°26' - 104°27' E and 27°57' - 34°21' N. The total area of this region is about 236,000 km², amounting to 41.6% of the provincial total, among which there are 13.9 million hectares of rangeland and 12.18 million hectares of available rangeland, accounting for 61.83% and 54.13% respectively of the total rangeland of the Province. Administratively, this region is divided into the Garze Tibetan Autonomous Prefecture and the Aba Tibetan and Qiang Autonomous Prefecture, which include 31 counties and 556 *Xiang*. The population in 1993 was 1.61 millions, which account for 1.46% of the provincial total (SICHUAN STATISTICAL BUREAU, 1994).

2.1.2.1 Topography and Landform - their Effects

Topographically, western Sichuan is a southeastern extension of the Qinghai-Tibetan Plateau, the average altitude of which above sea level is 3,500 meter. Mountains with an altitude above 4,000 m amount to 70%, and those above 4,500 m make up 60%. There are five mountains with the altitude above 6,000 m, i.e., *Gongga* Mountain (*Minya Konka*) (7,556 m), the main peak of Great Snowy Mountains; *Genie* Mountain (6,204 m), the main peak of *Shaluli* Mountains; *Siguniang* Mountain (6,250 m), the main peak of *Qionglai* Mountains; the main peak of *Quer* Mountains (6,168 m); and *Gongga* Snowy Mountain (6,032 m).

Owing to the rise of ist crust, western Sichuan has a marked north-south topographical trend, and consists mainly of many high mountains, deep valleys and plateaus. In the northwest, it belongs to the flat plateau, a kind of high tableland, with smooth slopes and wide valleys. These plateaus are generally 3,500-4,500 m with the relative altitude difference of about 50-200 m. The southeastern part belongs to mountainous areas, where, with the change of the direction of flow of rivers, from west - southeast to south - north, the mountains have been so deeply incised by rapid rivers that they became magnificent with deep valleys, which are so-called *Hengduan* Mountain Systems (Transection Mountains). The elevation difference between valley floors and mountain tops is more than 2,000-3,000

m. For example the elevation of the *Dadu* River in *Luding* County, Garze Prefecture is only 1,400 m, but that of the *Gongga* Mountain (the highest peak on the eastern Qinghai-Tibetan Plateau and only 25 km away from the River) is 7,556 m. As to the sloping topography, excepting *Baihe* (White River) and *Heihe* (Black River) in *Zoige* County emptying into *Huanghe* (Yellow River), most of the river systems in western Sichuan flow southward into *Jinsha* River (the upper reaches of *Yangtze*).

The rise of this region is a synchronous process with the Qinghai-Tibetan Plateau, which not only produces a unique climate and landscape on the plateau itself but also imposes important effects on the climate and landscape of the surrounding areas. In line with the description given by XU and PEEL (1991), the main effects are synthesized as follows:

Firstly, the plateau serves to bar the north-bound air current coming from the Indian Ocean. Today the south-west monsoon has to travel through gaps and canyons to move northwards, and is unable to go very far. Even if a fraction of the south-west monsoon happens to get through the gaps and canyons, the moisture carried by the wind will be trapped on the south slopes and precipitated as snow and rain. In western Sichuan this makes it almost impossible for the moist air current to surmount the obstacles of *Gongga* Mountain and reach the flat plateaus to the north, not to mention Xinjiang-Inner Mongolia Arid Region. Hence the unusually low atmospheric moisture and rainfall there.

Secondly, unlike other regions of high altitude, the immensity of the area and its height tend to make its atmosphere a source of cold in winter and of heat in summer. During winter the regional atmosphere becomes a cold high-pressure atmosphere, and the surrounding free atmosphere at the same altitude becomes a depression. This gives rise to a north-east wind over the plain to the east of the plateau, i.e., the western periphery of Sichuan Basin, which reinforces the north-east monsoon, due to the distribution pattern of the land and sea. This not only leads to a low temperature in the east of China but also aggravates the aridity in north-west China. In summer, a warm low pressure appears over the plateau and reduces the subtropical high pressure at this latitude. The rainfall over a large area in the east of China is greatly increased by this warm low pressure, which makes the south-east and south-west monsoons there even more powerful.

Thirdly, the height of the Qinghai-Tibetan Plateau also causes the prevailing northern air current in the Northern Hemisphere to diverge in winter into two branches around the plateau and then to converge to its east and continue to move eastwards. This partition process moves the westerly wind belt several degrees of latitude to the south. When the partitioned air flow subsequently converges a trough is formed; the cold air behind the through keeps moving southward and results in frequent southbound cold waves. In summer, because the prevailing westerly wind belt moves north, the southern branch disappears. However, the south-west monsoon then makes a northbound detour and often forms low-pressure eddy currents which move eastward, resulting in heavy rains and showers. This is the main source of rainfall in the Yangtze (*Chang jiang*) Valley and its vicinity in East China.

2.1.2.2 Climates and their catastrophes impacting on pastoral production

a) The general features of climates

Climatically, it is cool in the whole region, and the dry and wet seasons are apparent without an absolute frost-free season. The annual mean temperature is about -1.6 - 3.2°C (Fig. 2.4) and the annual accumulated temperature above 10°C is generally between 1,000 and 3,000 °C. The maximum monthly mean temperature (in July) is about 8 - 12°C (Fig. 2.5) and the absolute minimum temperature is as low as -40°C. In general, the annual difference of temperature is 16 - 22°C and the daily difference is as high as 10 - 16°C. The annual duration of sunshine on the Plateau is 1,800 - 2,600 hours and the annual solar radiation 120 - 150 Kcal per square centimeter.

Because of its high altitude and distance from oceans, the annual mean relative humidity is 60 - 70% and the annual precipitation is 500 - 800 mm (Fig. 2.6). The warm and humid monsoon coming from the southeast hindered by high mountains, there is more rainfall on the windward side than on the lee side. Crossing 30° longitude northwards, the surface of tablelands keeping completely and terrain becoming smoothly, the regional differentiation of precipitation is small, and the mean annual precipitation is about 700 mm. But going 30° southwards, the regional differentiation of precipitation change greatly, ascribing to the undulating landforms, greatly relative vertical difference. For instance, in the lower branch of *Yalung* River, the precipitation is high and always more than 1,200 mm, but in the valley of *Tongtianhe* River and in *Batang* County, located in the valley of *Jinsha* River, it is as little as 600 mm. On the other hand, the rainfall distributes unevenly in all regions and 70%-90% is concentrated between April and October.

Day length, temperature and precipitation are all influential features on the climate on the Qinghai-Tibetan Plateau. However, day length is rather uniform and precipitation is a dominant influence only where the relative altitude changes greatly, or in a macro-scale, such as compared western Sichuan with western Tibet or western Himalayas. Concentrating in western Sichuan, particularly in that pastoral area where nomadism or semi-nomadism is dominant, the mean annual precipitation is less than 800 mm, and the influence of precipitation could be neglected basically. The dominant influence overall is therefore temperature (Fig. 2.7; Table 2.1).

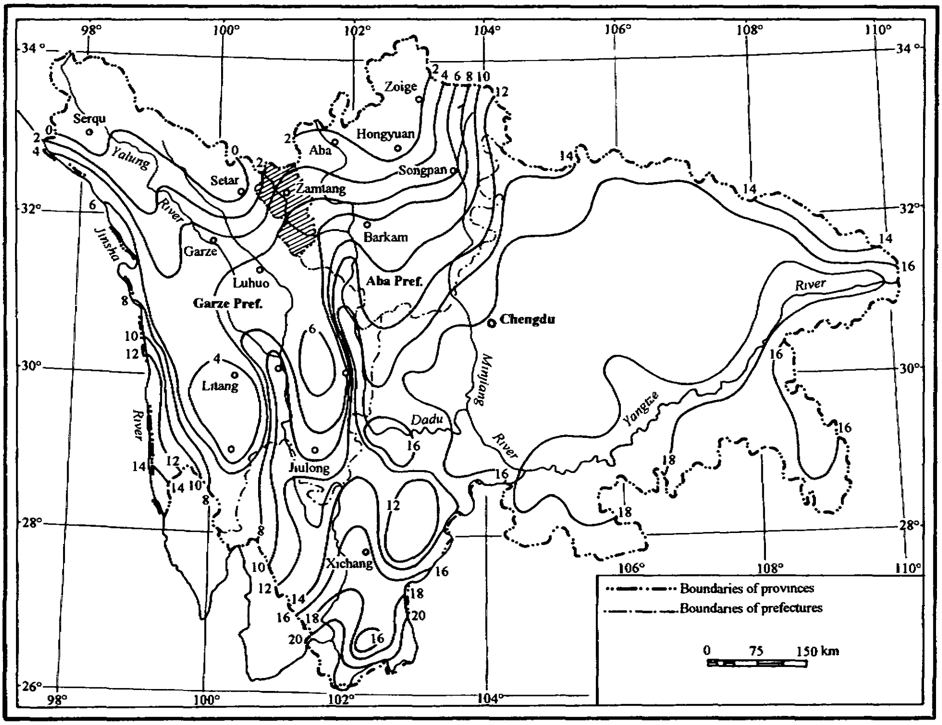

Fig. 2.4 Isotherm of Annual Mean Temperature (in °C) in Sichuan
Source: EDITORIAL BOARD OF "VEGETATION IN SICHUAN", 1980.

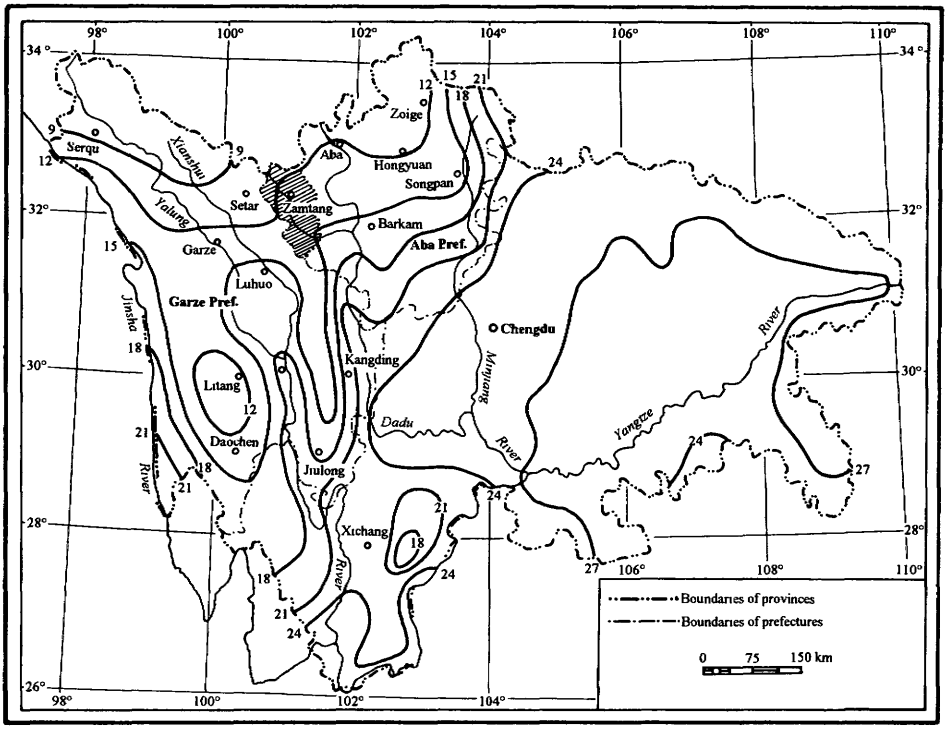

Fig. 2.5 Isotherm of Mean Temperature in July (in °C) in Sichuan
Source: EDITORIAL BOARD OF "VEGETATION IN SICHUAN", 1980.

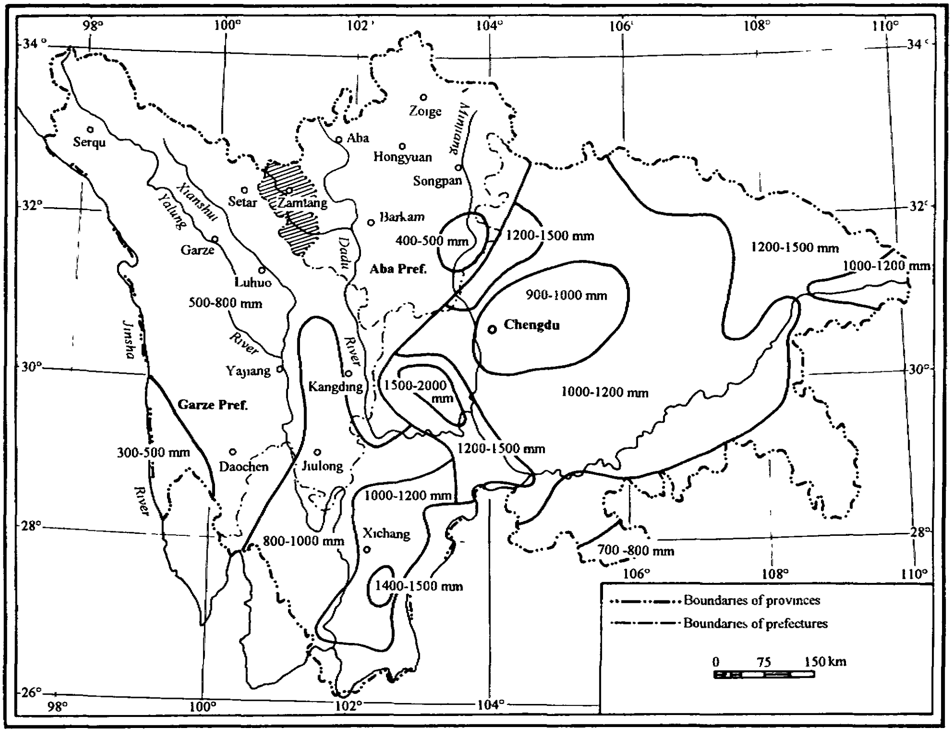

Fig. 2.6 Isohyet of Annual Mean Precipitation in Sichuan
Source: EDITORIAL BOARD OF "VEGETATION IN SICHUAN", 1980.

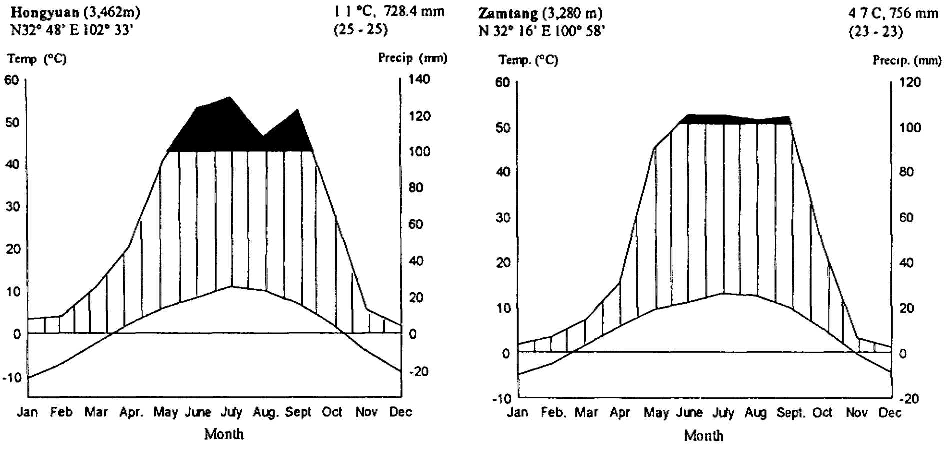

Fig. 2.7 Climatic Diagrams of the Pastoral Counties Represented by *Hongyuan*, *Zamtang* in Western Sichuan

Source: Meteorological Stations of *Hongyuan* and *Zamtang*

Design: WU NING

Table 2.1 Important Climatic Features in some Counties of Western Sichuan and their Comparison

County or City	Alt. (m)	N-Lat.	Annual mean T (° C)	Mean T in July (°C)	Annual mean Precipitation (mm)	Frost free period* (day)	≥ 0° C accumulated T (° C)	Sunshine time yearly (hour)
Serqu	4200	33°14'	-1.6	8.7	560.2	13.2	960.4	2516.5
Sertar	3893	32°25'	-0.2	10.2	639.8	13.9	1245.1	2441.7
Litang	3948	30°00'	3.0	10.4	731.0	43.4	1650.0	2617.6
Luhuo	3250	30°25'	6.4	14.9	642.2	94.3	2575.7	2591.3
Zoige	3446	30°20'	0.6	10.9	645.4	12.6	1360.4	2363.2
Hongyuan	3462	32°48'	1.1	11.2	728.4	22.0	1350.0	2402.0
Aba	3275	32°40'	3.2	12.7	702.6	23.7	1889.7	2353.8
Songpan	2850	32°39'	5.7	14.5	729.7	60.0	2396.3	1827.5
Zamtang	3285	32°16'	4.7	13.1	756.1	48.0	2130.9	1843.9
Barkam	2598	31°51'	8.6	16.5	758.5	129.1	3191.7	2212.0
Chengdu	545	30°40'	16.1	24.7	716.5			991.3
Lhasa	3658	29°42'	7.5	15.5	443.6		2888.0	3021.6
Xigaze	3836	29°13'	6.3	14.6	434.1		2566.0	3248.2

Key: * These figures refer to the absolute frost-free days.

Source: 1) AO, 1988; 2) ZHOU, 1982; 3) SICHUAN STATISTICAL BUREAU, 1994; 4) STATE STATISTICAL BUREAU OF CHINA, 1994.

b) The main catastrophic climates impacting on pastoral production

(i) Low Temperature and Snowstorm

Low temperature and snowstorm are the most important climatic influences on the features of rangeland ecosystem and the production of livestock husbandry. Except for the direct frost damage, low temperatures can also affect many aspects of the environmental conditions, and in the end lead to the changes of biological character in plants and the ecosystem, which are summarized as follows:

- affecting the flowing rate of matters and energy in rangeland ecosystem;
- the effective physiological radiation only making up 30 - 40% of the total radiation and the usable efficiency of solar energy being less than 0.1%;
- declining in the solubility of nutrient elements in soils, and obstructing the assimilative ability of root systems;
- the rate of biochemical reaction falling due to the weakening activity of enzyme;
- the reversal flow of matters and loss of energy in rangeland ecosystem, because of consuming period of matters and energy being longer than the accumulating period so that plants having to consume the assimilated nutrients in order to support their biological activities;
- morphologically and physiologically, plants being dwarfed and stretching flatly on the ground in order to capture more solar radiation;
- over-wintering bud growing under the ground surface and being covered by protective layer;
- root system distributing in the surface layer of soils in order to utilize the limit thermal resource in soils;
- the accumulative rate of organic matter, in the range of effective temperature, being higher; and
- more nutrient matter being formed by every assimilative organ in a definite time.

With the increase in altitude, the temperature on the Plateau falls rapidly and the vertical climate assumes the important role. Except the valley area in the south with the annual mean temperature above 10°C, in most areas it is below 8°C. In the northern Plateau, the temperature is below 4°C and even below 0°C in *Serqu* County and *Serta* County. The minimum temperature is generally 12°C - 20°C and the lowest is -37.7°C in *Serqu* County. The maximum temperature is between 28°C and 35°C. The winter is very long and frigid, and lasts five months in the south and seven months in the north, and even nine months in *Serqu*. In September the northern part at first enters winter, but the southern part meets the spring earliest in the next April. The convenient time in a year to fatten livestock, lasts from the beginning of daily accumulated temperature above 10°C to the end above 20°C, in the area above 3,000 m a.s.l is about half a year (April - October), in the alpine meadow of the northern area it is only three or four months (June - September), and in the northernmost county, *Serqu* only one and a half months.

Wind blows frequently throughout the Plateau and the days with strong wind average more than 60 days over most of the area, and in the alpine and tablelands to the north of *Shaluli* Mountains and to the west of *Yalung* River are as many as 60 - 80 days. The annual mean wind speed is 1.5 - 3.0 meters per second.

Snow becomes the main form of precipitation, and in the north it could occur all the year round. The annual snow days are always 50 - 70 in the north, but 10 - 40 days in the south. At the end of winter and at the beginning of spring there are most snow days and accumulated snow on the ground. The deepest depth of accumulated snow is generally between 10 and 20 cm, but on the alpine area and shelter side, the depth of snow is even 1 - 2 meters.

Since the most days of snow and strong winds are concentrated in winter and spring and the facilities for fighting natural calamities are in short supply, livestock inevitably suffers hunger and cold, lose the balance of energy budget, and in the end many of them lose weight, emaciate and even die. In 1980 there were 58,400 animal deaths resulting from snowstorms and shortage of foodstuff in Aba Prefecture, amounting to 60% of the total dead animals in that year. Owing to the loss of fat in winter, it is estimated that the total loss of meat from all animals was as high as double the total actual production of the Prefecture.

(ii) Frost

The mean duration of frost in western Sichuan is above 100 days, but in the northern part, *Batang* County and *Daochen* County it is 200 - 300 days. With the temperature falling in autumn and winter, frost, a kind of low temperature's jeopardizing, leads to the withering of grasses and loss of weight of livestock. The period available to fatten animals in western Sichuan is between the beginning of daily mean temperature above 8°C and the end of the daily mean temperature above 20°C (Table 2.2). The period when animals easily lose weight is the days when the daily mean temperature is below -5°C (Table 2.3).

Table 2.2 Period Available for Fattening Livestock in some Pastoral Counties of Western Sichuan
(Daily mean temperature between 8°C and 20°C)

County	Beginning (day/month)	End (day/month)	Days
Serqu	30/6	8/8	40
Sertar	22/6	2/9	73
Baiyu	13/4	14/10	185
Litang	22/5	18/9	120
Zoige	21/6	4/9	76
Aba	18/5	27/9	133
Hongyuan	13/6	11/9	91
Zamtang	28/4	29/9	155

Source: Sichuan Animal Husbandry Bureau, 1989

Table 2.3 Period of Easy Losing-weight in some Pastoral Counties of Western Sichuan
(Daily mean temperature below -5°C)

County	Beginning (day/month)	End (day/month)	Days
Serqu	3/11	15/3	133
Sertar	8/11	11/3	124
Litang	10/12	10/2	63
Zoige	19/11	2/3	104
Aba	29/11	14/2	78
Hongyuan	19/11	2/3	104
Zamtang	15/12	20/1	37

Source: Sichuan Animal Husbandry Bureau, 1989

(iii) Hailstone

The pastoral area of western Sichuan is hit by hailstones mainly in spring and autumn. The spring hailstones have a disastrous impact upon the regular growth of young grasses, and the autumn hailstones have an influence upon the harvesting of hay leading to the reduction of grass seeds. Hailstones always occur between April and October, but concentrate in May, June and September. Mostly it comes in afternoon and evening. During this time, it becomes a restricting factor for the animal grazing in the remote summer pastures.

2.1.2.3 Vegetation in western Sichuan

The subtropical latitude and the monsoonal climate, together with the great altitudinal range, has produced a rich natural flora and complex vegetation formations, which have attracted innumerable Chinese and western scientists to probe the mysteries in them since the middle of 19th century. The rise of the Qinghai-Tibetan Plateau disrupts the distribution law in zonality in China, and also exercises a deep influence upon the evolution and distribution of plants in western Sichuan. For the last hundred years, scientists have done a great deal of investigation work in this region and its neighboring areas. Western Sichuan was also one of the regions under priority investigation. However, large-scale and multidisciplinary investigations began after 1950s. Until today the most outstanding and most comprehensive works about the vegetation in western Sichuan, or even all of Sichuan, could be found in "Vegetation in Sichuan" (1978), "Grassland Resources in Sichuan" and "Forests in Sichuan"(1992), all of which are the distilation of the works from 1950s or even earlier. In the following paragraphs, the author will concentrate on the vertical zonation of vegetation in western Sichuan because of its importance for understanding the seasonal utilization in rural society, and in the vegetation formations in case studying areas.

a) Vertical zonality of vegetation

Along with the complex topographies and landforms mentioned above, and corresponding to ecological elements, such as climate and soil, which exert a great influence on the distribution of flora and formations, vegetation in western Sichuan presents a change law of obvious horizontal and vertical zonalities.

It should be mentioned that vertical changes of vegetation are on the basis of the horizontal zonality. For example, forests in western Sichuan have a wide distributive range in the horizontal direction and comparatively great continuity and conformity along a certain altitude, and the transition of varied types of forests is gradual. To a large extent, the vertical zonality is similar to the distribution law of vegetation in horizontal zones. In this wide region, however, the numerous changes in landforms from vegetation zones in the form of discontinuity, regrouping and consisting of vegetation types with different vertical zonal patterns.

In western Sichuan, vegetation mainly displays a regular vertical change owing to the continuous rise of the altitude and the changed hydro-thermal conditions. For example, varied types of vegetation are found such as evergreen and deciduous broad-leaved forests, mixed broadleaf-conifer forests, coniferous forests, alpine bushlands and alpine meadow (including the rangelands in the northern plateau). However, the features of the vertical zonal patterns of vegetation on any mountain body depend on the features of the horizontal zonality. Accordingly, generally speaking, there is no doubt that the base zone in the structure of typically vertical zonality of vegetation in western Sichuan is evergreen broad-leaved forest. Yet, it should also be noticed that the changes in the vertical zonality of vegetation are also very different in varied geographic regions of western Sichuan because the great disparities in altitude affect the redistribution of hydro-thermal conditions. For example, on the east-facing slope of *Gongga* Mountain, the base zone of vertically zonal patterns is a humid evergreen broad-leaved forest while on the west-facing slope the base zone is a subalpine dark coniferous forest (LIU, 1985).

From the above statement it can be seen that the base zone of zonal patterns has an obvious differentiation just on the other side of a mountain. Another example, in high mountains and canyons area (i.e., River Gorge Country in literature) of southwest Sichuan, the base zone of vertical zonal patterns of general forests is a mixed broadleaf-conifer forest, but the vertical base zone, after extending northward into plateaus, becomes subalpine dark coniferous forests. This is in close relationship with the rise of the whole topography, range upon range of mountains, steep valleys, different trends of mountains as well as distinct hydro-thermal conditions. Hence it can be seen that the regularity of geographic distribution of vegetation is independent of a single factor but restricted by integrated natural factors. Especially in such a specific natural condition of western Sichuan, the regularity of geographical distribution of its vegetation is affected by the horizontal zonality in body latitude and longitude, and also restrained by the vertical zonality of mountainous areas, showing the basic characteristics of the vertical zonality on the basis of the horizontal zonality and a relative conformity in the horizontal zonality under the control of the vertical zonality.

Furthermore, the variations in ecological environment resulting from the rise of the Qinghai-Tibetan Plateau have given rise to the complicated distribution and grouping of vegetation. Consequently, the mountain vegetations in western Sichuan have both zonal and non-zonal distribution laws, for instance, differences in the forms of forest vegetation found in arid river valleys, on shaded and sunny slopes, etc. Particularly, vegetation in western Sichuan is located in an east-extended part of the Qinghai-Tibetan Plateau, a "three-dimensional complex" showing an obvious mingling of altitude, longitude and vertical differentiation. Just as the statement in "Forests in Sichuan"(1992): The Qinghai-Tibetan Plateau including its neighboring regions, in a sense, can be regarded as an epitome of the vegetation distribution in the world.

b) Vegetation formations and the vertical utilization

Utilization of the different biotopes at various altitudes seems to be one of the most important economic strategies of people in mountainous regions (GUILLET, 1983). But this vertical control cannot be applied generally for all of the Qinghai-Tibetan Plateau, as in the Central or Northern Tibet located between *Yalung Zabo* River northward and Qunlun Mountains southward and in Qinghai Province, where the different regions and biotopes can often be reached and exploited by horizontal wandering (TIST, 1992). For the eastern Qinghai-Tibetan Plateau, however, and particularly for western Sichuan or all of the *Hengduan* Mountains, a generalized vertical control is regarded as the most important strategy of mountainous farmers and mountain nomads, who use all or almost all altitudes. Now detailed description of the vegetation formations and the utilization in every belt are given mainly based on the case studying area - *Zamtang*.

No specially concentrative vegetation studies about *Zamtang* have been published, although some works and articles mentioned forests or rangeland. In the absence of detailed information, preliminary survey of vegetation was undertaken and its results are reported in this paper. Owing to restrictions caused by the natural conditions, vegetation cover in *Zamtang* is clearly demarcated and complicated and varies according to topography (Fig. 2.8).

(i) Forests

In *Zamtang* forests mainly distribute in southern part of the County and on the north-facing slopes of the plateau; some blocks of woodland occur commonly.

Broadleaf & Conifer Mixed Forests

These forests lying mainly on the lower branches of *Do-que* River, at elevations below 3,100 m a.s.l on south-facing slopes and 2,800 m a.s.l on north-facing slopes, and on the lower branches of *Zhe-que* River, where *Zamtang* bordering with *Baima* County, are the Mountain broadleaf forests with spruce (*Picea spp.*) giving way to, and often associated with Juniper (*Sabina spp.*), which often occurs on the south-facing slope or in xeric environments.

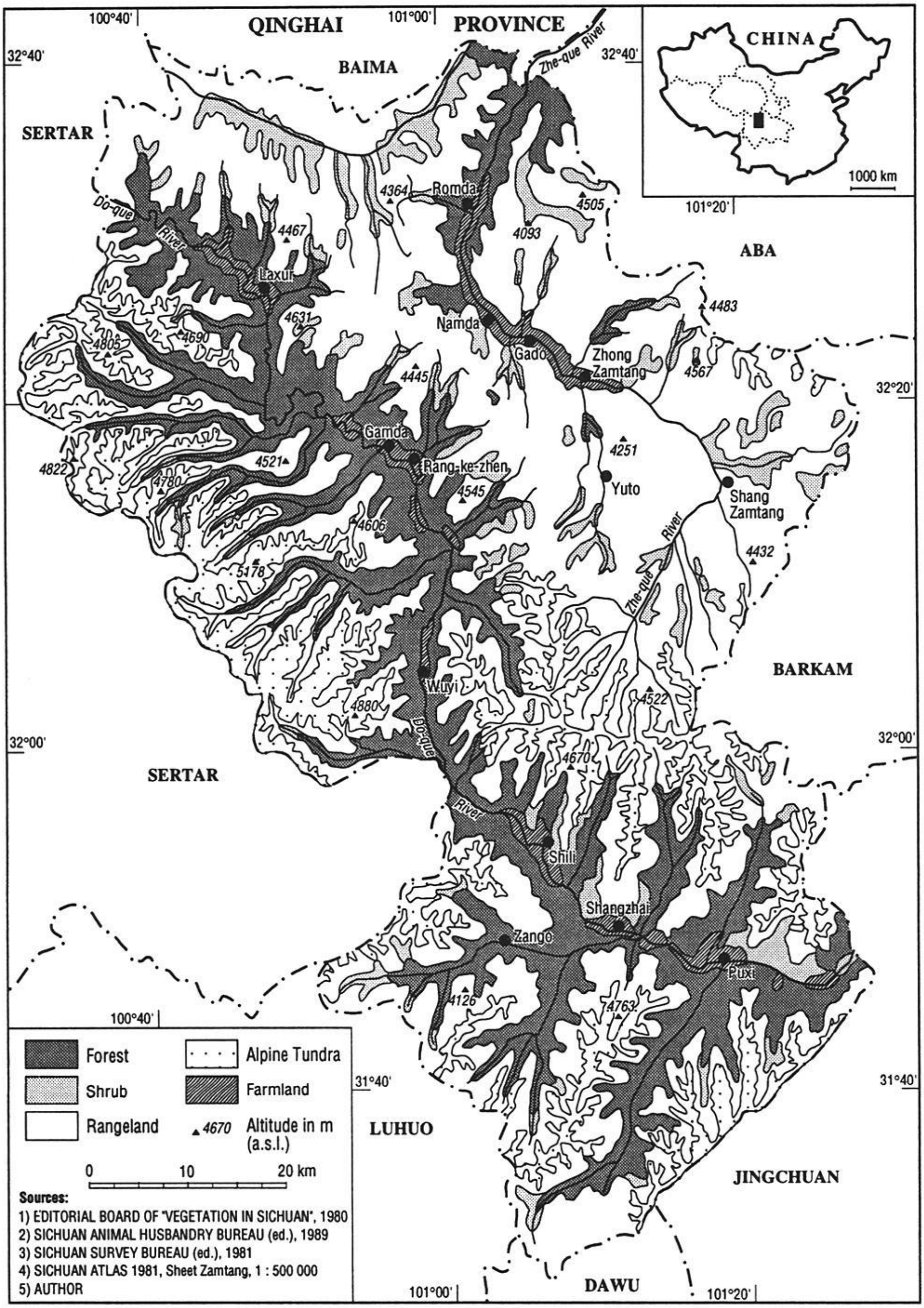

Fig. 2.8 Vegetation Distribution in Zamtang
Design: WU NING 1995

Oak (*Quercus aquifolioides*) forests are particularly characteristic of lower branches of *Do-que* River, southeastern *Zamtang*, where they form a zone below 2,800 m a.s.l. The physiognomy of community is yellow-green with some darkgreen spots and its coverage of canopy is between 40 and 80 percent. In some place the canopy is sparse which may result from human activities. The heights of dominants are between 15 and 25 m, with which spruce, maple (*Acer spp.*) and *Populus* are commonly associated.

Birch (*Betula platyphylla, B. utilis*) forests were found growing at higher altitudes than oak, and showed a preference for south-facing slopes, where the association with relic spruce is distinct. The physiognomy of community is yellow-green and its coverage of canopy is always less than 30 percent. It appears to replace spruce, where it occurs in xeric, previously disturbed conditions. It shows a preference for north-facing slopes, and may form an intermittent zone with spruce or subalpine meadow on a gentle sloping plateau, probably derived from these as a result of over-felling.

Constant associates in scrub are *Spiraea alpina, Rosa omeiensis, Lonicera tangutica and Rhododendron spp.* The coverage of understorey is variable with the differences of canopy. Grasses are not abundant as litter covering ground densely. *Cacalia palmatisecta, Dryopteris spp., Thalictrum finetii, Thalictrum alpinum, Arisaema flavum, Fragaria orientalis* and *Carex spp.*, are common components. Moss layer is developed and *Useae longissima* hang on the branches.

The broadleaf and conifer mixed forest zone in *Zamtang* is the main farming area, where Tibetan barley (*Hordeum vulgare var. nudum*) and maize (*Zea mays*) are the cultivated staples; the latter sometimes is interplanted with potato (*Solanum tuberosum*) and broad bean (*Vicia faba*), and its upper limit of cultivation is about 2,600 m. Buckwheat (*Fagopyrum esculentum*) and spring wheat are always rotated with Tibetan barley, which can also be found in the areas of neighboring counties in an altitude between 2,400 and 2,800 m, and the sequence of rotation is: Tibetan barley - autumn buckwheat – spring wheat – lying fallow. Some economic trees are also found in this zone, such as apple (*Malus pumila*), walnut (*Juglans regia*) and Chinese pepper (*Zanthoxylum bungeanum*) (Fig. 2.9). In addition, the collection of edible fungi, such as oak mushroom (*Tricholoma matsutake*) brings a main cash income for local people. It is said that this kind of mushroom has brought considerable benefits for households, but there are not detailed official statistics about its production and amount sold due to its private trade. However, the figures for the Garze Prefecture can provide a reference. In 1988, oak mushroom brought in a revenue of 80 million Yuan (RMB) in Garze, and this averaged out at 100 Yuan per capita. Earning in

Xiangchen, *Daochen*, *Yajiang*, and *Jiulong* counties were as high as from 10,000 to 20,000 Yuan (LIU and WU, 1992).

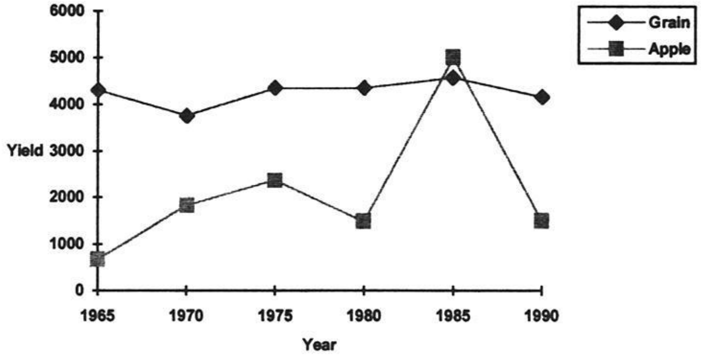

Fig. 2.9 Development of Grain Yield and Apple Production in Zamtang
Key: The unit of grain yield is in ton; apple yield in 10 kg.
Source: AO et al., 1988;
HUANG et al., 1992.

Coniferous Forests

In *Zamtang* subalpine coniferous forests mainly are dominated by spruce (*Picea purpurea, P. balfouriana*) and fir (*Abies faxoniana, A. squamata*), at elevations between 2,800 and 3,800 m a.s.l, with a cold temperate climate, which extends to and forms the timberline, and is almost certainly under climatically induced physiological stress.

Spruce forests mixed with birch occur at elevations below 3,800 m a.s.l and show a distributive bias toward the more southwesterly area of *Zamtang*, on plateau areas they may form a discrete zone below alpine meadow.

Picea purpurea forests are found more around *Gamda* (*Xiang*) and to the northward and eastward. They are suitable for north-facing slopes, where it is cool and humid. The physiognomy of community is dark-green and the structure is simple with the coverage of canopy between 50 and 80 percent. At about 3,900 m a.s.l the vegetation degrades into sparse and dwarf aspects. An understorey of *Ribes glaciale, Spiraea myrtilloides, Cotoneaster microphyllus* and *Rhododendron anthopogonoides, Rh. cephalanthum* occurs in the less disturbed areas, whilst *Sibiraea angustata, Lonicera hispida, L. microphylla* and

Dasiphora fruticosa are present in almost all stands influenced by casual extraction, road-building or livestock grazing.

Picea balfouriana always dominates in more westerly areas. Both of the above spruce species are difficult to be classified, because *Zamtang* is the mosaic area of their distribution (KUAN, 1982). *P. balfouriana* forests are less disturbed, often close-canopied forest, in which spruce is commonly associated with fir on the high altitude and north-facing slopes, and with deciduous broadleaf trees, such as *populus*, birch, maple, oak, on the south-facing slopes or burnt places. It is particularly abundant in the high valleys along *Do-que* River, where it provides an important resource for a timber extraction industry. The physiognomy is dark-green and the canopy is uniform with the coverage between 60 and 80 percent, height 30 m or more. The composition of shrub layer is changeable with the different elevations. On the higher altitude area or less disturbed places, some broad-leaved evergreen species, including *Rhododendron yunnanensis,* occur consistently, forming an understorey which may include *Spiraea alpina, Ribes meyeri, Sorbus Koehneana* and *Prunus pilosiuscula*, but on the lower altitude area or near villages, it is thin and discontinuous, with *Dasiphora fruticosa, Sibiraea angustata, Berberis dasystachya* and *Cotoneaster microphyllus* occurring commonly. *Useae longissima* hang on the branches and there is a deep cover of moss on the ground.

Fir (*Abies faxoniana, A. squamata*) forests are most commonly found in western *Zamtang*, but may occur in the east toward the heads of high valleys where clouds form, or on cold, wet, north-facing slopes which environment indicates that fir competes successfully under less xeric conditions than spruce. Fir is associated with broad-leaved deciduous species, including birch and *populus*, where some impedance is recorded and is fairly commonly associated with spruce in the more gently sloping or drier parts of the range. Larger leafed *Rhododendron* species, especially *Rh. agglutinatum* and *Rh. vernicosum*, are common components of forests. The soil is rather more organic and usually covered with a deep layer of needle litter, which may help retain moisture.

These forests are the fundation of the timber industry in the County. They are extremely productive, a large proportion is of important commercial timber species. Although some areas are accessible by road, and extraction, especially by rolling timbers down-slope toward the road and the river, has been destructive, elsewhere the resource is substantial. The Forestry Bureau is monitoring felling and comparing clear, strip, and selective methods with a view toward improving rates of natural regeneration. The reforestation began in the middle of the 1960s and was accelerated in the 1980s, because this region has been defined as the area of conservation forests for water source by state government.

In the conifer forests zone the agricultural activities, mainly including grain cultivation, mix with pastoral activities, specially in the lower parts. The staple crops planted in this zone are Tibetan barley, spring wheat and potatoes. The upper limit of Tibetan barley distribution is about 3,400 m, above which steady yields can not be harvested. In this zone all crops are sown in spring and there is only one harvest yearly. The settlements and winter houses of pastoralists also locate in this zone, since the winter pastures (cold-season pastures) involving the grasslands (subalpine meadow), bushlands (bush meadow) and woodland meadow are mainly distributed in these altitudes.

(ii) Shrub

Shrub vegetation is mainly distributed on the south-facing slopes of mountainous area and the north-facing slopes of the plateau area, or in the valleys, or on the terraced land, with a wide altitude range. At about 3,900 m a.s.l (lower on south-facing slopes) the vegetation becomes shrubby, with low growing *Rhododendron, Caragana* species, degrades into alpine pasture.

(iii) Rangeland

The area of them is 261,118 hectares, which account to 87.19 percent of the total area of rangeland in *Zamtang* (source: COUNTY ANIMAL HUSBANDRY BUREAU). There is no absolute frost free season in the area above 3,600 m a.s.l, which has a sub-frigid climate with a mean annual temperature below 0°C and the highest mean monthly temperature below 10°C. The soil is covered with a sod layer and contains rich organisms.

Since solar radiation is strong and the daily range of temperature is great, the photosynthesis process is active, so the productivity of grasses is great, the utilization ratio and nutritive value are high and the palability good. Except for the part distributed in the broad valley of lower altitude used as winter-spring pasture and natural cutting pasture, the most parts distributed on high altitude and slopes above the timberline are used as summer-autumn pasture. Because the temperature is too low, the growing period for grass is too short in the area above 4,200 m, the yield of grass is lower and only a short time in summer can be used.

2.1.2.4 Subdivision of the pastoral area in western Sichuan

The pastoral area in western Sichuan is generally defined as an ecological zone characterized by flat plateau, rugged plateau or alpine with an elevation above 3,500 m a.s.l., rangeland vegetation, high-frigid climate, yak and Tibetan sheep grazing system, and nomadism or semi-nomadism. According to the grazing-system, it can be subdivided into two subsectors, pure pastoral area and semi-pastoral area (Fig. 2.3).

a) Pure pastoral area (IIIA)

Characterized by flat plateau or rugged plateau, pastoralism is the main activity of pastoralists. There are no arable activities for crop cultivation. Although sometimes herdsmen are also engaged in planting herbaceous forage near their winter houses or shelters, this only occurred two decades ago under the encouragement of governments. This area can be distinguished according to isotherm. The 15 °C isotherm of mean temperature in July roughly corresponds to the southern border of this area. Although there are also some farmlands in this area, such as around the town of *Aba* County and the town of *Garze* County, pastoralism takes the predominant role in the whole area, and nomadism or semi-nomadism becomes the main subsistence. The whole population roams using stable routes and having winter centers. This kind of economy is based on keeping the livestock at grass all the year round. The cases in point are the northwestern Sichuan. Generally speaking, this area includes administratively *Aba, Hongyuan, Zoige, Zamtang* and *Songpan* counties in Aba Prefecture and *Serqu, Sertar, Dege, Baiyu* and *Litang* in Garze Prefecture.

b) Agro-pastoral Mixed area (IIIB)

Characterized by rugged plateau or high mountains, pastoralism and crop cultivation share the pastoralists' life. The number of yak and Tibetan sheep decrease apparently, and to some extent cattle and goats mingle in livestock crowd. Besides grazing animals, the cultivation of barley and rape provide the important subsistence for local people. The 21°C isotherm of mean temperature in July can distinguish it with the farming area, i.e., distinguish semi-nomadism from sedentary farming geographically along the line passing through *Nanping, Danba, Kangding, Jiulong* and *Muli* counties (Fig. 2.3). The kinds of economic activity involved in this area include two types:

- The whole population roams during the spring, summer, and autumn in vertical directions, spending the winter in permanent settlements. Agriculture is practiced alongside nomadic yak breeding, but only as a subsidiary branch.
- Part of the population roams during this or that part of the year in vertical directions, while the remaining part leads a sedentary life, being engaged mostly in farming.

According to this classification, therefore, the 15°C and 21°C isotherms of mean temperature in July demarcate the pastoral area in western Sichuan, which is bounded on the northwest by a transitional zone to the center of the Qinghai-Tibetan Plateau, and on the southeast by a transitional zone to the Sichuan Basin, the *Han* people living in compact communities.

2.2 The Case Study Area - Zamtang County

1) Location and landform

The site of case study, *Zamtang* County, is located in the west of Aba Prefecture, Sichuan Province. It lies between 31°8' - 32°0' N latitude and 100°2' - 101°9' E longitude, and borders on the north with *Baima* County, Qinghai Province; on the west with *Luhuo* County, *Dawu* County and *Sertar* County. *Jinchuan* County and *Barkam* County are situated on the south of *Zamtang*, and *Aba* County and *Barkam* County are on the east. The longest distance from south to north is 136 km, and from west to east 90 km (SICHUAN SURVEY BUREAU, 1981). The total area is 6,606 km², out of which, 3,993 km² or 60.45%, is natural grassland. Of this, 85 percent or 3,394 km² is usable (XIE, 1988) (Fig. 2.8).

The overall relief consists of high mountains and plateau. With the average elevations exceeding 3,000 m, there are 60 mountains above 4,500 m. The highest peak is 5,178 m and the lowest spot is 2,650 m in the valley of southeastern part. The *Du-ke* River (*Do-que*) and the *Zhe-que* River flow through the vast land of this county, both of which are tributaries of *Dadu* River. The *Do-que* River rises in *Bayan Hal Shan* (*Ba-Yan-Ka-La*) Mountain, Qinghai Province and flows by way of *Baima* County, *Sertar* County into *Zamtang*, which is the main channel of timber-transportation. The *Zhe-que* River within the county originates in *Namqi*, which forms a confluence on reaching the northwestern border of the County, and drains some large and small areas of alluvial flatland and terraces. This area is characterized by wide valleys, and a few deep valley slopes. *Zamtang* lies on the contact zone between mountainous area and plateau's area, which landforms are complicated. The principal geomorphologic characteristics include:

- high mountain areas at elevations between 3,800 m and 5,000 m in the northwestern part and south- western part of the county, i.e. on both sides of the *Do-que* River and *Zhe-que* River below *Zango*; the depth of incised being exceeding 1,000 m and the angle of mountain slopes ranges always between 30 and 50 degrees;
- middle mountain areas at elevations about 3,500 m on both sides of the *Zhe-que* River between *Zango* and *Namda* (*Xiang*) and the *Do-que* River above *Yutuo* (*Chun*); The relative depth of incised being less than 1,000 m and the angle of slopes about 30; and
- plateau area at elevations about 3,800 m and the relative vertical difference being about 500 m ; consisting of fairly smooth slopes and terrain.

2) Climate

The principal climatic features are that annual range of temperature is small, but the daily range is great, with little temperature accumulation and a short frost-free season. The records of the County Meteorological Station, located in *Gamda* at the elevation of 3,284 m a.s.l, show the accumulated temperature ≥ 0°C as 2,130.9°C, the absolute frost-free period being about 48 days in average. The mean annual temperature is 4.7°C. The highest monthly mean temperature is 13.1°C in July and the lowest is -5.0°C in January. The annual precipitation is 756 mm. Spring season and autumn season are very short, so there is not an apparent division of four seasons. Seasons are alternately wet and dry and over 90% of precipitation is concentrated in summer mainly from May to September, during which it is fairly hot with few clouds, strong radiation and wide differentiation in daily temperature. This helps in the growth of fodder grasses and in the accumulation of nutrients, since strong ultraviolet rays help synthesize protein (Fig 2.8).

3) Soil

This region mainly consists of alpine meadow soil, some cinnamon soil below the timber-line and grayed meadow soil or peat soil in the depressions and wet areas. The alpine meadow's soil is generally acidic with the pH value of 5.0-6.5. Large amounts of humus are found in the soil, but it can not be easily decomposed because of the low temperature and can not be absorbed by plants because there is not enough nitrogen, phosphorus and sodium. The well-developed sod layer is so dense that water and air cannot be easily percolated. In addition, the low temperature affects plant growth so greatly that the grasses in *Gramineae* and *Cyperaceae*, as well as the erect dicotyles grow very dense in large areas.

4) Population

The total population of *Zamtang* is 29,730 (1990 data) and this is smaller than that of other counties in Sichuan Province. The average density is 4.5 persons per square kilometer, which is also lower than the average of other counties in the Province (HUANG et al., 1992).

Apart from the Tibetans, who comprises 77 percent of the population, there are several minority ethnic groups in *Zamtang*, such as the *Han* 22 percent, the *Qiang* 0.5 percent; in addition, there are small groups of *Huis*, *Mongolians* and *Manchus*. Within the territory of the County, two groups of Tibetan can be distinguished. One is the *Amdo*, who mainly engage in pastoral production in the north; another is *Jiarom* (*Garzom*)[25], who mainly take cultivation as their occupation and are distributed in the south.

The total number of people engaged in agriculture (including livestock husbandry) is 24,194 or 81.4 percent (1990 data), among which there are 13,936 pastoralists and 10,258 farmers. This means that the cultivated land and breeding livestock absorbs most of the labor force. The illiteracy and semi-literacy rates are as high as 42 percent and 58 percent of the population are over twenty years of age.

2.3 Role of Pastoralism in Economic Development

Agriculture is obviously of great importance in the economy of Western Sichuan: it forms over 37.6 percent of the Gross Domestic Production (GDP) as a whole for 1992, compared to figures of 49.83 percent for Tibetan Autonomous Region and under 40 percent for all the other western provinces in China (Table 2.4). But given the low population densities and the altitude, one would not expect the kind of intensive crop production that takes place in inner China and elsewhere in south and east Asia to occur on the Qinghai-Tibetan Plateau.

[25] Within the territory of western Sichuan, Tibetan people are generally classified into three groups. The first group is *Kham*, who is distributed in the southwest of Sichuan and the east of Tibet (TAR). In Sichuan it can mainly be found in Garze Prefecture. The second is *Amdo*, who is distributed in the northwest of Sichuan and the south of Qinghai. This group of people are mainly engage in nomadic pastoralism. The third is *Jiarom* (*Garzom*), who is mainly found in the middle of western Sichuan and is located in the areas between the above two groups, such as *Luhuo*, *Kangding*, *Dawu*, *Danba*, *Xiaojin*, *Heishui*, *Jinchuan*, *Lixian*, *Barkam* and *Zamtang*. This group is characterized by farming production in the mountainous region.

Table 2.4 Composition of the GDP in different Provinces of Western China (1992)

Province or Region	GDP	Primary Industry[26] (Percentage)	Secondary Industry[27] (Percentage)	Tertiary Industry[28] (Percentage)
Inner Mongolia	378.62	126.86 (33.5%)	152.56 (40.3%)	99.20 (26.2%)
Yunnan	510.03	186.80 (36.6%)	219.03 (43.0%)	104.20 (20.4%)
Tibet	33.29	16.59 (49.8%)	4.46 (13.4%)	12.24 (36.8%)
Gansu	301.64	74.21 (24.6%)	128.66 (42.7%)	98.77 (32.7%)
Ningxia	78.62	18.31 (23.3%)	34.05 (43.3%)	26.26 (33.4%)
Qinghai	84.32	19.44 (23.0%)	36.31 (43.1%)	28.57 (33.9%)
Xinjiang	382.26	114.50 (30.0%)	147.65 (38.6%)	120.11 (31.4%)
Sichuan	1481.22	480.27 (32.4%)	608.99 (41.1%)	391.91 (26.5%)
West Sichuan	28.91	10.90 (37.7%)	10.36 (35.8%)	7.65 (26.5%)

Key: The unit in the table is hundred million Yuan. The GDP in every province or region is considered as 100%.

Source: 1) STATE STATISTICAL BUREAU OF CHINA (ed.), 1994.
2) SICHUAN STATISTICAL BUREAU (ed.), 1994.

The total grain output in 1993 was recorded as 296,200 ton; the production figure was around 183.58 kg per capita (1993), and the figures for the yield of grain on this cultivated land approach 1756.37 kg per hectare, which is far from marginal. However, the agricultural production in overall western Sichuan is not primarily or solely based on crop production. These crops are grown mainly in the southeast and east, which, like a microcosm of the polity of China as a whole, have higher population densities than the west, specially the northwest. But this arable land of 1,687 square kilometers constitutes only 0.007 percent of the land area of the western Sichuan (Table 2.5).

2.3.1 Pastoralism - the basic Subsistence

Western Sichuan, owing to its geographical, social, climatic and edaphic conditions, is essentially a pastoral region. Pastoralism remains important both for the subsistence of the majority of the rural population and for the entire national economy. Livestock is the mainstay of the Tibetan socio-economy, since 59 percent of the regional total land surface can be considered as exclusively rangeland; nearly 87.6 percent falls into the category of available rangeland. In the absence of alternative opportunities for local employment of any significance, most people (about 274,200 in 1990 (HUANG et al., 1988)) earn their livelihood from pastoralism.

[26] "Primary Industry" means to agriculture, which including planting (cultivation), forestry, animal husbandry, rural sideline product and fishery;
[27] "Secondary Industry" includes industry and construction;

Table 2.5 Agricultural Situation in Different Provinces or Regions of Western China

Province or Region	Agricultural percent in GDP	Grain yield (mn ton)	Cultivated land (1,000 ha)	Agricultural Labor Force[29] (mn persons)
Inner Mongolia	33.51	11.08	5171.7	5.00
Yunnan	36.63	10.85	2854.7	16.10
Tibet	49.83	0.65	223.6	0.87
Gansu	24.60	7.58	3480.6	6.79
Ningxia	23.29	2.05	803.1	1.34
Qinghai	23.06	1.18	581.4	1.27
Xinjiang	29.95	6.95	3120.2	2.79
Sichuan	32.42	41.51	6231.5	41.33
West Sichuan	37.60	0.29	168.7	0.70

Source: 1) STATE STATISTICAL BUREAU OF CHINA (ed.), 1994. 2) SSB (ed.), 1994.

In this region the majority of the regional population are herders, pastoral livestock production is the main economic activity, which approaches 54 percent of the Gross Agricultural Output Value (GAOV) of the western Sichuan as a whole (Fig. 2.10). Livestock contributes directly to private earnings and government revenues. As extensive technical and economic reports mention, purchasing of animal products have generated no less than half of earnings since 1975 (Table 2.6). It is a commonly quoted statistics in western Sichuan that animals outnumber people by 4.6 to one. This is borne out, more or less, by the official record which, in 1993 gave the figure of around 7.35 million large animals (including yak, cattle, cows, horses, etc.), sheep and goats, with the human population of 1.61 million. But for China as a whole, the ratios by this crude measure are much lower, at around 0.4 animals per capita, and the principle animal is the pig, which is unusual in this area.

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[28] "Tertiary Industry" indicates other occupations excepting primary and secondary industries, which mainly include transportation and communication services, and commerce;

[29] "Agricultural Labor Force" refers to total laborers who are directly engaged in production of farming, forestry (excluding workers in forestry enterprises), animal husbandry, and fishery.

Fig. 2.10 Role of Animal Husbandry in the GOVA of Western Sichuan
Source: Sichuan Statistical Bureau (ed.), 1994.

On a macro-level, the role of livestock in the region can be summarized as follows:

- it provides food and material for the population;
- it supplies government revenue;
- it contributes to the gross domestic product (GDP); and
- it provides employment and income.

It should be explained at first that, since pastoralism involves the maintenance of self-sustaining herds on pasture, cases when small numbers of livestock are raised by farmers on farm lands cannot be included under this term. Similarly, herds forming part of an artificially organized commercial enterprise have to be distinguished from the true communities of pastoralists for whom pastoralism is a way of life.

The pastoralism of western Sichuan is not the commercial animal production of the developed world in which grain production is chained to livestock: there is no production of crops mainly for animal feed; mechanization and intensification have only recently begun on agricultural land. Rather, in nearly everything but its trade and marketing, pastoralism is still primarily traditional, and is based on open grazing on the extensive rangelands. The pastoral livestock sector can therefore be regarded as traditional rather than modern. A large proportion of herders are in a phase of transition from a traditional subsistence-based system to a market-integrated commercial system. Moreover, the livestock herds are probably the most readily exploitable economic resource of the region, the output value of which in 1985 increased to treble of that in 1950 (Fig. 2.11). Clearly the livestock sector should be a matter of prime importance in all development efforts. If this region is to make progress in economic development, good performance of the livestock sector is vital. Despite the tremendous importance of pastoralism for the majority of the population and of the livestock sector for the regional economy, only a very small percentage of the national budget is allocated to programs benefiting livestock pastoralists or the development of the livestock sector.

Table 2.6 Main Animal Products in Different Provinces or Regions of China (1993)

Province or Region	Beef (10,000 ton)	Mutton (10,000 ton)	Milk (10,000 ton)	Sheep wool (ton)	Goat wool (ton)	Cashmere (ton)
Inner Mongolia	10.6	15.9	44.9	55,305	2,641	2,420
Yunnan	4.4	2.0	10.0	1,540	57	4
Tibet	4.9	4.3	18.6	8,376	995	445
Gansu	5.6	5.3	9.9	15,411	1,248	275
Ningxia	0.8	1.4	7.1	3,021	262	144
Qinghai	5.5	5.5	19.6	17,044	534	173
Xinjiang	9.3	18.6	40.9	50,818	1,944	642
Sichuan	11.6	5.2	28.9	3,040	270	3
West Sichuan	4.44	0.37	15.84	1,249	226	

Source: 1) State Statistical Bureau of China (ed.), 1994.
2) Sichuan Statistical Bureau (ed.), 1994.

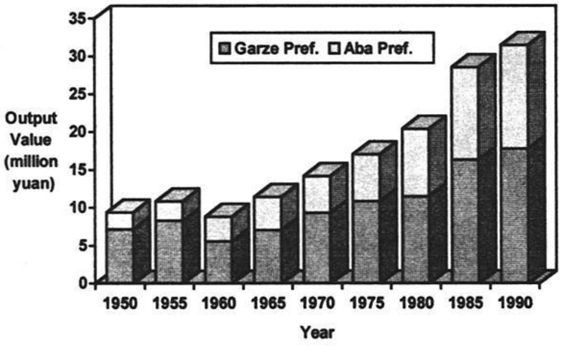

Fig. 2.11 Development of Output Value of Animal Husbandry in Western Sichuan from 1950 to 1990

Note: Output value is calculated in 1980 invaried value.

Source: AO et al., 1988;
HUANG et al., 1992.

Now we can probe into the role of animal grazing in the case study areas. Since the grain crop cannot be harvested steadily in most parts of *Zamtang*, pastoralism plays the more important role, which is mainly developed in the area below 4,200 m a.s.l.

An analysis of the economic production shows that *Zamtang* is a predominantly pastoral county. With that, animal husbandry is and has been the main activity. The gross output value of agriculture accounted for 62.5 percent of the GDP of the county in 1990, in which animal husbandry and planting (mainly cereal production) make up 48 percent and 8 percent respectively (SSB, 1991) (Fig 2.12). In addition, 13,700 labor force is engaged in agriculture. About two-thirds of them are a pastoral population, and the level of urbanization is low, for example, the County town, *Rang-ke-Zhen*, has a population of only 5,050 (in 1988).

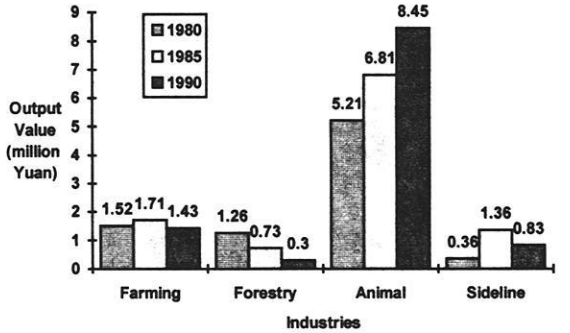

Fig. 2.12 Comparison of Output Value between Animal Husbandry and other Industries Included in GOVA in Zamtang (1980, 1985 and 1990)

Source: 1) AO et al., 1988;

2) SSB, 1991.

Design: WU NING

2.3.2 Livestock - Supporting Pillar

1) Role and Composition of Livestock

Although the compositions of grazing animal herds in different ecological regions are varied, livestock is always an important means of subsistence and of productivity in all pastoral societies (Table 2.7). They contribute more than meat, milk and clothing materials.

When associated with cropland they often contribute manure and traction. It is also common for livestock to be used for transport and as a form of capital and security. In pastoral societies they may contribute blood to the diet and invariably they are used to build and maintain social relationships. Hides and skins are used for housing and water containers as well as for clothing, and dung may be used as fuel instead of manure.

Table 2.7 Composition of Grazing Animals in Different Provinces or Regions (1993)

Province or Region	Large animals[30]	Cattle, cow or yak	Horse	Donkey	Mule	Camel	Goat	Sheep
Inner Mongolia	685.8	365.4	151.1	90.5	62.9	15.9	939.1	1921.2
Sichuan	1110.3	1041.7	57.6	4.8	6.2		623.9	358.3
Yunnan	939.0	766.0	94.0	30.0	49.0		508.0	119.0
Tibet	618.1	567.2	35.6	14.1	1.2		590.3	1188.4
Gansu	596.4	345.3	39.5	144.9	64.1	2.6	228.8	796.8
Qinghai	575.1	509.1	38.2	11.5	14.6	1.7	213.4	1421.7
Xinjiang	563.8	331.6	99.7	112.8	2.6	17.1	448.1	2394.7
Ningxia	76.0	34.0	2.0	25.0	15.0		72.0	177.0
West Sichuan	470.46	432.25	35.45		2.76		94.99	169.69

Key: Unit in table is 10,000 head.

Source: 1) STATE STATISTICAL BUREAU OF CHINA (ed.), 1994.
2) SICHUAN STATISTICAL BUREAU (ed.), 1994.

Different species perform different functions in different livestock production systems. In western Sichuan there are many variations, but typically yaks provide milk, butter, hair, transport and traction, or meat for the commercial market (Table 2.8), sheep and goats provide wool, cashmere, meat and sometimes milk. All livestock contributes skins or hides according to their kind and all contribute dung, though most of that used as fuel comes from yak. The functions which livestock fulfills in a given situation derive from an interaction between species, environment, human need and custom.

Every family operates self-sufficiently, where yak (*Bos grunniens*) and sheep wool are woven into tents or rips. Cheese and butter are also manufactured on a household basis and hides are tanned by individual families. The products that are not used by the family are sold, or bartered with farmers and salesmen. It is quite clear that most of the yak are owned by the pastoralists who live in the northwest, whose per capita holding is eight; similarly, the cattle are owned by the villagers/ mixed agriculturists rather than by the pure pastoralists/nomads.

[30] "Large animals" in statistical yearbooks refer to ox (which inlude cattle, baffalo, cow and yak), horse, donkey, mule and camle.

Table 2.8 Summary of the Different Functions of Yak on the Qinghai-Tibetan Plateau

Relating to crop production
- tillage (plowing, ridging, weeding)
- provision of manure
- transport (of inputs and produce; also wood, water etc.)

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

Household finance
- investment of crop income (capital growth through herd growth)
- savings (capital storage: for school fees, bridedowries)

Social
- ritual purposes (e.g. honouring of ancestral spirits, ritual slaughter, bridedowries)
- social status and pleasure in ownership

The number of livestock kept by a nomadic family is seen as the important strategy (see 5.2.3 of this book) by which to survive in a harsh climate. Herbivores exist invariably in the interrelationship with rangeland, both of them are the basic structural elements of range ecosystem. The formation of herbivore population and their quantitative dynamics always are related closely to range resources. According to the statistics of 1994, for example, in western Sichuan there were 4.32 million yak (including some cattle and *zu*), 0.35 million horse, 2.65 million sheep and goat. These livestock are grazed on the different grasslands all the year round. More than 90% foodstuff are taken in from the grasses and the edible plants of these grasslands.

The composition of livestock in *Zamtang* County is dominated by yaks, Tibetan sheep (*Ovis aries*) and goats (*Capra hirtus*); in addition, a few horses are kept. In 1988, there were 167,247 yaks, 4,955 cattle 17,043 sheep, 24,181 goats and 9,905 horses (provided: COUNTY GOVERNMENT OFFICE) (Fig 2.13). These were all indigenous species of multipurpose breeds and were well adapted to the adverse ecological conditions, such as high elevation, freezing climate, lack of oxygen, and short grass.

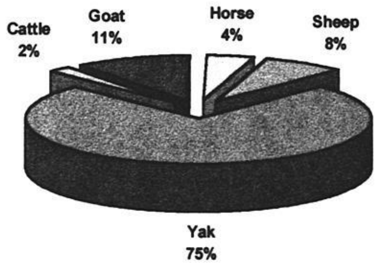

Fig. 2.13 Composition of the Main Domesticated Animals in Zamtang (1988)
Source: Provided by COUNTY ANIMAL HUSBANDRY BUREAU
Design: WU NING

2) Indigenous Livestock

People always associate the high and frigid range on the Qinghai-Tibetan Plateau with yak and Tibetan sheep (Fig. 2.14). Yak (*Bos grunniens*) is the multipurpose high altitude large mammal belonging to the *Bovidae* family under the tribe *ruminantia* and the only species of bovines that, even today, can adapt itself to the physical environment of the Plateau (SCHOLZ, 1995). Man said: "Without yak it is difficult to imagine the situation of animal husbandry on the Qinghai-Tibetan Plateau." This implies that it is impossible to separate the yak production from the climate of the Plateau, alpine pastures and the daily life of Tibetans.

Yak are found extensively on China's plateaus in alpine and sub-alpine regions at altitudes from 2,000 to 4,500 meters with a cold, semi-humid climate. From the central "core" (the Qinghai-Tibetan Plateau) of the yak's distribution, the animal has spread to adjacent territories (Table 2.9).

> "*To the east, they migrated from the Bayan Kala mountains into Songpan grasslands and into the Daba mountains. To the south, the migration went through passes in the Himalayas on to the mountain grasslands of the southern slopes of the range. To the west, yak entered Kashmir through the Ali grassland and to the north the migration took the yak over the Kunlun mountains into northern Pamir, northern and southern Tianshan and Altai. The present day distribution of the yak developed gradually from these migrations.*" (CAI and WIENER, 1995: 3-4)

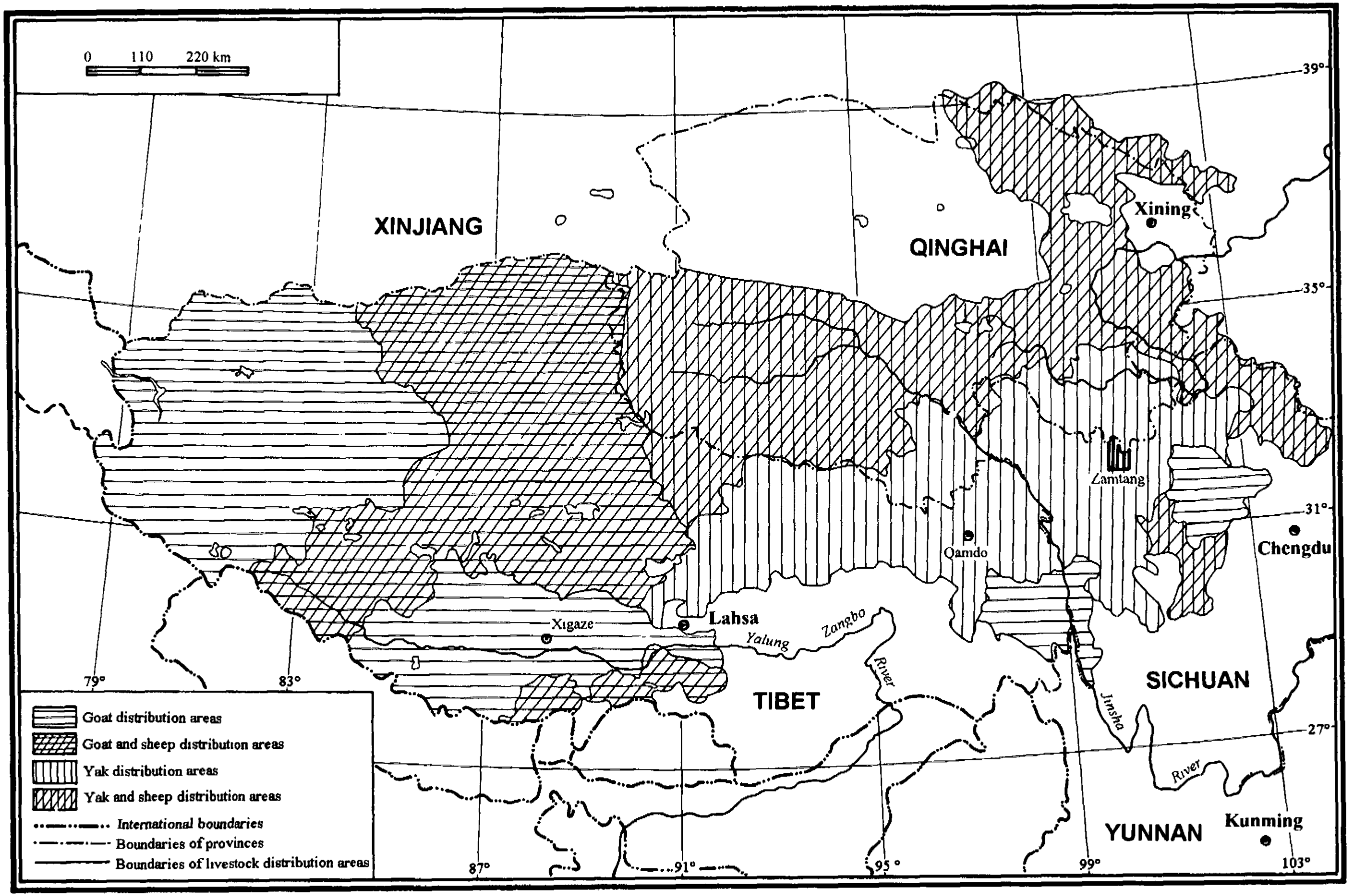

Fig. 2.14 Distribution of Yak, Sheep and Goat on the Qinghai-Tibetan Plateau
Source: 1) GIAS, 1990; 2) TIST, 1992 **Design:** WU NING

Table 2.9 Distribution of Yak in the World

Country	Region	Amount (1,000 head)
China (in 1983)	Sichuan (western)	3363
	Tibet (whole region)	3954
	Yunnan (northwestern)	50
	Qinghai (exclude Haidong)	4500
	Gansu (southern)	800
	Xinjiang (middle sector of Tian-shan Mt.)	250
	Others	3
	Subtotal	12920
Mongolia (in 1994)	Altai Mt.	571(+56 cross)
Former U.S.S.R (in 1981)	Kirghize, Tadzhike	140 (?)
India (in 1993)	Northern Himalayan Region	31 (+14 cross)
Others (Nepal, Bhutan, Pakistan, Afghanistan, Kashmir region, etc.)		51
Total		13783

Source: CAI, 1990; CAI and WIENER, 1995.

Some 14 million yak, 30 million sheep and goats (MILLER, 1990) – and, of course, the herdsmen's horse – co-exist together over large parts of the Plateau. The present domestic yak is thought as that it is descended from wild yak caught and tamed by ancient *Qiang* people[31] in the *Qiangtang* and other areas of northern Tibet (CAI, 1992).

> "*This process is thought to have begun in the late Stone Age, about ten thousand years ago, and led to the primary yak industry, beginning in the period of the Longshan Culture of the late New Stone Age (2,800-2,300 BC). The history of China's yak industry is thus at least 4,500 years old.*" (CAI and WIENER, 1995:3)

[31] Chinese historians regard the ancient *Qiang* people, around 30 000 years ago, as the first intelligent true humans (QIAN, 1979; SHI, 1994). These people developed probably the earliest animal husbandry culture of quality in the world - the *Qiang* Culture. The outstanding achievement of the *Qiang* Culture was the taming of wild beasts for domestic purposes. Sheep and goats had been successfully tamed and this led to the taming of yak, horse and other herbivores. People even think that nearly all the nationalities which presently keep yak are related to the ancient *Qiang* people, or the nationalities developed directly from the *Qiang* people (CAI and WIENER, 1995). Now *Qiang* people have mingled into other ethnic groups in most areas where they distributed originally and the remnants only can be found on the upper reaches of *Minjiang* River, Sichuan Province.

The features of the living area of the yak are: high altitude (2,500-6,000 m a.s.l.), low temperature (annual mean temperature around and even below 0°C), great difference of diurnal temperature (above 15°C) and low atmospheric pressure (below 110 mm mercury high). Alpine meadow, with dwarf grass but in good quality, is the main food source of yak in this region. Since the result of natural selection of the special and harsh ecological environment after a long time, yak has a very strong ability to survive, has a strong body frame, structure and physiological functions resist the harsh environment (CAI, 1990; 1992). According to the researches by CAI and WIENER (1995), in general, temperature is the single most important factor in determining the distribution and stocking density of yak. Yak survive and perform adequately if the annual mean temperature is below 5°C and the average in the hottest month is not above 13°C. Subject to the availability of adequate grazing, the distribution and stock density of yak increases with altitude. However, altitude is of lesser importance than air temperature, because the relationship between altitude and latitude can be mediated through air temperature. In western Sichuan, the annual precipitation of the area where yak distribute is 600-700 mm and the relative humidity is 60-65%, which are different gently from that in the center of the Plateau where the precipitation and relative humidity are less to some extent.

In western Sichuan, the distribution of yak is in relation to the latitude. From the 31° latitude going northwards, the lowest limit of yak's distribution is about 2,500 m. Otherwise, yak can not migrate down below 3,000 m from this latitude southwards. Consequently, the number of yak in the north is generally more than that in the south (Fig. 2.15; Table 2.10). Owing to the special biological, economical and distributive characters, yaks play a special role in the regional economic, furthermore, it can make use of the vast range resources on this plateau which almost can not be grazed efficiently by other kinds of livestock.

Tibetan sheep are another fine local breed that can adapt specially to this high altitude and the short growing period of grass, with its great grazing ability and high fat storage. Besides its wool, Tibetan sheep also provide meat. The percentage of dressed animal carcase is as high as 54-60%. More than 5 kg fat can be found in the viscera of 30% of those animals which are slaughtered in the late of autumn.

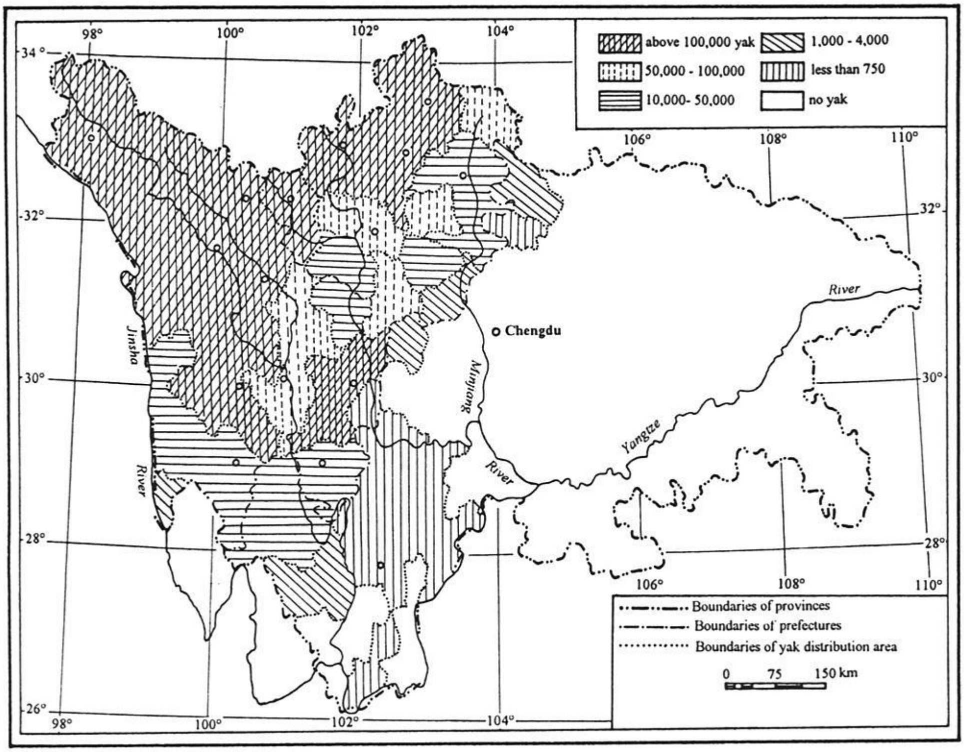

Fig. 2.15 Density of Yak in Sichuan
Source: CAI, 1990

Table 2.10 Distribution of Yak in Sichuan

County	Amount (head)	County	Amount (head)	County	Amount (head)
Serqu	445,193	*Yajiang*	62,616	*Nanping*	56,261
Dege	286,820	*Batang*	42,102	*Heishui*	51,491
Sertar	258,947	*Daochen*	35,723	*Xiaojin*	51,149
Garze	172,986	*Danba*	25,382	*Wenchuan*	29,900
Litang	147,320	*Xiangchen*	22,881	*Lixian*	18,581
Baiyu	116,072	*Jiulong*	21,951	*Songpan*	18,490
Luhuo	112,028	*Zoige*	309,055	*Maoxian*	10,527
Kangding	108,036	*Hongyuan*	281,367	*Muli*	36,656
Xinlong	102,308	*Aba*	228,888	*Barkam*	70,376
Dawu	89,561	*Zamtang*	124,271	*Others*	26,144

Source: CAI, 1990

3. RANGELAND RESOURCES ON THE PLATEAU

3.1 Range Resources in Western Sichuan

A number of factors determine the natural occurrence and extent of high-frigid rangelands in their various physiognomic forms. The most significant of these can be grouped as geomorphology, precipitation, temperature factors and grazing. It is important to realize that rarely is only one of these factors solely operative in the ecosystems under discussion. Most often several work at the same time in a particular ecosystem and their joint impact may have a cumulative effect upon the system, but occasionally it also may have an entirely different effect. Frequently one of the factors dominates a particular ecosystem, according to the differently geographical scales.

Rangeland is an integrated natural system which is composted by the main body, grasses (including herbaceous shrub and semi-shrub), and the basic condition, their soils (see 1.5 of this book). HÜBL defined it as "land carrying natural or semi-natural vegetation which provides a habitat suitable for herds of wild or domestic ungulates" (1986:55).

The land classification figures clearly indicate the importance of the grasslands as a resource. Some 58.9 percent of the western Sichuan is grassland, and accounts for 3.5 percent of the grassland within the polity of China. And of this 13.9 million hectares of grassland in the western Sichuan as a whole, 12.18 million hectares are useable. This is a figure of around 7.55 hectare of available pasture per person and around 9 hectare for per rural person.

The division of rangeland is mainly indirected by different kinds of grasses. Although there are trees or bushes scattered in some places, such as woodland meadow and bush meadow, these trees or shrubs are relegated to a secondary position and taken as the indicator of the habitats, when classified.

At first it should be claryfied that in China there are different criteria for the classification of rangelands, especially between vegetationists and agriculturists. The western Sichuan's natural rangelands suitable for grazing are distributed over a large area. The complex landforms and changeable climate have made them greatly varied in this region, which is probably one of the regions with the most varied types of grasslands in China.

In this context there is no intention to discuss the criteria and give a standard classification system. In the following discussion the most popularly accepted system suggested by JIA (1980) will be adopted, which classified the rangelands in western Sichuan into 7 kinds, 18 groups and 32 types (NI, WEI and DONG, 1984), and the high-frigid rangelands into 4 kinds, 12 groups and 22 types (Table 3.1).

Table 3.1 Classification of High-frigid Rangelands in Western Sichuan

Kinds	**Sub-kinds**	**Groups**	**Types**
High-frigid Meadows	Subalpine Meadow	Gramineal grasses on plain land	*1) Arundinella chenii* *2) Elymus nutans, Roegneria nutans*
		Sedge[32] on slope	*3) Kobresia setchwanensis, K. capillifolia*
		Forb[33] on plain or slope	*4) Anemone rivularis, Potentilla anserina* *5) Polygonum viviparum, P. sphaerostachyum*
	Alpine Meadow	Gramineal grasses on the top of hills	*6) Festuca ovina*
		Sedge on plain or ridge	*7) Kobresia pygmaea*
		Forb on plain or slope	*8) Spenceria ramalana* *9) Anaphalis flavescens, Leontopodium longifolium*
	Moist Meadow	Sedge on low temperature land	*10) Kobresia humilis, K. tibetica* *11) Carex spp., Deschampsia caespitosa*
Swamp Meadows		Sedge on accumulated water	*12) Carex muliensis*
Alpine Shrub Meadows		Shrub meadow on shade slope	*13) Salix ernestii* *14) Sibiraea angustata, Dasiphora fruticosa* *15)* leaflet *Rhododendron* *16) Caragana jubata, C. erinacea*
		Shrub meadow on sunny slope	*17) Quercus monimotricha* *18) Sabina pingii var. wilsonii*
Subalpine Woodland Meadows		Open woodland meadow on shade slope	*19)* Fir, spruce open woodland *20)* Alpine Oak (*Quercus spp.*) woodland
		Open woodland meadow on sunny slope	*21) Sabina spp.* open woodland *22) Pinus densata* open woodland

Source: NI, WEI and DONG, 1984.

32 "Sedge" in this study refers to the plants in the family of *Cyperaceae*.

33 "Forb" in this study refers to the herbaceous plants excluding gramineal grasses and sedges.

On the other, this text will be mainly concentrated in the high-frigid rangelands, which is the main body to support the living-system of pastoralists in the study area and even in all of the Qinghai-Tibetan Plateau. Other kinds, such as grasslands in dry valley and on low altitudual slopes, are excluded in following discussion.

3.1.1 High-frigid Meadows

The high-frigid meadows are mainly composted by perennial and medium (eumesophytic) herbaceous plants, and formed under the physical conditions of plateau, alpine and cold-humid climate, which, with about 8 million hectares of available area in the western Sichuan accounting for 62.28% of the total rangelands, distribute between 3,000 (2,800) - 4,700 m a.s.l in the western Sichuan and extend widely and continuously to the north, such as *Hongyuan*, *Zoige*, *Aba*, northern part of *Zamtang*, *Serta*, *Serqu*, *Garze* and *Litang* counties.

This kind of rangeland has an obvious sod-layer, which is one of its most important characteristics. Due to the difference of hydro-thermal conditions in different places, the density and thickness of the sod-layer differ. Generally speaking, the colder it is, the denser and thicker it is, because there are more biomasses accumulated in the underground parts of plants than in the aerial parts and the discomposition of organic matter is slower. Conversely, this layer is relatively looser and thinner and the discomposition of organic matter in the soil occurs quickly. In additions, with the conditions of high altitude, cold climate, long winter, short growing period and great day-night differences of temperature, there are apparent similarities in species of grasses and definited distribution-law.

At first, the cold-tolerant and perennial plants are the main members, which could be represented by *Kobresia* which grow thickly in clumps and in the frequency of 80-100%. Secondly, the creepers, such as *Potentilla*, the plants growing in the form of lotus-fruit, such as *Polygonum* and *Primula*, and the plants growing in clumps, such as *Festuca, Poa* and *Elymus*, are the main dominators or companions. In the different latitudes and altitudes, the proportions of these representative plants always change regularly. The more northerly the latitude, the higher the altitude and the colder the climate, the more important *Kobresia* would be, and would become the dominator. The more southward, the lower the altitude and the warmer the climate, the more grasses of *Graminae* there are in the communities. The height and productivity are also in a negative correlationship with the latitude and altitude. The more northerly the latitude and the higher the altitude, the lower the grasses and the yields are. The more southward and the lower the altitude, grasses grow higher and yield increases.

Since the high-frigid meadow is distributed extensively and with a great vertical difference, the characters and its properties vary. In the different literature, it was formerly divided into alpine meadow and subalpine meadow ascribing to its extending across sub-frigid and cold-temperate zone vertically. In China the division borders of them are always identified as follows:

- alpine meadow distributed on the zone between tree-line and alpine-tundra at elevations between 3,800 m a.s.l and 4,600 m a.s.l in northwestern Sichuan;
- subalpine meadow distributed on wide valley, terrace and south-facing slope in mountainous area at elevations between 3,000 m a.s.l and 3,900 m a.s.l, which distributive zone being analogous to subalpine coniferous forest.

At present they are united under the name of high-frigid meadow, which is used specially to indicate the meadows on the Qinghai-Tibetan Plateau and the area with similar conditions. The following discussion considers the two climatic zones separately.

In the sub-frigid area of plateau and alpine, with an altitude above 4,000 (4,200) m a.s.l, where the annual mean temperature is generally below 0°C, the mean temperature in January is below -10°C, the mean temperature in July is not more than 10°C, without an absolute frost-free season, and the growing period of grasses is only 60-120 days, the alpine meadow soil is the main type of soil. In the wide valley or small basin, the weathering intensity of soil is low, the texture is coarse and the soil layer shallow which is 30-50 cm. There is a compact sod layer with the thickness of 8-15 cm and the vegetation cover is easily impacted by the physiological dryness. On terraces or small tablelands the layer of soil is as thick as 60-100 cm and sandy loam or loamy soil is dominant, the pH of which is 6-7 or seldom 7-8 on lime mother-rock.

Under the conditions of climate and soil expressed above, the composition of plants is simple, the grass-layer is compact and low. The main species are the plants in *Kobresia*, such as *K. pygmaea, K. setchwanensis, K. capillifolia, K. humilis* and *K. kansuensis*; the plants in *Polygonum*, such as *P. viviparum* and *P. sphaerostachyum*, and some species of *Potentilla*. Additionally, some important companions could be found, such as *Carex spp., Festuca ovina, F. rubra, Poa pratensis, Saussurea spp., Gentiana spp., Ranunculus brotherusii, Aconitum szechenyianum, Anemone rivularis, Trollius ranunculoides, Caltha scaposa, Thalictrum alpinum, T. finetii,* etc.

As to the heat-deficit, grain crops cannot be harvested regularly in this area, where these are always under stress from frost damage and snow storms. Animal husbandry, specially pastoral nomadism, plays the more important role. Since solar radiation is strong and daily range of temperature is great, the photosynthesis process is active, so the ranges show that the productivity of grasses is great, the utilization ratio and nutritive value high and the palability good.

This kind of range is tolerant to grazing and is mainly used as grazing land, specially as summer pastures. It should be noted that this range is big enough in many areas to be used as grazing pastures in summer on the one hand though its yield of grass per area is relatively low, but on the another it only can be used in a short period of a year because of the harsh climate and inaccessibility.

In the cold-temperate zone with an altitude of 3,000-4,000 m a.s.l, where the annual mean temperature is 0-6°C, the mean temperature of January above -10°C, the mean temperature in July is as high as 12-15°C, the annual precipitation 600-700 mm, the growing period about 120-180 days, the soil is subalpine meadow soil, the soil layer is thick and loose, and the sod layer is not more than 8 cm thick. Based on these better hydro-thermal conditions and rich organic material in the soil, plants grow luxuriantly and the coverage of grass is high. There are different sublayers of grass which can be identified and the composition of species is more complex. Besides the dominators of *Cyperaceae*, such as *Kobresia setchwanensis, K. humilis, K. kansuensis* and *K. tibetica*, there are more species taking the dominant role in communities, such as *Carex digyne, C. enervis, Festuca ovina, Elymus nutans, Deyeuxia scabrescens, Poa pratensis, Stipa capillacea, Deschampsia caespitosa, Potentilla spp., Spenceria ramalana, Polygonum viviparum, Saussurea spp., Anaphalis lactea, Leontopodium spp., Juncus amplifolius, Stellera chamaejasme*. Companions are abundant, which leads to a mutable seasonal picture and presents the so called "colorful meadow".

The ranges in these lower regions are mainly used as grazing land in winter, but parts of them are fenced by people to be used as the hay-making pastures in order to store hay to supply fodder during the winter. Since the grazing time of winter pastures is as long as 6-7 months and the area is small, there are overstocks to different degrees and degradation though its yield is higher. Being constrained by communications, water supply and other factors in some places, parts of the ranges have not been utilized enough. There is great difference in the quantitative and qualitative use of the pastures and the yields of grass also change to a large degree.

Apart from the main types of rangeland mentioned above, some minor types should also be mentioned here.

3.1.2 Subalpine Open-woodland Meadows

When forests are distributed sparsely, as at the edge of forests, clear-cut plots or the belt near the timber-line, subalpine open-woodland meadow (open park-like stands) occurs. A woodland has a well-developed dominant open tree layer with canopy cover of less than 50%, i.e. on average of less than one-third crown diameters not touching but crowns are predominantly not interlocking. Shrubs may scatter in the undergrowth. The groudlayer consists of grasses, herb and forbs; it is well-developed but usually not very dense (WERGER, 1983).

Mainly occurring on the valley slopes or on the north-facing slopes of wide valleys and its distributive elevation being 3,000-4,200 m, the soil layer of open-woodland meadow consists of mountainous brown soil, mountainous grayish brown soil, cinnamon soil and podzolic soil. The major trees on the north-facing slopes or shady valleys are the species of spruce and firs, such as *Picea likiangensis, P. balfouriana, P. asperata, P. purpurea, P. wilsonii, Abies fabri, A. faxoniana, A squamata* and *A. georgei*. On the sunny slopes some xerophilous species, such as *Sabina spp.* and *Pinus densata,* are common.

The density of tree crown is 0.3-0.5, and the coverage of the herbaceous layer is about 30-80%, which differs from the different tree crown density. Shrubs in the understory are dominated by the species of *Rosa*, leaflet *Rhododendron, Lonicera, Spiraea, Cotoneaster, Ribes*, etc. There are relatively abundant Gramineal grasses, such as *Elymus, Poa, Deyeuxia, Roegneria, Ptilagrostis* and *Avena*, which are commonly associated with *Kobresia setchwanensis, Carex spp., Pedicularis, Anemone geum, Leontopodium longifolium, Polygonum viviparum* and *Fragaria orientalis*.

The area of these rangelands is 1.13 million hectares in the western Sichuan, making up 8.1 percent of the total rangeland and its mean yield per area is below 1,500 kg/ha. The yield of Gramineal grasses account for 3-8%, the sedges for 6-10%, but forbs for more than 80%. The legumes are rare. It is always used as natural hay making pastures and grazing land in winter and spring. The belt near timber line is occasionally used in summer and autumn when nomads migrate for alternating seasonal pastures.

3.1.3 Shrub Meadows

Shrub vegetation is mainly distributed on the south-facing slopes of mountainous area, or in the valleys of plateau area, or on the terraced land, with a wide altitude range from 2,500 - 4,500 m, which analogous to the altitude from the belt of subalpine conifer forests to the seasonal snow-lines. The coverage of shrubs is always between 30 and 80 percent, but if the coverage is over 50 percent, they are difficult browse or graze by livestock. On the contrary, they become a kind of useable pasture, shrub meadow.

Its soil layer contains mountainous brown soil, grayish brown soil, cinnamon soil and alpine shrub and meadow soil. The area of this pastures ranks second, being 3.17 million hectare, and accounts for about 24.9% of the natural rangelands, with the mean yield of 2,250 - 3,750 kg/ha.

The major dominant bushes are some leaflet species of *Rhododendron*, such as *Rh. anthopogonoides, Rh. intricatum, Rh. fastigiatum, Rh. flavidum* and *Rh. violaceum*, the heights of which are always about one meter. These plants cover the north-facing slopes in large areas on the gentle plateau, but they are not of important in grazing value.

The herbaceous layer is highly used and consists mainly of about 65% edible forbs or more, such as *Polygonum viviparum, P. sphaerostachyum, Potentilla anserina* and *Hedysarum sikkimensis*, which are of good palatability and high nutrient value. The grasses of the *Gramineae* and *Cyperaceae* account for about 9.0% respectively. The common species are *Kobresia setchwanensis, K. humilis, Festuca ovina, Roegneria brevipes, Poa tibetica, P. pratensis* and *Elymus nutans*. This type is mainly used as summer-autumn pasture and natural hay making pasture, but the part on lower elevations is also used as winter-spring pasture.

In the western Sichuan, shrubs, such as *Sibiraea angustata, Dasiphora fruticosa, Spiraea myrtilloides, Salix rehderiana, S. myrtillacea, S. ernestii* and *Caragana erinacea, C. jubata, C. tibetica*, as well as *Rhododendron spp.*, have become a nuisance to the pastures specially on the lower part of summer pastures and winter pastures. The carrying capacity of the existing land where such weeds predominate, has been considerably reduced. Local authorities and pastoralists have been attempting to eradicate the bushes, thistles, thorns, and obnoxious and ordinary weeds. Their eradication by application of herbicides is cost prohibitive. The effective and practical method for removal of such bushes and weeds seems to be the manual cutting of the aerial portion of the plants and then burning the stump so as to check its further growth (see 5.2.4 in this book).

3.1.4 Swamp Meadows

Swamp meadow is distributed in the special areas on the plateaus, such as the depression areas, the areas with poor drainage, the areas with seasonal water accumulation, swamp margins, bottoms of wide valleys and the base of hills with springs. Most of them occur within *Hongyuan* and *Zoige* County of Aba Prefecture, where the elevations are about 3,400 m or more. Its soil layer is composed of peat grayed soil and peat soil.

The species in this meadow are not rich and are mainly composed of moist-eumesophytic plants and moist plants, mixed with a few swamp plants and aquatic plants. The dominators commonly are *Kobresia tibetica, K. humilis, Carex atrofusca, C. moorcroftii* and *C. muliensis*. Additionally, some companiors can also be found easily, such as *Poa pratensis, Trollius ranunculoides, Sanguisorba filiformis, Triglochin maritimum, Caltha scaposa,* etc. The coverage of communities is averagely about 60-85% and the height about 20 cm.

The fresh grass yield is about 5,000 kg/ha, of which the yield of sedges account for 63-99%, the Gramineal grasses for 3% and forbs for 7-16%. The grasses in this region turn green very early, so it is an important spring range, specially for the relieving of starvation in early spring. But there are a lot of parasites and water on the surface of the soil, which makes the infection of animals with disease easy. Generally speaking, the utilization ratio of this kind is low. For example, in *Zamtang*, swamp meadow is distributed mainly on the upper reaches of *Zhe-que* River with gentle slopes and low-lying land at elevation about 3,800 m a.s.l and it is easy for water accumulation in the rainy season, and, therefore, in summer only the edge area it can be used. In addition, the peat in swamp sometimes is dug out by local people as fuel, which can be found in *Hongyuan*.

In the case study area, *Zamtang*, four kinds of rangelands can be found, which make up the main component in pastoral system (Fig. 3.1).

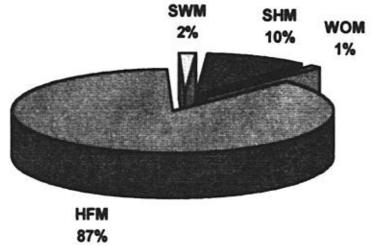

Fig. 3.1 Composition of Rangelands in Zamtang

Note: HFM= High-frigid Meadow; SWM= Swamp Meadow; SHM= Shrub Meadow; WOM= Open-woodland Meadow

Source: XIE et al., 1988

3.2 The Flora of the Rangelands

Owing to the short history of the formation of the Qinghai-Tibetan Plateau and the harsh ecological conditions, the development of the flora in this region has been restricted. According to the incomplete statistics (LIU, 1991), there are about 350 species of plants in the high-frigid rangelands, but the dominants are only about 30 species.

Among the various plants, the wild forage grasses are extremely abundant, and according to their amount, yield, palatability and feed value. Grasses (*Gramineae*) and sedges (*Cyperaceae*) are found as the dominant plants. The grasses in *Gramineae* not only have a great number in species, but also distribute widely over the vast natural rangelands. These grasses, with fine palability and high nutrient content, are very important for fattening animals in autumn, and also the major hay making grasses. However, the area of rangelands covered mainly by these grasses are small and their yields are lower than those dominated by the species of *Cyperaceae* and dicotyls. The most important fodder grasses of *Gramineae* in the natural rangeland in western Sichuan are:

Elymus nutans, E. sibiricus, E. tangutorum, E. dahuricus, E. breviaristatus, Festuca ovina, F. rubra, F. sinensis, Deschampsia caespitosa, Agrostis hugoniana, A. limprichtii, Bromus sinensis, Helictotrichon schellianum, H. tibeticum, Koeleria cristata, Poa pratensis, P. alpina, P. alpigena, P. chalarantha, P. pachyantha, P. sphondylodes, *Roegneria brevipes, R. breviglumis, R. melanthera var. tahopaica, Trisetum spicatum, Deyeuxia scabrescens, D. tibetica, Brachypodium sylvaticum.*

After the lengthy experiments and tests in different place, some of them have been selected so that their seeds can be used to resow in order to restore the degraded pastures, such as *Elymus nutans, E. sibiricus, Festuca rubra, F. ovina, Poa pratensis* and *P. pachyantha.*

The species of the *Cyperaceae* are not as common as those of the *Gramineae*, but they are very important for the natural rangelands, especially the species with low temperature resistance *Kobresia* and *Carex*, which predominate in the most high-frigid meadows. In Garze and Aba Prefectures the pastures dominated by the plants of *Cyperaceae* make up 68% and 71% of the total area of rangeland separately. With the high nutrient value, these plants are of high palability and specially fitful to the yak's grazing. The most important species of *Cyperaceae* which can be found in the western Sichuan are as follows:

Kobresia setchwanensis, K. pygmaea, K. tibetica, K. kansuensis, K. capillifolia, K. humilis, K. macrantha, K. royleana, Blysmus sinocompressus, Carex enervis, C. muliensis, C. moorcroftii, C. praeclara, C. nubigena, C. schneideri and C. kansuensis.

The wild legumes are also found very abundantly over the various rangelands of western Sichuan. The common genera[34] are *Medicago, Hedysarum, Vicia, Indigofera, Astragalus, Caragana* and *Oxytropis*. Based on the tests and analysis made by the Chengdu Institute of Biology, the amino acid contents of these plants are very high. Because of the limits of natural conditions, large-scale introduction of fine species[35] of legume is difficult in this region (see 5.3.3 of this book). Therefore, it is an emergency problem to develop and breed the local wild species.

Excepting the Gramineal grasses, sedges and legumes, forbs also have many species and are widely distributed in this region. Their yields rank first among the other herbage (usually above 50%). The edible forbs take up one half or one third of the total forbs, and some are palatable for animals. The content of crude protein is always higher than that of the Gramineal grasses and sedges. On the Plateau and the alpine area common forbs are as follows:

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[34] "Genera" is the plural of genus, which refers to a group of related species and is a particular rank in the taxonomic hierarchy, between the species and the family.

[35] "Species" is a particular kind of plant or animal, which maintains its distinctness from other kinds in nature over a period of many successive generations (CRONQUIST, 1982).

Polygonum viviparum, P. sphaerostachyum, Aster alpinus, Saussurea quercifolia, S. globosa, S. bodinieri, Artemisia spp. Taraxacum maurocarpum, T. mongolicum, T. lugubre, Heteropappus bowoeri, H. altaicus, Potentilla anserina, P. saunderiana and some species in *Anaphalis, Leontopodium* and *Potentilla.*

Furthermore, in terms of the type of floristic distribution, most of the genera mentioned above can be ascribed to the type of Arctic-Alpine Distribution, China - Himalayas Distribution or Endemic of Qinghai-Tibetan Plateau, which belong further to Cosmopolition or North Temperate Distribution (WU, 1979). Of these plants, *Kobresia pygmaea, K. humilis, K. royleana* and *K. capillifolia* belong to the elements of China - Himalayas or Highland of Middle Asia; *K. setchwanensis, K. tibetica, K. prattii* are the Endmic elements of Qinghai-Tibetan Plateau; *Carex moorcroftii* and *C. scabrirostris* are the endmic elements of Qinghai-Tibetan Plateau and alpine area of western China; *Polygonum viviparum* belongs to Arctic-Alpine distribution; *P. sphaerostachyum* distributes endmically from the Himalayas to eastern China. In companions, the species of Arctic-Alpine Distribution rank firstly, such as *Thalictrum alpinum, Pedicularis oederi, Lagotis brachystachys,* etc.; second role is the elements of Himalayas, such as *Lancea tibetica, Primula sikkimensis, Caltha scaposa,* etc. In additions, most species in *Gramineae*, such as *Festuca ovina, Elymus nutans* and *Koeleria cristata,* belong to North Temperate Distribution. Generally speaking, the flora of the high-frigid rangelands mainly immigrate from the neighbouring regions or have developed autogenetically with the rise of the Plateau (LIU, 1985).

3.3 Quality of Natural Pastures

The pastoral system carried out in the western Sichuan is similar to that on other high-frigid pastoral areas of the high Himalayas (NEGI, 1990; WANG et.al, 1992), therefore, the study on the grass quality is helpful for understanding the situation of high-frigid rangelands in this region.

Restricted by the natural conditions, the high-frigid rangelands produce a high quality of grass but low yields. Conferring the analysis of the nutrient composition of mixed grass samples collected on different pastures in the western Sichuan, showed that rangelands in this area contain high protein, nitrogen free extract (NFE), fat and lysine in protein, but with low crude fibber with a high digestion coefficient (WEI and WU, 1988; HUANG, 1992).

In the high altitude area of western Sichuan, most species in *Gramineae* are the plants with high permissible off-take because of their root or inferior propagation, rich foliage, soft texture. In comparison with other grasses, the nutrient value of Gramineal grass is lower, but they are still the main foodstuff for domesticated animals due to their abundance, high palatability, convenience in processing, carrying and storing. Only in view of crude protein Gramineal species take the lowest place among different kinds of herbaceous plants, most of which only contain 10% or less. The contents of crude protein and crude fat in some common genera list in table 3.2.

Table 3.2 Nutrients in Common Genera of *Gramineae* of the High-frigid Rangelands

Genera	**Crude protein (%)**	**Crude fat (%)**
Agrostis	12.00	2.86
Roegneria	12.41	2.42
Elymus	10.18	2.98
Bromus	10.56	2.51
Festuca	12.61	2.40
Poa	12.33	2.75
Brachypodium	11.80	2.20
Calamagrostis	9.57	2.46

Note: The analyzed samples are mixed. Every figure implies an average number in the genus.

Source: Sichuan Animal Husbandry Bureau, 1989.

Although the numbers of legumes in the range are not as many as the Gramineal grasses, they contain more protein, minerals (specially in calcium) and vitamins, which are available to the growth of livestock. The mean nutrient contents in legume, such as in *Medicago, Vicia, Hedysarum* and *Astragalus*, are that crude protein 20% (varied in the range from 10-20%), crude fat 3.1% and calcium 1.51%, among which the crude protein takes the highest role (dry matters) in all herbaceous plants.

Generally in Gramineal grasses nitrogen and phosphorus are diluted in lower concentrations than in legumes and forbs; they can produce more biomass on poor soils (low in N and P) than legume or forbs, but as a result their quality is lower (BEHNKE, 1992). Comparing the nutrients in legume and grasses, the average value can be shown in Fig. 3.2.

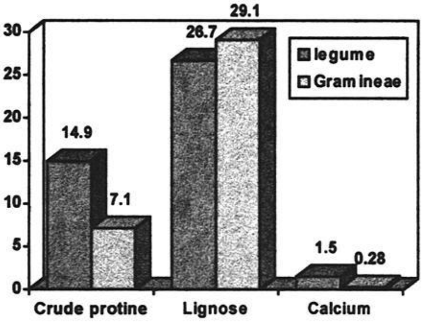

Fig. 3.2 Comparison of Nutrients in Legume and *Gramineae*
Note: The analyzed samples are mixed, which are collected in Hongyuan.
Source: ZHOU, 1982.

That is to say that the nutrient value of legumes is higher than that of Gramineal grasses. Additionally, due to the symbiotic nitrogen fixation of legume bacteria and the developed root system, legumes are very important in the improvement of soil structure and fertility in the remote rangeland.

The plants in *Cyperaceae*, specially *Kobresia* and *Carex*, make up the main body of the high-frigid meadow on the one hand, on the other they have high permissible off-take and their nutrients are higher than that of Gramineal grasses. The species in *Kobresia* contain 13.49% crude protein in average, which is higher than that of other species in this family[36]. This character of *Kobresia* just makes up the deficit of legumes in the high-frigid meadows. However, sedges with some shortcomings, such as the high content of silicon, changeable yields due to seasonal alternation and their short bodies, lead to their disadvantages in yield. The crude protein in forbs is similar to that in sedges, which is always above 10%.

In order to improve the development of animal husbandry, an estimation of the amount of primary production alone is insufficient, since livestock can consume only a portion of it. Another important factor is the forage quality. The relationships between the quality and quantity of forage consumed by a ruminant and secondary productions are summarized in Figure 3.3.

[36] Botanically speaking, "family" refers to a group of related genera, which is a particular rank in the taxonomic hierarchy, between the genus and the order, such as *Gramineae* and *Cyperaceae*.

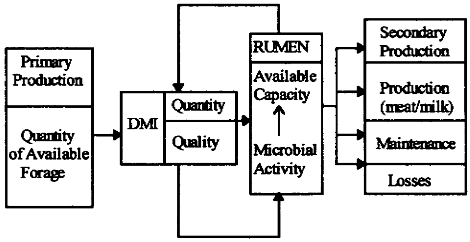

Fig. 3.3 Relation Between Quality and Quantity of Forage Intake by a Ruminant and Secondary Production

Note: DMI = dry matter intake

Source: RIDDER et al., 1982

A quantity of food (in terms of glucose, proteins, lipids, vitamins, minerals, etc.) is ingested by an animal per unit of time. The animal requires certain quantities of these elements to exist. If the quantity ingested exceeds this requirement, meat and milk can be produced; if it is less, the animal must live on its reserves and will lose weight. Obviously, the amount of forage on offer determines whether the quantity of forage that can be ingested, given its quality, is actually ingested. In this context forage quality is applied to "forage value, and depends on two essential elements: energy content and nitrogen content." (RIDDER, 1982:31). The energy content of forage is expressed in crude fat, and the nitrogen content in crude protein content.

Another concept is permissible off-take, which has been defined as the proportion of the total biomass produced, which is useable as animal feed, if range deterioration or degradation is to be avoided (SCHWARTZ, 1991). Biomass production in the herblayer, which is the major source of forage for yaks, sheep and horses, range from close to 2,500 kg/ha to just over 5,000 kg/ha.

3.4 The Ecological Characteristics of Rangelands

3.4.1 The Life-forms and Ecotypes of Plants

Being similar to high altitude plants in other parts of the World, plants on this Plateau are also composted mainly by perennials that require several years to attain maturity. Although the plants continue to grow for several years, they remain characteristically low and spread close to the ground. The dominant perennials of the highland ecosystem have annual aerial parts that wither away at the end of each growing season. They have on the other hand perennial underground stems, rhizomes, stolons, rootstocks, creeping and often also woody, long rooting runners, generally covered by thick layers of old leaf sheaths, expanded bases of petioles, etc., and send out fibrous roots. The perennials constitute the bulk of the cushion, spreading mats and polster plants of densely tufted, up to 30-40 cm tall, but usually only 15 cm high above the ground. Whether perennials or annuals, highland plants are predominantly dwarfs. In a number of lands the internodes are greatly shortened so that the leaves are largely or wholly all radical. The shortening and suppression of internodes and the formation of rosettes are common characters of the alpine-zone plants on nearly all high mountains, as well as in the sub-arctic, arctic and sub-Antarctic areas (MANI and GIDDINGS, 1980).

With the "Life-form" system developed by RAUNKIAER (1934), the plants varied in growth-form can be classified into different groups based on the position of over-wintering buds (Fig. 3.4).

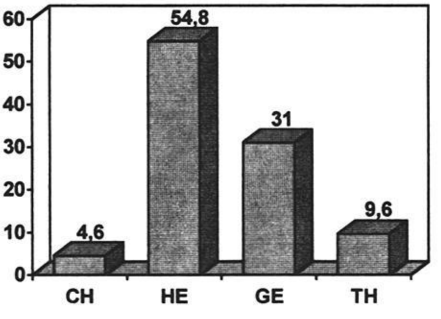

Fig. 3.4 Life-form Spectrum in Samples of Alpine Meadow in Zamtang

Note: Analysis is based on 78 species.
CH = Chamaephytes; HE = Hemicryptophytes;
GE = Geophytes; TH = Therophytes

Hemicryptophytes, which have the over-wintering buds growing point at or near the ground surface, account for more than half of plants in high-frigid meadows. This group includes not only perennial grasses and sedges, which in many types of rangeland make up the greater proportion of species, but also numerous dicotyledonous herb. Some of these, such as *Thalictrum alpinum* and *Pedicularis longiflora*, have a erect stem. Some of these, such as *Festuca ovina* and *Ptilagrostis mongholica*, grow in dense groves. Others have a rosette habit, such as *Polygonum viviparum*, *P. sphaerostachyum*, *Potentilla bifurca* and *Leontopodium nanum*. All are adapted by habit of growth and position of their apical meristem to withstand grazing and, hence, cutting or mowing.

Another type of plant found in rangelands is the geophyte, which passes the winter as a rhizome[37] or an underground tuber or modified stem. Alpine meadow contains 31.0% geophytes, most of which are the species in the family of *Cyperaceae*, such as the species of *Kobresia* and *Carex*. Chamaephytes form less than 5% of the life-forms of high-frigid meadow, which mainly include a few cushion plants, such as *Arenaria polytrichoides* and *A. kansuensis*, but this element becomes of greater importance in the warmer, lower altitude locations. Annuals (Therophytes) are not important components of closed communities, a characteristic feature of high-frigid meadow, but they make a significant contribution to the fenced pastures which have not been opened to livestock for at least two years, or the drier rangelands, such as the desertificated pastures in the basin of Yellow River's affluent and the alpine steppes in central Tibet (TIST, 1992).

Under the harsh climates, the plants in high-frigid rangelands form some special ecological features, which include:

Dwarf plants: The plants in high-frigid rangelands are never more than 15 cm, such as the meadow of *Kobresia setchwanensis*, which is the most popular type of alpine meadow, with the height of herb-layer being about 5-10 cm.

Rosular plants: These plants have a very short stem and their leaves extend radically from the base and form a rosulate, which can get more heat from overground parts, such as *Saussurea stella* and *Lamiophlomis rotata*.

Cushion plants: These adapt to the strong wind and severe cold on the highlands. The stems of these plants shorten so much, assemble tightly together and in the end become creeping stems. Their leaves shrinking in size and scale and withered plant-parts may become cushion like. These changes can function to prevent the dissipation and evaporation of water from interior tissues, and additionally retain body temperature and moisture. The common species are *Androsace brachystegia, A. mariae var. tibetica* and *A. erecta*, which always distribute on the alpine above 4,200 m.

Viviparous plants: These are a special adaptive character, in which the plants reproduce a new body on the mother plant (viviparous propagation), which (as small plants) fall on the ground after a short time and produce roots rapidly. This new plant hides under the cover of

[37] "Rhizome" is a creeping underground stem.

snow or surface soil to pass over the winter. This kind of plant can be represented by *Polygonum viviparum* and *Poa sinattenuta var. vivipara.*

Shallow-rooted plants: Owing to the restriction of permafrost in deeper layers of soil, plants on the high altitude have to stretch their roots horizontally, which concentrate mostly between 0 and 10 cm under soil surface and can easily absorb moisture and nutrients when the temperature of the soil surface rise.

In western Sichuan the distribution of high-frigid rangeland corresponds to the undulation of micro-topographies. The changes of topography results in the change of hydro-thermal conditions, and further in the difference of soil moisture, temperature, aeration and nutritional status.

Firstly, generally speaking, in the low-lying land where there are higher groundwater level and seasonally accumulated water, swamp meadow or moist type occur frequently, which dominants are *Kobresia tibetica, Carex muliensis* and *Carex atrofusca*; Secondly, on places a little higher the moist-eumesophytic meadow distributes in the transitional belt, where the dominants are *Kobresia humilis, Polygonum viviparum, Trollius ranunculoides* and *Sanguisorba filiformis*; Thirdly, eumesophytic meadows occur on the slopes, top of hills or high-lying lands where soil is in good drainage and appropriate soil moisture, which are dominated by *Kobresia setchwanensis, Anaphalis flavescens, Leontopodium longifolium* and *Spenceria ramalana.*

On the sunny slopes, dry-eumesophytic meadows are the result of the stronger solar radiation, longer illumination, higher temperature and related rapid evaporation of soil moisture, where some drought enduring plants, such as *Kobresia capillifolia, K. pygmaea, Festuca ovina, Stipa capillacea, S. aliena, S. purpurea, Poa pratensis* and *Saussurea spp.*, dominate in meadows (Table 3.3).

Table 3.3 Comparison of Temperature in Different Topographies*

Topography	Measuring Time	Temp. of Soil		Temp. of Grass			Temp. of Air
		Depth		Height of leaves			Height above ground
		20cm	2-3cm	5cm	10cm	top	100cm
sunny slope	12:30	15.3	21.6	12.1	14.8	14.5	14.0
shade slope	12:40	11.0	14.4	13.8	13.5	12.4	11.8
top of hill**	12:30	12.5	18.8	17.5	14.0	13.0	11.7
Hillfoot	7:20	11.0	8.2	0.2	0.2	0.0	0.2
sunny slope	7:30	10.2	7.5	4.5	4.9	3.7	3.2
shade slope	7:20	8.5	3.0	1.2	1.2	1.0	1.0
top of hill***	7:30	9.5	6.3	0.9	0.9	1.8	1.2

Key: * In September 1, 1976, these numbers were measured in Amuke, Hongyuan County.

** The relative altitude is 70 m between the hill foot and the top.

*** The relative altitude is 90 m between the hill foot and the top.

Source: ZHOU, 1982.

3.4.2 The Growing Phases of Plants

1) Germination or regrowth

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) and while temperatures are above that level the rate of growth is closely related to the input of solar radiation.

As to perennial grasses, such as *Kobresia* in *Zamtang*, they begin to grow at the end of April or at 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 their productions are also in a lower state. For the grasses reproduced by seeds, such as Gramineal grasses, the nature of the herbaceous stratum which develops during the growing season is also mainly determined by the amount and distribution of rain at the beginning of the season, taking into account the substrate and seed supply. The germination rate is an important characteristic, although other parameters play a role as well. In fact, it is obvious that rainfall influences the nature of a germination flush by determining the period of wetness of the substrate. The longer this period, the higher the proportion of slow-germinating species in the vegetation. It should be pointed out here that "rapid and early occupation of the available space is a great advantage for a species throughout the rest of the season." (BEHNKE, 1992:155). On the highlands, germination is not completed successfully until the seedling is well established.

2) Vegetative growth

After the commencement of growth, the growth tends to be rapid and the daily dry matter production of the pasture increases to a peak within six to eight weeks. During this period the pasture is growsing by two processes; leaves are extending from existing, parent tillers, while new daughter tillers are forming at the base and growing laterally. Thus, this phase of vegetative growth, as it is known, sees an increase in both the mean height of the pasture and in its density. In time, the new tillers develop adventitious roots which grow into the ground so that the daughter tillers become independent of their parents. In western Sichuan the commence of nomadic migration is in correlation with the growth of grasses, i.e., the time of nomads in a certain place begin to move from cold-season pastures to warm-season pastures in spring is almost equivalent to the time that the height of regrowing (regreening) tillers or newly plants are averagely about 5 cm in alpine meadow or 10 cm in subalpine meadows (see 5.1.3 of this book).

The total biomass produced during the growing season is determined by growth factors in short supply. For natural rangelands, this is at first, soil fertility, and secondly, of increasing importance for high altitude, water and heat availability. Tillering ability and establishment play an important role in the occupation of the space by various species. In this case, space is defined as the combination of factors influencing growth, such as water, light, minerals, nitrogen, and the physical space itself. Several characteristics of the species are equally important in determining their competitive ability towards these factors during vegetative growth. For example, the presence of a living vegetative apparatus in perennials enables immediate growth after the first rains falls in the spring. This, combined with a high root to shoot ratio – and therefore an extensive surface for nitrogen and phosphorus absorption – and a long growth cycle, enables perennials to better exploit the limited resources in comparison to annual[38] species.

On the other hand, plants which are frequently or intermittently defoliated must be able to regenerate new tissue if they are to survive in rangeland. Grasses produce fresh green material by tillering, the form of which is characteristic for each species, although this may be modified by other factors in the environment. LANGER (1956) has suggested that the grass plant is best considered as a dynamic aggregate of short-lived plantlets or tillers, the perennial habit being secured by the over-wintering shoots which produce themselves vegetatively and rarely survive the subsequent season. Moreover, plants which are

[38] "Annual" refers to a plant that completes its life cycle and dies in a year.

frequently defoliated must be able to synthesize and translocate reserve food substances to storage regions, so that after defoliation or dormancy the plant may produce fresh vegetation capable of photosynthesis. The amount of reserves (soluble carbohydrates) stored in the roots fluctuates throughout the year, generally being high in summer and low in spring. As might be expected, the time and intensity of defoliation affect root development, level of food reserves and ultimately plant vigor and competitive ability.

3) Reproductive growth

Throughout the phase of vegetative growth, the flowering stems of the plants remain short and close to the ground, but during late spring and early summer vegetative growth gives way to reproductive growth, and the flowering stems then extend and ultimately produce a flower. The commencement of the flowering phase is variable in different plants. According to the primary observation in *Zamtang* County, *Kobresia setchwanensis, K. pygmaea* and *Leontopodium nanum* begin to flower as early as in the early of June. These plants not only regreen and flower early, but fruit and dormant also. Some plants flower in the middle of July, the time of strongest growth, such as *Carex sp., Potentilla anserina* and *Oxytropis kansuensis*, etc. Others flower as late as in the middle of August, such as *Elymus nutans, Festuca ovina, Poa sp.* and *Gentiana straminea.*

Following inflorescence, the seeds within the flower head are shed and the tiller starts to die. No further extension of the leaves occurs, and the only new growth is through the development of tillers from the dying basal stem. At this stage, therefore, the net production rate of the pasture starts to decline as death of the tillers begins to balance the effects of renewed vegetative growth.

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

Most rangelands on the Qinghai-Tibetan Plateau are closed communities with a stratified arrangement of leaves and flowers leaving little or no bare ground. Flower and seed production by perennials vary considerably, the number of propagules and frequency of production being a characteristic of each species. However, these characteristics are also influenced by climatic conditions. Furthermore, the production of propagules can be greatly affected by management. For example, grazing at a time when a species is in bud may effectively prevent it from producing seed in that year. This applies particularly to monocarpic species but less so to those perennials which regularly reproduce by vegetative means. Studies on meadow plants in Russia (RABOTNOV, 1969) have demonstrated that in closed communities such as alpine meadows, the longevity of some of the constituent species may exceed 130 years, some not flowering until they are at least 20 years old. This work has shown that in any closed community there is likely to be a distribution of plants in different age classes. There will be seedlings, juveniles, immature adult plants, reproductive plants, vegetative adult plants and senescent plants of great age.

4) Senescence and dormant period

As the season progresses, senescence increases, for stresses upon the plants become greater due to lower radiation inputs and reduced ambient temperature, the plants cease to be able to compete so successfully, and new tillers fail to mature.

Plants are dormant in the form of various underground parts and seeds. The seeds and the dead residues of plants, i.e., straw, undergo several processes. These processes, along with previous plant activity, determine the development of the quantity and quality of forage with time, which concerns the next season's growth.

The finishing time of grazing on warm-season pastures (summer pastures) relates to dormant time of grasses. Generally speaking, in *Zamtang* as well as in the northwestern Sichuan grasses begin to wither and then dormant in the early of the November, which, of course, vary with climate. Nomads always drive their herds downward to cold-season pastures (winter pastures) about one month earlier before the grass withering (see 5.1.3 of this book).

3.4.3 The Features of the Rangeland Ecosystem

Rangeland ecosystem comprises three main components: the vegetation, the soil and the 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 behavior and development. In its own turn animal behavior influences the pasture and the soil. Finally, three components in the ecosystem as a whole connect with external socio-economic system, which has been explained in Chapter one of this book and shown in Figure 1.3.

The vegetation forms a central component in rangeland ecosystems. It receives inputs of energy from solar radiation, water and nutrients from the soil. It provides energy and nutrients to the 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 the grazing animals and the soil, absorbing some of the physical damage through propagatively regenerating themselves. The pasture is, likewise, influenced by animal behavior including the effects of trampling, selective defoliation and the return of faeces to the surface. All these processes affect the rate of growth and competitiveness of the herbaceous plants, and thereby influence pasture composition. These, in turn, control the productivity of rangeland.

Under natural conditions herbivores act as predators on the rangeland vegetation, and grazing must be considered as a natural influence in rangeland ecosystems, needed to maintain equilibrium. Pastures grazed lightly or moderately by animals remain stable and productive. Moderate grazing can stimulate productivity, with production of above-ground parts increasing to twice that of ungrazed areas. (HOLZNER, WERGER and KUSIMA, 1983)

Furthermore, there are indications that light or moderate grazing can maintain the balance between plants' species in rangeland for very long periods, perhaps several thousands of years (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 & MISRA, 1969). WHITTAKER (1977; 1980) drew out a similar result after his research 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-soiled hillsides. A more important fact is that over long periods of stress, vegetation can adjust, 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 grazing. The so-called 'sustainable development in pastoral society' means a rational utilization of rangeland rather than absolute protection.

The complex relationship between grazing animals and plant communities has long been recognized by pasture workers. ARNOLD (1964) pointed out that in most experimental work making use of 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 by trampling, which will be described in details in the following chapters.

Some indications of the interactions between the various components of rangeland systems, and the effects of them of different management procedures, can be seen by considering nutrient cycles at the farm scale. At this level, the main inputs of nutrients are from fertilizers, atmospheric deposition, nitrogen fixation, bedrock weathering and inputs of seeds. Outputs are by removal of the grass and animal products (e.g. milk, wool, carcasses), by leaching, volatilization and erosion. Within the system, transfers of nutrients occur from the soil to the vegetation and hence to the livestock, and from both these latter back to the soil. In addition, various other flows and stores can be seen, for example in corral manure, or in grass used for conservation purposes as hay, such as storing oat grass in *Zamtang*.

The magnitude of these various transfers, stores, inputs and outputs vary markedly according to the nature of the rangeland system. In general, the amount of nutrients in circulation is small in extensive grazing systems, and increases with grazing intensity. Unfortunately, in western Sichuan it is rare for all the components of the system to have been measured in detail; in particular, inputs from bedrock weathering have rarely been assessed while data on the internal transfers within the soil are often incomplete.

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

The aim of the pastoral herdsmen is to control all three components - by migration, by changing grazing routes, by regulating the duration of stay in one place, by determining the grazing season in different seasonal pastures and by controlling the livestock (see 5.2.1 in this text). They thereby regulate the inputs to and the outputs from the system, as well as its internal structure. It should also be remembered that they are affected by the operation of the system, not always directly, but often indirectly through the economic implications of rangeland productivity.

Over 50 per cent of the land surface of the western Sichuan is devoted to rangeland. Only in areas where marked sufficiently moisture occurs, or where altitude locations are so low that can support a forest cover, rangelands are the products of human activity, or consequent upon clearance of the original forest and maintained by grazing which prevents the regeneration of scrub or trees, and have developed as a plagioclimax, like most subalpine meadow; only when these pressures are released, by abandonment of the land or by deliberate enclosure of animals, does the vegetation follow its natural succession back to woodland.

While a certain amount of utilization of the rangeland production is needed to maintain equilibrium, overuse is detrimental. Although there are various degrees of overuse, and such factors as timing and duration enter the picture, the destructive effects of overuse have been noted worldwide. Both vegetation and soil are affected, and usually the rangeland goes through a sequence in which deterioration can be expressed in general terms (LOOMAN, 1983): good forage – intermediate forage – poor forage -weeds and open soil.

Generally speaking, degradation processes proceeds faster than regeneration processes (BEHNKE, 1992). Species that germinate slowly have resistant seeds, which are always present. The seeds of rapidly germinating species are less resistant; they may survive in a viable form in the soil for a year. Thus the seeds produced by these species in one year will determine the population of the following year; a long time must pass before a population of rapidly germinating species is built up. If degradation has been caused by overgrazing, the regeneration process will be protracted, since the soil surface has been destroyed (Fig. 3.5).

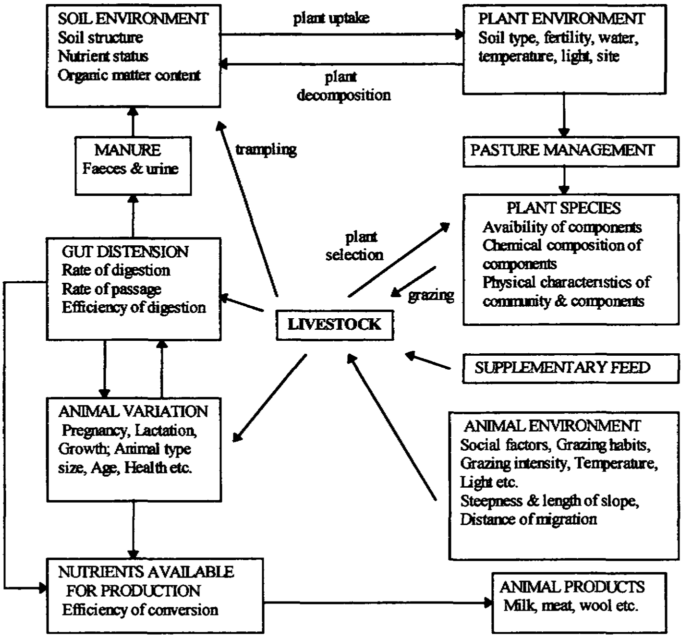

Fig. 3.5 Schematic Complexity of Soil-plant-animal Relationships
Design: WU NING

3.5 Carrying Capacity in Western Sichuan and its Dynamics

The "range resources" of an area are often talked about in the work of developmental economists, planners and political decision makers. "Carrying capacity" is the term which is generally used to describe the amount of these resources, which is taken as synonymous with "grazing capacity" and "range capacity" in this context. Corresponding to the definition given by BASS (1993), this term was used to describe the number of animals which a certain area could support without land degradation taking place in the long term.

Now we can consider the situation of carrying capacity in some pastoral counties. At first, it should be mentioned that the daily ingesting of fresh grass by one adult sheep was suggested by Chinese scientists as 5.6 kg (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989; TIST, 1992), i.e., the standardized figure of one sheep unit (SU) is 5.6 kg, and furthermore one yak or cattle equal to 5 SU, one goat is 0.8 SU and a horse is 3.2 SU. Generally, the carrying capacity in a certain place could be calculated out by way of investigating the total number of livestock in this place and the total production of fresh grasses. For example, according to the survey results sponsored by the Animal Husbandry Bureau of Aba

Prefecture, the theoretical carrying capacity[39] in Aba Prefecture was 6,111,772 sheep units, but in fact there were 6,808,852 sheep units (practical carrying capacity[40]) in 1985 (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989). The overstock number is 697,080 sheep units (Fig 3.6). In *Zamtang* there were 632,289 sheep units in 1985 and every sheep unit occupied 0.54 hectare useable pastures. The theoretical carrying capacity in this county is 479,412 sheep units, so the overstocking percentage was 31.89 (Table 3.4).

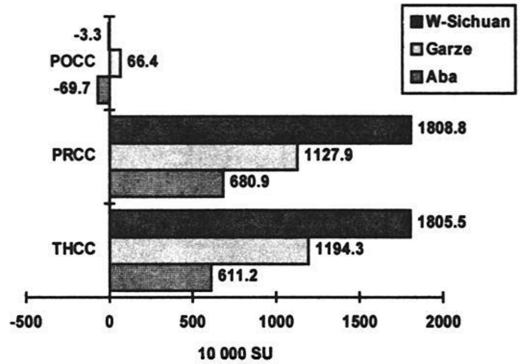

Fig. 3.6 Comparison of Carrying Capacity in Garze Prefecture and Aba Prefecture
Note: THCC = Theoretical carrying capacity;
PRCC = Practical carrying capacity;
POCC = Potential carrying capacity
Source: SICHUAN ANIMAL HUSBANDRY BUREAU, 1989.

But some authors thought that the determination of a rangeland's carrying capacity cannot be based solely on botanical considerations, but must also take into account the management objectives of rangeland users (BEHNKE, 1992), and they further pointed out:

"Misleading carrying capacity estimates are often based on a confusion between ecological and economic carrying capacity. Ecological carrying capacity can be defined as the point at which livestock populations cease to grow because limited feed supplies produce death rates equal to birth rates. Most livestock owners and range managers find it profitable to hold their livestock populations somewhere short of this ecological ceiling." (1992:2)

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[39] Theoretical Carrying Capacity (TCC) can be get from:

$$\frac{\text{grass yield in one unit (kg/ha)} \square \text{grassland area (ha)}}{\text{daily ingestion of one SU (kg/day. SU)} \square 365 \text{ (day)}}$$

[40] Practical Carrying Capacity is the total sheep units in a certain area, which is calculated from the total number of domesticated animals in this area.

Table 3.4 Carrying Capacity in some Pastoral Counties

County	Area of grassland* (ha)	Theoretical carrying capacity	Practical carrying capacity	Potential carrying Capacity
Hongyuan	747,221	983,576	1,319,564	- 335,988**
Zoige	651,966	1,542,204	1,891,076	- 348,872
Zamtang	339,410	479,412	632,289	- 152,887
Songpan	293,472	595,024	366,820	+ 228,204
Aba	716,274	967,860	1,004,408	- 36,548
Serqu	1,841,513	1,883,500	2,421,352	- 539,852
Sertar	822,051	1,513,628	1,244,904	+ 268,724
Dege	505,104	856,088	1,326,892	- 470,804
Litang	779,089	910,696	807,680	+ 103,016
Baiyu	533,657	715,412	623,872	+ 91,540

Key: * This area is that of available grassland.

** The ' -' implies an overstock situation.

Source: 1) SICHUAN ANIMAL HUSBANDRY BUREAU, 1989.

2) XIE, 1988.

It should be considered, meanwhile, that with the variability of ecological conditions and other episodic events control both plant and animal populations, the grazing systems may be in constant disequilibrium (BEHNKE, 1992). Conceived of as a single, safe stocking rate, the concept of carrying capacity is not appropriate to the management of grazing systems not at equilibrium. Recent ecological research in arid rangelands in Africa (ELLIS and SWIFT, 1988; ELLIS et al., 1991), where climatic variability is high and ecosystemic behavior very dynamic, suggests that most arid and semi-arid range ecosystems function as non-equilibrium systems. In these systems, range productivity is more a function of climate than of livestock stocking rate and the effect of livestock on the vegetation is sporadic rather than continuous. That means to that carrying capacity is not a static indicator rather than a fluctuating parameter, specially which can not be used as the solely ground to make decisions about destocking or restocking.

Assuming one has no better index to determine the strategy of grazing management, carrying capacity is still the useful parameter. However, it must be concluded that it is difficult to accurately estimate carrying capacity in the highly dynamic ecosystems where pastoralism takes place. (BARTELS et al., 1991)

The single most important question for applied research on pastoralism is to discover the upper limit of the carrying capacity of the pasture. It could be that at some critical juncture the changes in the pasture become, if not irreversible, then only reversible at great cost, that is lead to a relatively permanent ecological degradation. However, there is a major problem in obtaining extensive quantitative data directly from nomads, who move over vast areas of difficult terrain away from infrastructure and have a very low population density.

For a variety of reasons, nomadic pastoralists are able to profitably maintain higher stocking rates than commercial beef ranchers in Africa (BEHNKE, 1992). With respect to herd productivity, comparative studies of ranch and pastoral herd output in Africa pastoral systems demonstrate also that traditional pastoralism either equals or exceeds the productivity per unit land area of commercial ranching in comparable ecological environments. This concerns the strategies to exploit environmental instability and contingent events characterized by "opportunistic management" or "opportunism"[41] (SANDFORD, 1983; WESTOBY et al., 1989; MILLER, 1995). Pastoralists engaged in alternative systems of production will find it advantageous to maintain stocking rates appropriate to each system.

Determination of the 'correct' stocking rates in a particular area will be a process of reconciling these multiple objectives. Administrators and technicians can provide assistance in retermining the potentially conflicting demands of different classes of producers. The persistent inability of outside agencies to effectively control stocking rates suggests, however, that local communities must ultimately be responsible for enforcing agreements on stock numbers. This implies the devolution of authority over these matters and the provision of technical assistance to local communities, rather than the attempt to impose centralized control (BEHNKE, 1992). BEHNKE and SCOONES (1993) noted that traditional pastoral land use practices are an effective response to the difficulties of an difficult natural environment, and that the development of livestock production in harsh environments require the refinement and adjustment of these practices to changing circumstances, not their outright elimination.

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[41] "Opportunism" in this context basically means being prepared to respond rapidly to grazing opportunities and is a strategy that works in situations requiring high herd mobility and rapid destocking or restocking as forage conditions change (ELLIS et al., 1991). Traditionally, instead of considering "average estimated carrying capacity", an opportunistic approach bases the annual grazing strategy on that year's forage production, thus allowing herders to better adjust herd numbers to the spatial variability of forage, establish a better distribution of livestock to forage availability, and enable increased production (BARTEL et al., 1991).

4. STATUS AND TRENDS OF RANGELAND ECOSYSTEM

Rangelands are fragile ecosystems, the basis of appropriate management of which lies in not exploiting their use potential in the short term beyond their capacity to recover. Nowadays, however, this natural resource appears to be severely threatened on the Qinghai-Tibetan Plateau. Even in a situation as hard-pressed as the present one, the demand for increased production has to be carefully weighed against the need for preservation and balance in the natural environment. For that, the available fodder resources have to be evaluated to allow an estimate to be made of production potentials. The questions of rising importance are:

- What are the reasons for rangeland degradation?
- What are the characteristics of the degradation?
- How does the rangeland ecosystem respond to the changes?

4.1 The Causes of Rangeland Degradation

Degradation of rangeland due to overgrazing is manifest in almost all pastoral areas of the Old World Dry Belt (SCHOLZ, 1995). No areas are found where the present plant growth might be considered as the climax composition. However, what has been done so far toward discovering the major causes of degradation, ways of combating it, and producing an understanding of traditional pastoral systems of livestock and range management? At the risk of over-generalizing, STILES (1981) thought that there are two opposite positions. The first position is often associated with natural scientists (physical geographers, botanists, etc.), though many economists also support it, e.g., KONCZACKI (1978). It maintains that traditional pastoral practices are not rational in the long term and are the principal causes of environmental deterioration and desertification. Until now almost nobody can find a paper in Chinese academic publications which do not concur with this opinion. The second position is usually espoused by social scientists, particularly anthropologists, geographers and experts on development (or by natural scientists with practical experience with pastoralists), and it holds 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 to exploit and conserve the marginal resources. About the two positions STILES commented briefly as follows:

"The two groups, however, agree that desertification exists and it is a serious problem; high population numbers and density are almost always seen as bad by natural scientists, whereas social scientists often defend and rationalize their existence; natural scientists offer solutions to desertification and social scientists offer little concrete but criticize the natural scientists; social scientists stress political actions in recent times as the main cause of problems affecting pastoralists; natural scientists stress ecological factors; both stress political solutions, but natural scientists call for political will by governments to entice pastoralists into what they perceive as rational practices, whereas social scientists imply that political institutions must come to grasp the complexities of pastoral systems before solutions can be proposed and implemented. Oddly enough, neither position supports a view of climatic deterioration as being particularly important or relevant as a cause of desertification." (1981: 373-374)

In fact, the latter position has progressively assumed the lead in world-wide circles since the 1980s. I could go on, but enough has been presented to support my case. As the pastoral ecosystem is complicated, causes of degradation should not be given a simplistic explanation. I stand on the position that ecological factors, such as long-term climatic deterioration, globally climatic change and ecological fragility, are the internal causes; artificial factors, such as over-exploitation of environmental resources by humans and their grazing animals, misjudgment of political decisions or economic policies, etc., are the external impetus (SCHOLZ, 1991; 1995). To resolve this problem, one needs data on the interrelationships of demographic, economic subsistence, and environmental change in relation to climatic change before and since the adoption of pastoralism as an economic subsistence base. I do not propose to give an overall explanation about the causes of degradation in rangelands, because of its local differences. Here I only want to outline and describe some reasons limited to the case study area (Fig. 4.1)

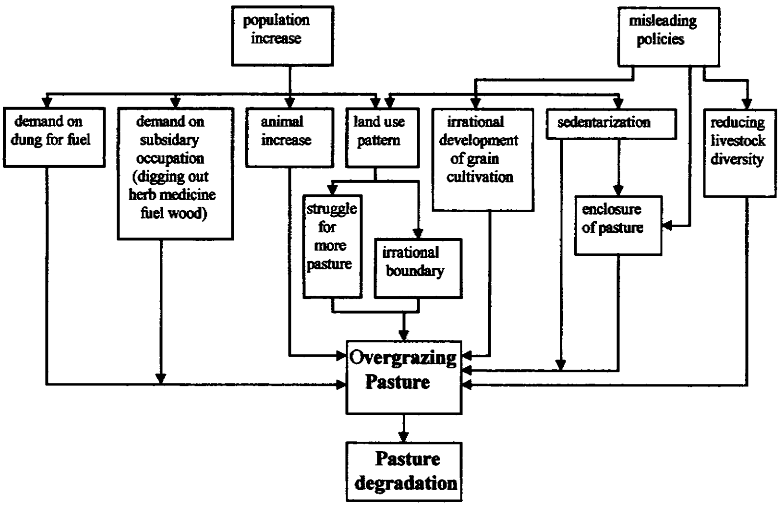

Fig. 4.1 Schematic Diagram of the Causes of Degradation in Rangelands of Western Sichuan

Design: WU NING

4.1.1 The Pressures of Population

The principle causes of degradation derive from human beings' demands upon the environment that exceed the natural regenerative capacity of the land. Increases in population and domesticated animals are blamed in the pastoral areas where population exceeds the carrying capacity of the land. When climatic deterioration is particularly intense, the effects on both the human population and the environment can be catastrophic and irreversible.

Most ranges that are used for extensive rearing of livestock have shown many signs of degradation in the western Sichuan, particularly the contiguous belts between warm season pastures and cold season pastures which are continually grazed all year round at a utilizing rate of 100 percent. In late autumn and early winter the pastures are denuded, giving the forage grasses no chance to rehabilitate since the regenerative rate is very poor.

In the pastoral nomad groups, the pattern which has emerged during the modern phase of development has been one of increasing pressure on pastures. As a result of successful attempts to reduce mortality rates, human population is growing faster and so is livestock. On the whole, efforts to increase the area of rangeland do not keep pace with the change in the two other variables. The overgrazing in a certain area can undoubtedly be caused by an excessive density of domesticated livestock, which further leads to a progressive deterioration in the quality of pastures. The familiar cycle of the earlier times: accumulation of livestock, and the eventual decimation from natural causes, followed by a new phase of accumulation - now reaches a stage of overstocking, and consequent overgrazing.

In recent decades human populations have increased steadily in the whole region (Fig. 4.2), specially in urban areas where the population increases from 53,151 in 1950 to 239,600 in 1990. Only during the period from 1970 to 1990, the increase of the urban population was as high as 122,365, a percentage of 104.38%. The pastoral population increased move smoothly, and changed from 155,085 in 1950 to 274,200 in 1990, at slower annual rates than in urban groups (8.77%), but also reaching as high as 1.92% per year. These increases have indicated that the development of population is no longer compatible with the human support capacity of the land.

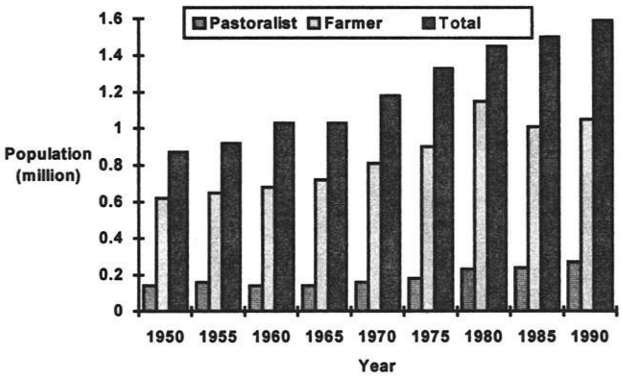

Fig. 4.2 Development of Population in Western Sichuan
Source: AO et al., 1988;
HUANG et al., 1992

Looking at the position of the rural population in *Zamtang* County, it shows that, over the past 40 years, the population increased from 15,000 in 1950 to 24,200 in 1990 (AO et al., 1988; HUANG et al., 1992) (Fig. 4.3), with a yearly increasing rate of 1.53%. The development of rural population in *Zamtang* has gone through three phases:

1) <u>The slowly increasing phase from 1950 to 1965</u>: The rural population increased from 15,000 to 16,600 with the annual mean rate of 0.71%. During this phase the under-developing economy, poor health security and high mortality, resulted in the slower increasing.

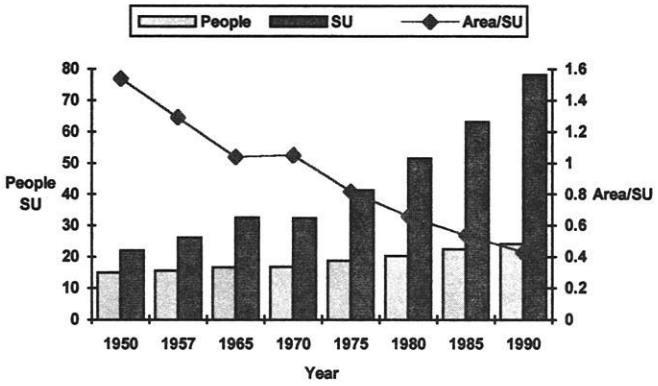

Fig. 4.3 Change Curve of Stock-raising Population and Animals in Zamtang from 1950-1990

Note: In the figure "People" refers to "rural population", which unit is 1,000 persons; "Area/SU" refers to the area of available rangeland for per sheep unit, which unit is hectare; "SU" is the abbreviation of "Sheep Unit", which unit is 10,000 SU.

Source: AO et al., 1988;
HUANG et al., 1992

2) The highly increasing phase from 1965 to 1980: During these 15 years, the rural population increased from 16,600 in 1965 to 20,300 in 1980, with the net increase of 3,700 and yearly increasing rate of 1.49%. This resulted from the improvement of living conditions and medical institutions and relevant lower mortality, and additionally from the misleading policies which over-emphasized the advantages of more people for national construction and eventually led to the anarchy in controlling population.

3) The steadily increasing phase from 1980 onwards: The pastoral population increased from 20,300 in 1980 to 24,200 in 1990, with the net increasing of 2,216 and yearly increasing rate of 1.09%; and meanwhile, the figure of pastoral population dropped from 16,400 in 1980 to 14,046 in 1985 and then to 13,900 in 1990 (AO et al., 1988; HUANG et al., 1992). During this phase the policy of "Birth Control"(or called "Family Planning" in some literature) has been put into effect, the increase in population has been controlled to a certain extent. Of course, the rapid decreasing in 1980s probably could not be attributed totally to the implement of the Policy rather than other reasons, such as the emigration of pastoralists from rural section to urban, or from pastoralism to other occupations (e.g., trading, marketing and local industries), because it was this period when the market economic has been pursued in China and already influenced the rural society in marginal areas.

To support their families, herdsmen use the milk, meat, butter and wool from their animals and exchange some surplus for grain and daily necessities. They raise both replacement and draft animals for their products, in order to meet their basic needs. The grazing capacity of pastures in *Zamtang*, however, has almost reached saturation point. Since the quality and productivity of livestock did not improve simultaneously, the population increases naturally led to a growth in the total number of livestock. The grazing stock on *Zamtang*'s pasture rose from 219,914 sheep units in 1950 to 782,169 sheep units in 1990; an increase of 255.67 percent, a yearly mean rate of 6.39 percent. During the period of "People's Commune", i.e. from 1957 to 1980, the figure of sheep units increased from 262,569 to 514,158, with a yearly increasing rate of 4.17%. From 1980 onwards, i.e. after the implement of "Responsibility System", this figure rose to 782,169, with a net increase of 268,011 (SU) and a yearly increasing rate of 5.21 percent.

According to a survey conducted in 1985 (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989), the area of available rangeland in *Zamtang* is 339,410 hectares. Therefore, it can be concluded that every sheep unit's occupancy of pasture fell from 1.54 hectare in 1950 and 1.04 hectare in 1965 to 0.82 hectare in 1975, 0.54 hectare in 1985 and then 0.43 hectare in 1990. In 1985, it was calculated that to maintain regular production, without supplementary feed, each sheep unit should have at least 0.79 hectare of pasture (XIE, 1988). It implies that from the early of 1970s onwards there has been overstocking of animals. The capacity of a pasture area should be determined according to the amount of green energy it contains. In *Zamtang* County, the livestock raised has apparently exceeded the carrying capacity of the pastures. This is the picture presented.

The availability of rangeland, together with the size of human population, imposes limits within which livestock population is changed. 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 the range available and the consumption needs of the human population. The other goal, that of security, requires some measure of insurance against emergency situations. Its magnitude is usually based on vague empiricism and it often shows itself as a tendency to maximize animal population. KONCZACHI explained:

> "*...the reasons for doing this are obvious enough: protection against famine, if drought occurs, and greater probability of survival of sufficient number of animals needed to recreate the depleted herd.*" (1978: 16)

That is to say that the trend of increase in stock number will be inevitable in a short period which resulted from the population increasing, because the number of animals is the insurance against constraining external events for every pastoral family (see 5.2.3 in this book). Therefore, with the increase of rural population in *Zamtang*, the sheep unit per capita was also maintained at a gentle increasing level rather than decrease. For example, in 1950 the sheep unit per capita for rural population in *Zamtang* was 14.65 SU; in 1965 the figure increased to 19.61 SU; in 1970 (after "Culture Revolution") the figure fallen to 19.22; in 1980 it increased again rapidly to 25.33 SU; in 1990 the figure became 32.33 SU due to the development of pastoral production after centrally collective management collapsed and the promotion of "Birth Control". Another example about the livestock increase in the western Sichuan also can illustrate this trend (Fig. 4.4).

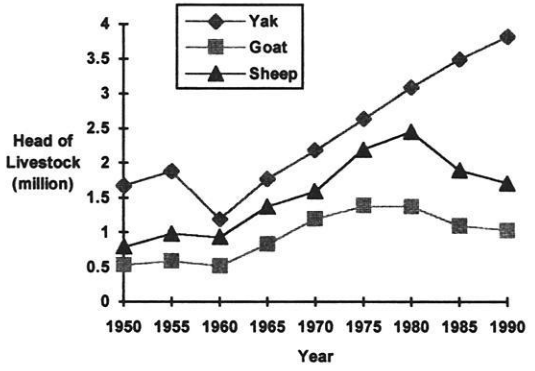

Fig. 4.4 Development of Yak, Goat and Sheep in Western Sichuan
Source: AO et al., 1988;
HUANG et al., 1992

4.1.2 The Contradiction between Private Livestock and Communal Land

The problem of overgrazing is said to arise principally because of a difference in the incentives facing individual livestock owners and the costs and benefits to the pastoral society as a whole resulting from grazing the rangeland (HARDIN, 1968). In many parts of the pastoral areas in China the communal system of grazing is usually followed. While such a system has certain advantages in a harsh environment, it can be an obstacle to rational utilization of the range and to range improvement practices.

Most livestock raised on the Plateau is raised under conditions in which the land is used in common by numerous herders. The individual owner sees the pasture essentially as a free commodity. If that person does not exploit it, someone else will. Where there is neither a fee nor a grazing quota, this presumably leads to a situation in which each herder maximizes the number of animals grazed on the rangeland. Intense competition may thus ensue for the use of this scarce resource, which further results in social costs imposed by deterioration and even destruction of the rangeland.

In addition, the problem has been that the concept of establishing rights to the use of specific areas of land is inconsistent both with traditional systems that provide for the sharing of pasture resources by different social groups, and with government policies proclaiming the openness of the rangeland to all. In years with natural disasters, any system based on fixed grazing rights tends to break down rapidly as a result of overwhelming demand for available pasture.

Over the past four decades the tribally based local administration system has been eliminated without being replaced by an effective local administration, although the land tenure system recognizes national ownership of rangelands. As a result, traditional grazing controls have been ignored and internal tribal conflicts over grazing have still occurred sometimes. Tribes from less productive grazing areas have migrated to other areas (outside their traditional territories) with richer resources. As a consequence of intertribal conflicts, some of the best grazing areas have been subjected to severe deterioration.

At present the basic institutions on the Qinghai-Tibetan Plateau are the family or individual ownership of livestock, and the common ownership of rangeland. "A common property resource is one that can be used by everyone at zero cost."(KONCZACKI, 1978:54). No value is attached by individuals to the benefits they derive from pasture and, from their private point of view, no question of costs arises. However, cost is borne by the community as a whole - it is a social cost. A commodity which is free for the individual becomes a scarce commodity for the society. Common use of pasture is open to every family in the group on an equal basis. KONCZACKI from a economist's opinion presented a good comment on that:

> "*An asset commonly owned is economically inefficient in that it tends to be over-used, unlike assets subject to more restrictive property rights. This is implied by the common saying that 'everybody's property is nobody's property'. For an individual pastoralist to restrict the use of pasture in order to preserve its quality for the future, or to invest in its improvement, makes no sense at all, because someone else will take advantage of his efforts.*" (1978:54)

With this statement, we have no doubt touched on a controversial subject of development politically and strategically that ought to be discussed thoroughly. For ecological and socio-economical reasons the large grazing area should be maintained and opened up by appropriate land-use practices. Otherwise, it will obstruct the developing of a sustainable process (see 6.2.3 of this book).

4.1.3 Destructive Effects of Treading

Instead of spreading out over the land to feed, livestock remains in dense groups, which increases the amount of vegetation removed from the area they are occupying. The trampling of such closely packed herds wreaks havoc on the vegetation and denudes the soil along the tracks they make around water holes and in the corrals, as well as along the paths made by their movements to and from them.

Especially, some forests (woodlands) on the subalpine belt, such as juniper, pine and oak forests, are suited in their original state to grazing due to their sparse canopy and a ground cover rich in sedges and grasses. Here treading by livestock at first disturb the forest's ability of self-regeneration and fully might prohibit it in the long run. The animals bite off shoots, trample seedlings and on top condense the top soil inhibiting the infiltration of water, increasing run-off and thus reducing the water availability in the ground. Therefore, it was thought as that sending animals into these open woodlands might lead to the degradation of forests into shrub- and grasslands, and further the treeline is being pushed down. (WINKLER, 1994)

It is well known that treading by livestock may have a considerable effect both on the structure and botanical composition of rangeland. The effects of treading on the soil (and ultimately on the vegetation) will depend on the nature of the soil, on soil moisture, and on the different kinds of animals. Reductions in aeration, water penetration and regrowth have been recorded as a result of soil compaction. THOMAS (1960) suggests that trampling by cattle is most dangerous in the tropics, causing erosion where the vegetation is worn away. This phenomenon is not ameliorated by relatively more precipitation in western Sichuan.

SEARS (1956) estimates that a Jersey cow's hoof applies a pressure of about 3.17 kg/cm^2 when walking, compared with 2.1 kg/cm^2 by a sheep. Although there is not information in detail about yak and sheep on the Qinghai-Tibetan Plateau, man can still observe that on steep slopes yak and sheep form paths which follow the contours of the slope and at high stocking densities. Then, gullies are formed and gradually encroach on neighboring land: in some rangelands with fragile soils, veritable ravines can now be seen where livestock tracks once existed. In addition, sheep and yaks are particularly harmful when too numerous crowding occurs because they tear away the turf of pastures as they graze. Sheep also cause quite serious erosion who scraping out hollows for shelter on exposed hillsides, the scars of which are often visible many years after sheep have left the area. On hillsides sheep and yak tend to graze predominantly on the upper sides of paths and to defecate on the lower slopes (ZHOU, 1982). This leads to a zonation of vegetation away from the paths. All of these in the end may result in erosion in rangelands.

4.1.4 The Declining of Animal Diversity

In fact, a great proportion of the ecological changes that occur in rangelands where there are extensive stock-rearing stems from the low diversity of the herds. Excessive populations of domesticated animals, because of their different behavior, produce effects that are still more harmful than those caused by wild animals. A fauna consisting of a number of wild ungulate species is replaced by yaks and sheep with a much more limited dietary range. As a result, only the preferred species of edible plants are consumed, leaving the way open for the proliferation of varieties with little or no food value: thorny or toxic species, for instance, or those with limited size or a very short growing season. These would only be poorly represented in an abnormal undisturbed plant community[42] because of inter-specific competition.

During the period of collective management, the composition of grazing animals was decided by the authorities concerned. In a definite area only specific animals were encouraged to be grazed (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989), such as the popularization of improved sheep in *Zoige* in 1970s, which inevitably led to the simplified structure of livestock. In additions, the preference of market has the same effect, which simply leads to the development of more economic herds, and ignores the balance of herd composition.

In a way, the animal's diversity is more fundamental than the conventionally known animal resources and falls outside a purely utilitarian and economic calculus. Animal diversity provides a fundamental base to the conservation of rangeland and even to the overall economic systems. It is the source of resiliency and regeneration, necessary for the sustainability of pastoral systems (see 5.2.3 of this book). It is the ultimate basis for local

[42] Any group of plants occupying a particular habitat at a particular place is called a "plant community" (CRONQUIST, A., 1982).

self-sufficiency, and bringing benefits to pastoralists in terms of material welfare in more ways than we realize.

4.1.5 Man's direct Destruction of Vegetation

Human activities affecting the plant cover directly, resulting in the deterioration of rangeland vegetation. In western Sichuan gathering of plant parts for food has probably never played an important role, except locally. Digging out of roots for food or collecting of seeds may have done damage to a small area, but this would have been temporary. Moreover, if occurring on a small scale only, such actions by man should be considered as a natural influence on the ecosystems, comparable to that of various species of wildlife. Such actions even may have a favorable effect in that they create local openings in the vegetation's cover in which several species can germinate and establish themselves. In this way species diversity of the grassland can be maintained at a high level. However, cutting or uprooting of medicinal plants or ligneous species for firewood has a manifest effect on vegetation in most areas due to its scale and frequency.

Western Sichuan is a very important resource pool for herb medicines, where the yield of some medicinal plants collected every year influences the markets of the hinterland profoundly, such as tendril-leafed fritillary (*Fritillaria cirrhosa*), Chinese caterpillar fungus (*Cordycepes* sinensis), medical rheum (*Rheum officinale*), Forbes' notopterygium (*Notoptergyium* forbesii), thick-stem gentian (*Gentiana crassicaulia*) and Chinese nardostachys (*Nardostachys chinensis*). Since collection has become an important income sideline for the local people in western Sichuan (Fig. 4.5), these plants have been rooted out in huge quantities, and every autumn many people (mainly children in pastoral families) wander on mountains collecting herbal medicines.

In addition, some other human activities, such as cutting bushes for firewood and removal of plants during the construction of roads, increase the area of desertified land, intensifies evaporation, and diminishes the water retaining capacity of the soil. A lot of yak droppings are collected for fuel, which leads to the decrease of fertility in soil and further to the degradation of pasture quality.

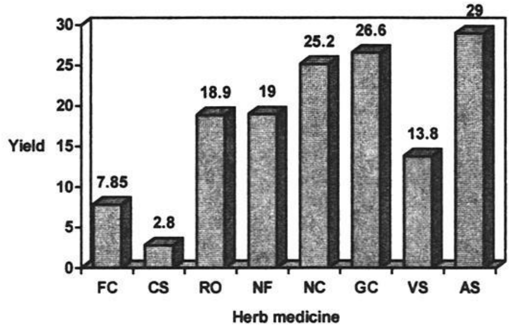

Fig. 4.5 Sales Volume of Major Medicinal Plants from Western Sichuan in 1990

Note: FC = *Fritillaria cirrhosa*; CS = *Cordycepes sinensis*;
RO = *Rheum officinale*; NF = *Notopterygium forbesii*;
NC = *Nardostachys chinensis*; GC = *Gentiana crassicaulia.*
VS = *Vladimiria souliei*; AS = *Astragalus spp.*

The unit of yield is ton for CS, GC and AS; 10 ton for others.

Source: HUANG et al., 1992

The effects of man on the rangeland vegetation may be direct on the vegetation cover itself or indirect through his influence on the other components of the ecosystem. Once vegetation cover is reduced by direct human destruction, hydrologic and soil deterioration sets in. Rain is not absorbed as readily into barren or sparsely vegetated land, and moisture evaporates more quickly from it; rainwater runs off the surface, taking with it the topsoil, containing nutritive organic matter. Eroded soils continue to degenerate from one season to the next, the area's water table falls, as less rainfall soaks in, and the streams or lakes dry up.

4.1.6 The Lack of Markets

The nomads' strategy aims at securing a rapid conversion of the growing vegetation by their animals, which is subject to erratic weather patterns. Meanwhile, 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, so that to governments pay less attention than to other occupations.

Schemes of pastoral development are often assessed with herd off-take and marketed animals. Yet, these rates are not simply a product of the various innovations of ownership, credit, fattening, etc., but are fundamentally influenced by marketing opportunities, requirements of the herd and its reproduction, and pricing structures. As long as prices are kept artificially low for the benefit of urban inhabitants, stockholders cannot be faulted for retaining stock. However, many people accuse pastoralists of not using the market and are indignant that pastoralists use unofficial marketing channels.

In western Sichuan the ineffective marketing outlets have led to the increase of a practical carrying capacity on the rangelands, and further to the decrease of prices. Although the private channels are never blocked (see 5.3.5 of this book), its capacity is still limited. Under the situation changing from a subsistence system to more marketing orientation, at least some herder owners would be given an impetus to trade and to breed more animals which have in good prospects in terms of price. However, if there are appropriate infrastructural facilities meeting the needs of the people and the flows of animal products, the prospective benefits cannot be realized and the overstock is inevitable. This is the picture presenting in western Sichuan as well as whole Qinghai-Tibetan Plateau, where the innovation of infrastructures are not yet compatible with the change of the economic system. Therefore, animal products cannot become commodities and are taken out of the pastoral system resulting in intensive pressures on vegetation in the end.

In addition to the factors mentioned above, it should be emphasized that there are also a number of other factors contributing to the overstocking and degeneration of pastures, decline in the quality of livestock, and unstable productivity with poor economic returns. Such are the adverse natural environment, low productivity of the pasturelands, poor quality and breed of livestock and mismanagement of pasturelands. However, to sum up, these factors always combine mutually and affect the ecological situation of rangeland together rather than singly. This implies a more severe impact. Under the status quo of rangeland management productivity is decreasing, but excessive reclamation and excessive grazing are continuing and the natural environments in the pastoral area are being seriously degraded. In the meantime the quantity of grazing animals rises, but not enough attention is paid to quality. Thus the problem of the relationship between livestock and foodstuff is the basic contradiction of pastoral production in western Sichuan, which gets gradually more acute year by year.

4.2 The Effects of Degradation

The degradation of rangeland is the inevitable outcome when rangeland is exploited irrationally by humans. Concurrently, even under long-time normal use, it is the natural process that an herbaceous community develops from a pioneer association to a climax and then dies out. This results from the changing processes of soil, such as the decreasing of soil porosity, increasing soil exhaustion and loss of soil nutrients. Theoretically, the composition and structure of a climax community can be used as the criteria to evaluate the overgrazing degree in the same region, because the degradation is considered as a reversed succession of vegetation. For practical purposes, however, the climax community should be ascertained at first, which will be difficult in an area where the pastures have been grazed by livestock for a long time.

Through two field investigations by comparing the pasturelands in different grazing conditions, some of the ensuing problems are described in the following passages. As mentioned in the introduction, the vegetation is the first indicator to note. Visible changes in the vegetation composition are the first signs of degradation. Increasing erosion is the next stage, as protective vegetation cover with its soil-holding root system is reduced. The original plant coverage tends to decrease with increasing length of use. In contrast, the proportion of undesirable invader plants increases with the length of use. No single criterion alone is absolute proof that overuse has taken place, but in combination they are.

4.2.1. Decrease in Edible Forage and Increase in Poisonous and Harmful Plants

Perhaps the most important aspect of grazing which affects the structure and botanical composition of rangeland is animal selection of some plants and avoidance of others. The famous botanist, LINNAEUS, in 1748 (quoted in DUFFEY et al, 1974) commented:

> *"This summer I continued my investigations as to which plants are consumed by cattle, which are ignored and which are avoided; this work in my opinion is of fundamental importance both for private owners of livestock and for animal husbandry as a whole."*

Of the many other factors which determine the selection of species in a pasture, availability is the most important. As the quantity of herbage on offer to the grazing animal decreases, selective preferences change and species which previously were rejected may be eaten. In addition, species are not uniformly selected throughout the year, changes in preferences being dependent on the palatability of species at a particular time, such as *Scopolia tangutica*, which is refused as browsing in summer owing to its poisonous properties, but in autumn and winter when it withered its leaves can be consumed.

After a long selection time, technically speaking, concentrations of excessive numbers of animals in one area (at high stocking densities) will inevitably result in disappearance of the more palatable and valuable forage species, and their replacement by less nutritious vegetation. Perennial grasses give way to annuals, and these in turn to weeds. In western Sichuan all pasturelands, except perhaps a few alpine areas above 4,200 m, are over-grazed or threatened with degradation, which is evidenced by the great mass of invasive plants which are encroaching in all areas.

Decreases in amount of plant material are relevant only, when the remaining above-ground green parts are too little to photosynthesize sufficiently to restore the vegetation cover, or when this decrease concerns only some species in the vegetation which as a consequence receive a strong competitive disadvantage over neighboring species. In this latter case an increase in unpalatable or in poisonous plants will result. While studying degradation in tropical grasslands, WERGER pointed out:

> "... *when the grazing of palatable plants is so severe that it prevents the production and storage in underground parts of sufficient carbohydrate reserves to enable vigorous regrowth in the next season, the proportion of palatable plants in the grass sward will decrease and signs of degradation of the vegetation cover soon will be noticeable.*" (1983:126)

As observed by the results in *Zamtang*, when subjected to grazing by herds of domesticated herbivores, the species composition of plants is profoundly modified under the combined effects of an excessive population and preferential grazing of certain plants (Table 4.1). The ground becomes gradually invaded by vegetation rejected by the animals. Edible forage plants, such as grasses (*Gramineae*) and sedges (*Cyperaceae*), decrease, and poisonous and harmful plants, such as *Potentilla anserina, Anemone rivularis, Saussurea spp., Ranunculus brotherusii, Aconitum szechenyianum, Delphinium trichophorum,* and *Ligularia virgaurea* increase. In shrub meadow and woodland meadow vegetation covers are the proliferation of thorny legumes, such as *Astragalus strictus* and *Caragana erinacea*, or these communities are invaded by *Aconitum spp.* and *Delpinium tatsienense* that are avoided by livestock. The pastures along the river have been overrun by *Stellera chamaejasme*. In the winter pasture, especially around winter houses, wide areas have become strongly invaded by harmful weeds. In many regions, over-trampling by animals has also drastically reduced the varieties of edible plants. Only the hardiest species can withstand the constant mechanical stress. Extreme overuse may eventually result in erosion and the exposure of bare hardpan.

In the high-altitude pastures, overgrazing has caused the disappearance of many tall grasses which are easy to be taken by animals, such as the plants in *Bromus, Elymus, Festuca* and

Table 4.1. Successional Changes Related to Grazing and its Effect on Grass-Yield in *Zamtang* County (1991, 1992)

Succession	Light grazing, good Condition protected	Average grazing, mediocre condition	Overgrazing
Grazing or Protection	Grazing ⟶	Grazing ⟶ ⟵ No grazing	⟵ No grazing
Dominant Species	*Kobresia setchwanensis* *Ptilaqrostis dichotom* *Poa sphondylodes* *Polygonum viviparum*	*K. setchwanensis* *Carex kansuensis* *Anemone rivularis*	*Potentilla leuconota* *Saussurea sp* *Pedicularis sp*
% of plant cover	91.5	78.7	45.1
Fresh Grass Yield (in kg fresh matter/ha.yr)	10192.0	7720.2	3514.5
Edible productivity (in kg fresh matter/ha.yr)	8153.6	5404.2	1239.5
Carrying capacity (ha/1 sheep unit)	0.22	0.34	1.47

Deyeuxia, etc. Instead, there has been a proliferation of many geophytes (various *Liliaceae* plants, *Lancea tibetica, Potentilla spp.* and *Rhodiola spp.*, which are harmful or inedible). With shallower root systems, the new invading geophytes provide less ground cover, which further reducing soil stability. Unfortunately, because of ridiculously intense grazing unrelated to the carrying capacity of the land, various *Graminae* grasses decline and are too often eliminated by competition from weeds. The disadvantage of these is that their tight network of rhizomes and dense mat of ground cover make it a veritable couch of grasses and prevent recolonization by forage plants. This increases the difficulties of rangeland improvement. The regrowth of the vegetation preferred by herbivores is also hampered by overgrazing, which eliminates seed carriers and prevents dissemination. Inedible woody or herbaceous plants tend to proliferate and not only reduce the yield usable by livestock but tend as well to reduce the area available to edible plants by covering the ground with a layer of unsuitable litter.

4.2.2. Shortening Grass-layers and Declining Grass-Yields

The yields of pasturelands and thus the meat/milk-producing potential is drastically reduced by overgrazing. Each type of pasture has a limited carrying capacity defined as the maximum density of livestock or, more generally, of herbivores that it can support without risk of degradation. Unfortunately, it is a parameter rarely taken into account in the exploitation of rangelands with the result that overgrazing is now endemic.

The detrimental effects of overgrazing on the yields of pasturelands may be direct, but they can also be indirect and delayed in time. The effects of over-exploitation on the make-up of the plant communities have already been cited, but the changes produced may not only be qualitative but quantitative as well, through the inter-specific competition introduced.

Usually the decline in the productivity of the pastures has a cumulative effect: overgrazing causes a drop in forage quality and productivity, so that grazing pressure increases causing further decreasing in quality and productivity and so on. Having compared the light-grazing pasture and heavy-grazing pasture (Table 4.2), one can find that the mean height of community drops from 31.8 cm to 15.25 cm, and the total yield of fresh grass from 10,192 kilograms per hectare to 3,514 kilograms per hectare. However, it should be elucidated that the yield of poisonous plants increases from 187 kilogram per hectare to 978 kilograms per hectare simultaneously. Meanwhile, the vegetation cover become more sparse, which has been indicated by the change of coverage from 97.5% to 44.1%. Another example can be found in Table 4.1, in which the coverage decreases from 91.5%, to 78.7% and then 45.1% with the increase of grazing pressures.

Table 4.2. Comparison of light Grazing and heavy Grazing Pastures in Zamtang

Date: Oct.,1992 Site: the pastures of *Cao-si-zhan*

Kinds of Grasses	**Light-grazing Pasture**			**Heavy-grazing Pasture**		
	Coverage (%)	Mean Height (cm)	Yield (kg/ha)	Coverage (%)	Mean Height (cm)	Yield (kg/ha)
Legume	8.5	25.8	585	0.0	0.0	0.0
Gramineae	25.0	67.4	3,140	2.5	21.7	118.0
Cyperaceae	30.5	21.2	3,325	18.0	6.8	1,121.5
Forbs	32.0	15.6	2,955	15.0	5.2	1,297.0
Poisonous	1.5	28.8	187	8.6	27.3	978.0
Total	97.5	31.8	10,192	44.1	15.25	3,514.5

4.2.3. The Increase of Rat-damage and Pest-damage

Overgrazing reduces the density of the herbaceous ground cover: it becomes patchy and this in its turn creates new factors that further reduce the primary productivity. Denudation of the soil and increasing adaptation to dry conditions, for instance, encourage infestation by various species of rodent and by pests. All these contribute to a reduction in that part of the vegetation available to domesticated livestock.

4.2.3.1 The Increase of Rodent-damage

The damages caused by rats to the rangelands are very serious in western Sichuan, and greatly affect the animal production there. Based on the surveys conducted in Aba Prefecture, the daily intake of 50 - 60 plateau pikas (*Ochotona curzoniae*) is equivalent to that of one sheep (ZHOU, 1984). Plateau pikas live underground and eat grass roots, which cause the death of grasses in large areas. In some places, where all the grasses are eaten up by rats, the land becomes black. According to the observations, the vegetation recovery process in the serious rat-damaged areas is similar to the succession of the vegetation on abandoned land. At first the unpalatable weeds grow on the rat-damaged land, then the edible plants, such as grasses (*Gramineae*) or sedges (*Cyperaceae*), which would grow out 3-4 years, and finally the land needs 7-9 years to become available rangeland.

In *Zamtang* County, it was known that an increase in field mice (*Pitymys leucurus*), plateau pikas, Tibetan woolly hares (*Lepus oiostolus*) and Himalayan marmots (*Marmota himalayana*) has attributed to the overpopulation by livestock. However, because of the vague relationship between the rodent damage and rangeland degradation, rangeland degradation should not be confirmed as the direct cause of rodent expansion. In *Zamtang* , rat-caves are seen frequently on the damaged areas, but is not as serious as that reported in neighboring counties. Because of the limit of investigation time, we have not made a thorough and quantitative study of the rat-damage and pest-damage in *Zamtang*. Some useful reports about these in western Sichuan will be cited as our reference.

Considering the statistics, in western Sichuan there were about 600,000 hectares of the rat-damaged land, accounting for 5 percent of the total area of the region. According to the existing grazing capacity of rangeland (0.42 ha/one sheep unit), 1.42 million sheep unit would be lost. Because of the serious rat-damage, the rangeland productivity decreased by one third averagely and every year about 473,000 sheep would be "eaten" by rats (WEI and WU, 1988). The harmfulness of rodents includes following aspects:

a) <u>Consuming grasses and competing with livestock for forages</u>

According to the survey (ZHANG, 1964), comparing with the normal pastures, in a medium damaged- pasture where there are 20-30 holes per hectare opened by marmots, the yield of grass decreases about 54.5%. The daily intake of a plateau pikas is about 77.3 grammes of fresh grass, and the total intake during its growing period (about four months) can amount to 9.5 kilogrammes of fresh grass. The daily intake of a field mouse (*Pitymys leucurus*) is about 14.5 grammes of dry grass and 5.29 kilogrammes of dry grass could be consumed in a year.

b) Destroying the vegetation cover

In the rat-damaged pastures, vegetation is covered partly by the soil dug out. According to the survey in Tibet Autonomous Region (TIST, 1992), the mound near the mouse hole occupied 0.27 square meter on average, i.e., 880.2 square meters ground surface is occupied by these mounds in each hectare of pasture. In the seriously damaged sections there are 3,390 mouse holes per hectare, and the destroyed cover amount to 10.8% of the total area. With the greater destruction, marmots excavation may lead to the loss of 26% surface.

c) Reducing the coverage of vegetation and increasing the evaporation of water contained in soils

Owing to a great deal of mounds, puddles, and the loose of soil resulting from rodents excavation, water in the damaged area is move easily evaporated, amounting to 4.78% of total contained water in top-soil (TIST, 1992), which leads to the increasing of barren surfaces, the decreasing of vegetative coverage, and the retardation of grass growth; in the end the occurrence of reverse succession.

d) Affecting the fertility of soil and changing the composition of plant communities

The digging activities of rodents are mainly carried out in the A layer and B layer of soil. The fertilized soil is dug out onto ground the surface and piled up in mounds, which are easily eroded by wind during the dry season. The loss of fertilizer in the soil would inevitably influence the growth of grasses and result in the increasing of unavailable grasses or even poisonous plants.

4.2.3.2 The Increase of Pest-damage

In Garze Prefecture there were 438,000 hectares with pest damage which accounted for 4.6% of the total area of the prefecture, and for 5.3% of the total usable grassland by the end of the 1980s (YANG, 1991). Every year about 146 million kilogrammes of grasses are lost because of insect pests. This amount of grasses could raise 80,000 sheep. The major pests in these areas are *Gynaephora spp.* and *Acrididae*. The latter usually distributes in the areas with relatively low elevation of about 3,600-4,000 m and mainly eats the fine grasses of

Gramineae and sedges of *Cyperaceae*. These pests sometimes damaged repeatedly, i.e., in rat-damaged land they cause secondary damage. Although the two kinds of pests are very small, they could cause great and serious damage when plagues took place. In 1987, the insect pests were not too rampant, but the damage was still serious (JIA, 1991). About 146.2 million kg of grasses were lost by *Gynaephora spp.* and 328.9 million kg lost by *Acrididae*. Those grasses could raise 260,300 sheep. In Aba Prefecture, the area damaged by pest was about 85,700 ha and accounted for 3.12% of the total usable rangeland, among which about 5.75 million kg of grasses were consumed by *Acrididae* and 39.95 million kg taken by *Gynaephora spp*. Those grasses could raise 21,560 sheep (WEI and WU, 1988).

The *Gynaephora* mainly eat the leaves and stalks, and seriously weaken whole plants. With the increase of age, the activities and the capacity for eating of the larva increases simultaneously. When it comes to its peak eating period in summer (from the end of June to the end of August), it can bring the greatest destruction to pastures. In the seriously damaged section, the density of population is as high as 9 per square meter, and it results in a decreasing of 68.5% in grass yield (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989).

4.2.4 Soil Erosion and Desertification

Overgrazing depletes the vegetation cover, which always leads further to soil erosion. In some mountainous area provision of water supplies has made it possible to expand cultivation and increase livestock numbers, which also may cause environmental degradation. When field-layers are open, soil on the steep slopes is easily carried away by run-off water. In addition, when the top soil is loose, the effects of trampling are more damaging: the weight of the animal mechanically damages the roots of the plants when they are squeezed between the sand grains of the loose top soil, which may cause the plant to die. In some cases it may be no more than the replacement of vegetation of grazing value, by worthless or injurious weeds. The greatest danger, however, lies in the fact that overgrazing may destroy the vegetation and expose the surface. Normally the vegetation breaks the violence of the storm and retains some of the water; the roots hold the soil together, but wherever the surface is bare the flow gets concentrated and will begin to attack the soil at any break in the surface, with the result that the soil itself begins to wash downhill with astonishing rapidity.

Denudation and subsequent erosion of the top soil always occurs with very high and prolonged stock loading. It is also easily achieved, however, in the high-frigid areas where after heavy grazing the growth season is too short for sufficient regrowth. In *Zoige* County, whose rivers belong to the Yellow River System, denudation and even desertification occurs on a very large scale, specially concentrating in sandy habitats. The average annual precipitation in this County, however, is 647.6 mm, which is totally different to the situation of rainfall in tropical grasslands where the rainfall is less than 500 mm annually (WERGER, 1983), but the results are surprisingly similar.

Sand dunes in western Sichuan are distributed between 33°15' - 34°00' N and 102°15' - 103°00' E and are located in the middle or lower reaches of the *Heihe* River and *Baihe* River (branches of the Yellow River). These sand dunes consist of fine sandy soil, silts and gravel soil accumulated by river alluvia, and cover a total area of about 1,100 ha, of which 90% are found in *Zoige* County and rest in *Hongyuan* County.

During the glaciation of the Quaternary Period, some intermediate and unequal sinks took place in the earth crust in this region (EDITORIAL BOARD OF "VEGETATION IN SICHUAN", 1980). The center area of these sinks was of the middle and lower reaches of the *Heihe* River. Then the crust was thrust up. Therefore, the rivers and lakes changed direction several times and many ancient river beds were left in the region. On these river beds large amount of fine sands and crude sands were accumulated and have become the source of present sand dunes.

With a high underground water table, large amount of silts, great humidity and precipitation in the region, these dunes were slowly invaded by the plants of the nearby meadows and gradually became meadows with a thick sod layer. Also some sand dunes, with low underground water table and high contents of fine sands and crude sands, were invaded by plants very slowly and become the sparse meadow. However, most of the sand dunes now distributed in the region are those newly formed by overgrazing, human activity, agricultural activity, as well as the dry climate and strong winds in the region. In the beginning, these dunes were small and ignored by people. Consequently, they gradually became larger and larger. Based on the reports (LIU, 1991), these dunes are expanding northward continuously and their invasive speed is about 16.4 m yearly in average.

Human activities became the external cause of dune formation or expansion. The invasion of dunes leads not only to the loss of pastures, but also to the invasion of new floristic elements which only occurred in the semi-arid or arid area of northwestern China or even central Asia (LIU, 1991). Since this region is in a transitional belt (ecotone) between the humid forest region of eastern China and the semi-arid and arid region of western China, environmental fragility is very apparent, which implies the difficulty for the rehabilitation of the vegetation.

4.2.5. Unstable Production and low Economic Returns

During the green period, the forage on pastures is of good quality and nutritive value, but, during the withering period, the protein content and nitrogen-free extract diminish by 70-80 percent, in comparison to the green period (ZHOU et.al, 1984). It loses almost all vitamin content and the proportion of crude fibber increases, while its digestibility drops sharply. The loss of yield is more than 15 percent (CAI, 1990). What is more, because of the long period of withering and the diminishing area of winter grazing land, animals go hungry and when winter comes, they have to rely upon their own muscle and fat to survive. After winter and spring, the loss in weight for different types of livestock is: yaks 20-30 kg, sheep 5-7.5 kg, and goats 3-4 kg (XIE et.al, 1988).

Figure 4.6 shows the rise in the amount of livestock over 40 years. In the 1960s, the forage was still good enough to support healthy stock with supplemental feed. In the 1980s, there was a severe shortage of forage grass. In order to reduce the mortality, the animals were fed hay as a supplement. The amount of supplement given was greater than tons per year, and this was also given along with different productions of the Common oat (*Avena sativa*).

Although the total number of livestock rises, it does not mean that the economic returns also increase. In fact, owing to the degradation of rangelands, the quality of livestock decreases and animals usually die from weakness and thinness since weak and thin animals have less resistance to disease. This also influences the price of animal products. Meanwhile, the degraded rangelands with decreasing grass yield not only cannot provide enough foodstuff for the development of animal production, but also are easily affected by the capricious climate on the Plateau due to their simpler community structure. Therefore, the unstable yield of pasture finally results in the unstable pastoral production.

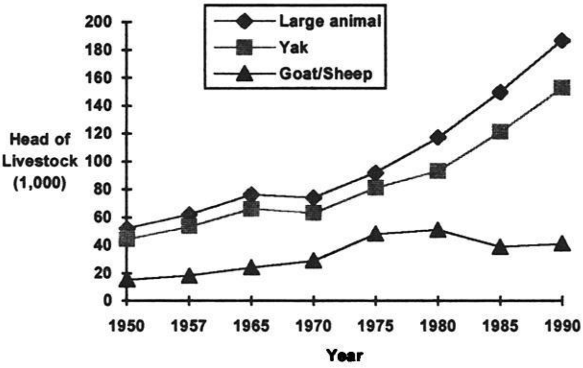

Fig. 4.6 Development of Livestock in Zamtang during 1950-1990
Key: "Large animal" includes yak, cattle and horse; "Yak" includes yak and *Dzu*.
Source: AO et al., 1988;
HUANG et al., 1992

4.2.6. Degeneration of Cold Season Pastures

There is a popular view that the degeneration of cold season pastures is more serious than that in warm season pastures, since there are more grazing stresses on cold season pastures (ZHOU, 1984; CAI and WIENER, 1995). According to our survey in *Zamtang* County, there are always higher grass yields in cold season pastures than in warm season pastures, and the quality of grass species composition is better (Table 4.3).

Naturally, in comparison with the yield measured in 1985 by the Animal Husbandry Bureau, it decreased as 15-20 percent, but this is including warm season pastures, which could not indicate more serious degeneration occurring in cold season pastures. Because of the location of cold season pasture always in valleys and flood alluvial fan-shaped land, the hydro-thermal conditions and soil fertility are better. In addition, grasses withering in winter, their seeds fall and are buried in soil, snow cover prevents a lot of grass loss. The regrowth of grasses could not be affected seriously by livestock grazing, and cold season pastures can rehabilitate easily during the next green period.

The natural environments on warm season pasturelands are adverse. The domesticated herbivores ate the green part of grasses above ground, which leading to a quantitative decline in the seeds and storing nutrients in rhizome, and a consequent fall in their life vigor and that only the rhizome geophyte could regrow easily. In additions, due to the loss of leaf, the decline in the ability to photosyntheses, which led to the fall in their productivity and the degeneration of warm season pasture.

Table 4.3. The Characteristics of warm Season and cold Season Pastures in Zamtang

Date: Oct.,1992 Site: *Jiou-dao-guai*

Pasture type	**Warm season pasture**	**Cold season pasture**
Common species	*Kobresia pygmaea* *K. setchwanensis* *Stipa capillacea* *Festuca ovina* *Aristida triseta* *Poa pratensis* *Ligularia virgaurea* *Taraxacum dissectum* *Anaphalis flavescens* *Polygonum viviparum*	*Kobresia setchwanensis* *Festuca ovina* *Poa pachyantha* *Koeleria litwinowii* *Roegneria nutans* *Agrostis schneideri* *Potentilla bifurca* *Anemone rivularis* *Gentiana algida* *Anaphalis flavescens* *Polygonum sphaerostachyum* *Stellera chamaejasme*
Coverage of community (%)	75	85 – 90
Mean height (cm)	15	10
Fresh grass yield (kg/ha)	4390.5	8835.5
Alt. of measuring site (m)	4,100	3,560

Consequently, the shortage of winter grass mainly results from the fact that grasses could not be used enough and the insufficiency of cold season pasture, not from the degeneration of all cold season pastures. Meanwhile, however, the degradation of pastures around winter houses or shelters is obvious. This even leads to the occurrence of bare patches. This phenomenon mainly results from the uneven distribution of livestock, which are limited in movement due to the winter settlements.

Besides the loss in life, therefore, the loss in the condition of animals has greatly augmented costs and reduced the profits from animal husbandry. To sum up, the growth in population, the growth in livestock, and the excessive demands on pastures have all led to overstocking, overgrazing, and pastures degeneration, with an accompanying reduction in carrying capacity, a decline in the quality of livestock, and diminished output. As a result, livestock numbers have again begun to rise due to the consequently increasing demand on animal products for sustenance and marketing and rangeland pastoralism is once more bogged down in an irreversible vicious circle (Fig. 4.7).

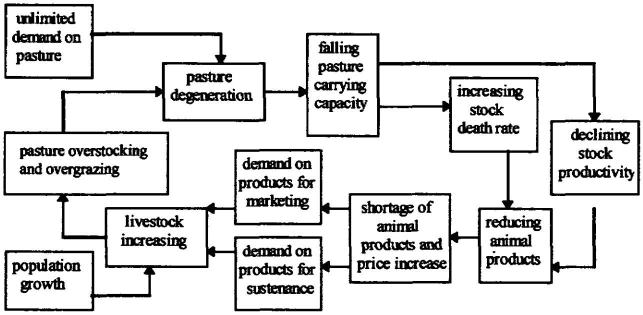

Fig. 4.7 Schematic Diagram of the uncontrolled Production Cycle of Pastoral Husbandry
Design: WU NING

4.3. Rangeland Ecosystems Response to Pressures

Every ecosystem operates under the pressure of two factors, internal and external. Internal factors arise from the development of a community and the associated changes in the habitat conditions, while the external ones are usually community-independent, e.g. meteorological conditions. The pressure of the human population, referred to as the anthropogenic factor is also great. 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 human grazing activity and exploitation are a major agent in the system's economy.

Rangeland ecosystems, functioning in the high altitude or arid zone, have developed under the conditions of a climate displaying seasonal variations. Therefore, fluctuations of a given environmental factor are much greater in an ecosystem associated with a zone of a highland or arid climate than in lowland or humid ecosystems. Functioning under variable environmental conditions, involves special ecological adaptations, which permit ecosystems to survive through periods of strong pressure. Such adaptations are more easily recognised at the level of individual morphology and physiology, but they are also found in the organization of ecosystems, being expressed both in their structural properties and in their response to environmental pressures.

Protective responses of ecosystems directed at preserving ecological homeostasis follow a certain strategy. The principles of operation of homeostatic processes were formulated twenty years ago (TROJAN, 1974). They may be used for an analysis of an ecosystem's response both to the pressures due to the normal variability of the environment and to such pressures as can be regarded as new. The latter are usually anthropogenic.

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 the surroundings. These agents will be referred to as pressures. It is not so easy to differentiate between such pressures and normal variations of environmental conditions. It is assumed that pressures should be associated with the introduction of new agents, which have never been encountered by ecosystems throughout their history. Pressures cause so great a deformation of the elements within an ecosystem that they begin to display a range of variations extending, mostly unilaterally, far beyond the regular limit. Anthropogenic pressure is a major type, which affects as a rule a system through a whole set of factors and through a fairly intense action, which impedes the adaptive processes in an ecosystem.

A new pattern of environmental relationships in pastoralism which arises due to such a pressure, usually entails a response of the ecosystem's biological components, i.e., rangeland and livestock. In a community, it may evoke a great many concomitant reactions, which depend on the effect of a given pressure on particular species and their resistance to it. An obvious response is a change in the dominance structure of plant associations, which are adjusted in this way to a new ecological situation resulting from grazing to a different extent. Furthermore, the response of communities also consists in triggering ecological succession and transforming the system to achieve better adaptation to the new environmental conditions.

Under strong pressures, some rangeland ecosystem components may be eliminated as a result of natural selection, and such pressures cause effective and directional natural selection in the various species, producing changes in the genetic structure of populations. These phenomena have been described for species from heavily overgrazed pastures (see 4.2.1 and 4.2.2). Changes in population structure are associated not only with diversity, but also with interspecific competition, e.g. in interspecific association. Beside these changes in their genetic structure, populations display increased resistance to an overstocked environment.

What can be regarded as a new phenomenon caused by pressure is ecological degradation. This may be defined as a process of impoverishment of the community organization through a decrease in the number and abundance of species and also through a restriction of the functions performed by a given ecosystem. An anthropogenic pressure may cause degradation of the environment and hence degeneration of communities leading to ecological disasters.

It is very important to know in what way the community organization responds to a given pressure. Its reaction to normal environmental factors chiefly consists in restructuring the associations composing different links of trophic chains. In the case of strong pressures, one can expect more profound changes in rangeland and in livestock numbers and composition. Vegetation subsystems store their reserve chains, composed of associations of very low densities and consisting of species sporadically observed in a given ecosystem. Under normal conditions, these chains are not essential for the ecosystem's functioning, but in a new situation they may sometimes take over the functions of the chains that have been eliminated or strongly reduced. Thus, the reaction of ecosystems to pressures would consist in restructuring the pattern of pathways for the energy flow through the subsystems.

A plant community subjected to heavy grazing pressure over a long period of time will undergo a process of change, eventually achieving a grazing climax which may be characterized as anti-pastoral. Plant adaptation to herbivores includes escape in space and time as well as production of toxins, uncommon amino acids and other digestibility-reducing substances (NYERGES, 1979). Over evolutionary time, plant species already dominant in the environment will evolve toxicity specifically in response to new grazing pressure. Also, toxic species in the vegetation, evolved prior to domestication, will be favored under the new selective regime and will tend to increase. In either case, toxicity is favored in the plant community and plant evolution occurs such that excessive foraging is prevented. Either **1)** plants and animals become closely co-adapted so that a sustained level of foraging is possible but overgrazing is prevented by toxicity, or **2)** the relationship fluctuates in a cycle: at first an increasing animal population overgrazes the non-toxic species in the range until only toxic species remain, animal starvation and poisoning ensue, and a crash in the population of grazers and the eventual return of non-toxic species to the range follows (e.g., FREELAND, 1974).

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 optimize nutrient intake and minimize or avoid consumption of toxins. Possible animal adaptations to plant poisons include detoxification of plant secondary compounds in the gut 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 is geared to optimize consumption, but these strategies must be understood in the context of plant adaptations to escape or minimize herbivore. (NYERGES, 1979)

In addition, the impact of grazing on the environment is 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, and vegetation response to grazing will therefore vary with distance from them, such that nearby vegetation is more strongly modified than vegetation further out (Fig. 4.8). This is the reason why the cold season pastures experience an uneven degradation (see 4.2.6 in this text). Thus, the frequency and distribution of settlements and permanent sources of water, which constitute crucial central places in ranges, strongly influence the impact of grazing. The optimization strategies of organisms in a rangeland ecosystem are highly dependent on these factors, and the study of pastoral ecology, therefore, becomes a study of the spatial distribution for the adaptive strategies adopted by organisms.

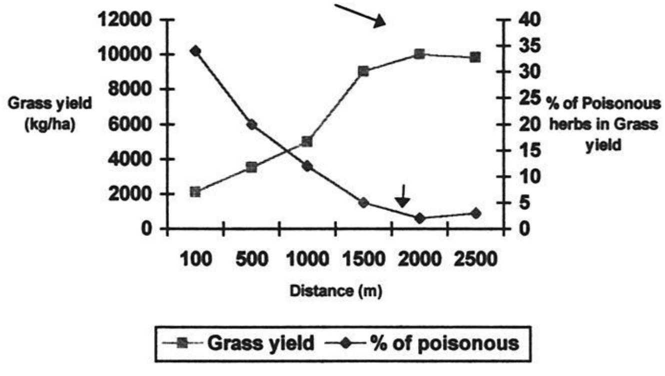

Fig. 4.8 Correlationship between the Quality of Pasture and the Distance from Settlement (Indicating with the Distance Increasing the Quality of Pasture Decreases)
Key: 1) Curve of exponential regression; 2) Curve of logarithmic regression.
Design: WU NING

Variable features of animal ecology and behavior establish the basic productivity of a pastoral system and provide opportunities for manipulation by nomads. Under conditions in which herd sizes are allowed to closely approach carrying capacity, competition between species of domesticated animals results in the establishment of niche differentiation, or its maintenance if originally present in the progenitor species. Age and sex differences result in further quantitative and qualitative differences in foraging that increase the breadth of the pastoral niche and which may be exploited in grazing strategies to further optimize forage utilization.

It should be realized, however, that grazing does not exercise an exclusively destructive influence upon the grazed vegetation. It can work positively in a number of ways, provided the grazing pressure is kept to a limit. MCNAUGHTON (1979) reviewed the literature on potentially positive effects of grazing upon the productivity of grazed vegetation and summarized his conclusions in nine points:

> "*Productivity of herbivore affected plant tissues may be compensated or stimulated by (1) increased photosynthetic rates in residual tissue; (2) reallocation of substrates from elsewhere in the plant; (3) mechanical removal of older tissues functioning at less than a maximum photosynthetic level; (4) consequent increased light intensities upon potentially more active underlying tissues; (5) reduction of the rate of leaf senescence, thus prolonging the active photosynthetic period of residual tissue; (6) hormonal redistributions promoting cell division and elongation and activation of remaining meristems, thus resulting in more rapid leaf growth and promotion of tillering; (7) enhanced conservation of soil moisture by reduction of the transpiration surface and reduction of mesophyll resistance relative to stomatal resistance; (8) nutrient recycling from dung and urine; and (9) direct effects from growth promoting substrates in ruminant saliva.*" (1979: 702-703)

It also is well-known that prolonged moderate to fairly heavy grazing stimulates the storage of assimilates in roots and stolons as well as their growth. These positive effects for the vegetation under moderate to considerably heavy grazing pressures point to the conclusion that many of the characteristic structures and properties of natural grazing land ecosystems with their large game populations are the results of a long co-evolution of plants and herbivores. (WERGER, 1983)

5. FROM THE TRADITIONAL STRATEGIES TO THE MODERN MANAGEMENT

For long-term success a management scheme must meet the needs of plants, livestock and the people involved. Range management means the synthesis of administrative and technical measures, which was summarized by DICKIE (1984) as the science and art of optimizing the returns from rangeland in those combinations most desired by and suitable to society through the manipulation of range ecosystems, and which thus including:

- management of range vegetation;
- conservation of rangeland; and
- management of grazing animals.

Of these, the management of range vegetation plays the most important role, because it is the base and prerequisite of grazing stock management. Secondly, what should also receive more attention is that grazing intensity, grazing season and rational organization of grazing stock must be judged on the basis of the types, quantity and quality of forage grass resources. The following passages will discuss the traditional strategies and modern technologies carried out in the pastoral area of western Sichuan.

The western Sichuan has for centuries been the home of pastoral nomadic communities – populations whose way of life has been based on the raising of yak and sheep on natural grazing and forage for the production of milk. At the center of their way of life was migration that was structured around a combination of seasonal and ecological variables in the location of pasture and water. Survival of both herds and herders made movement from deficit to surplus areas vital. Their way of life continued for centuries interrupted only occasionally by natural disaster, disease, and political conflict. But the balance between man, animal and land remained in equilibrium and the carrying capacity of the land was not strained. Their goal – a common goal for all people – was to survive and pass on to the next generation their culture and social organization. Over the years, they have adapted their way of life to their changing environment.

In spite of the rapid development in science and technology, it should be remembered that the physical conditions in a region, specially climate, can not be changed, but the activity of humans in utilizing rangeland could be controlled. No matter how the management system in the pastoral area of the Qinghai-Tibetan Plateau changed historically, seasonal mobile keeping of livestock was always characterised the highland animal husbandry up to now.

5.1 Seasonal Characteristics of the High-frigid Rangelands

The seasonal characteristics of rangeland refers to the withering and greening variation of herbaceous cover or its seasonal aspect, which exerts a great impact on animal husbandry and even leads to the special migratory character of pastoral activities in a region.

5.1.1 The Causes of Seasonal Pastoralism

The vertical change of climate caused by the variation of topography leads to the formation of different seasonal pastures, and the seasonal difference of grazing time, i.e. seasonal pastoralism. In western Sichuan, topographies always change vertically, in the north the plateau surface present an undulated appearance, but in the south, mountains with deep valleys characterize the topographical features. Since the grazing animals demand different fodder and ecological environments (e.g., temperature, water source) in different seasons, the composition of livestock and their population structure, as well as pasture resources, present a vertical pattern also. For example, the pastures locating on the sheltered side of hills or in the valley and at lower altitude, where it is warmer, can be grazed in winter and early spring. On the other hand, the alpine area pastures are difficult to use in winter due to the frigid weather, strong wind, great snow, and the related withering grasses, but they are the ideal pastures in summer because of the cool, rainy weather, and the greening grasses there.

Restricted by the natural conditions, the duration of greening and withering period of grass always differentiate in different locations and specially at different altitudes. In western Sichuan, such as in *Hongyuan*, *Zoige*, *Zamtang*, *Serta* and *Serqu*, where the altitude of rangelands is averagely above 3,300 m, the greening period in a year is only about 100 days, and at most not more than 170 days. The withering period is as long as 250-270 days, which lead to the shortage of foodstuff and the high mortality rate of domesticated animals.

In the more favorable places, such as the lower altitudes or the more southward place, the greening period is about five months, which continues from May to September. In general, with the increasing of altitude, the greening period becomes shorter, but the withering period longer, and the utilizing value of pasture also decreases.

Another factor that should be mentioned here is the direction facing of slopes, which can also greatly affect the productivity of pastures, the efficient using of fodder and the use period of pastures. Generally speaking, in winter-spring pastures south-facing slopes (sunny slopes) can be used for a longer time and the winter settlements of herdsmen are also always built up on the south-facing slopes, which lead to a bigger grazing intensity (more livestock grazed on sunny slope) and the grass taken by animals (eating capacity) is higher. However, the amount of fodder which are provided to livestock is not in direct ratio with the grazing time, because the yield of grass on the south-facing slopes of winter-spring pastures is lower than that of north-facing slopes. Conversely, in summer pastures the grazing time and the eating capacity on north-facing slopes are longer and bigger, but the conflict between the available fodder and grazing intensity is not so acute due to their much bigger area. Following figure (Fig. 5.1) shows the utilization of different slopes in Tibet.

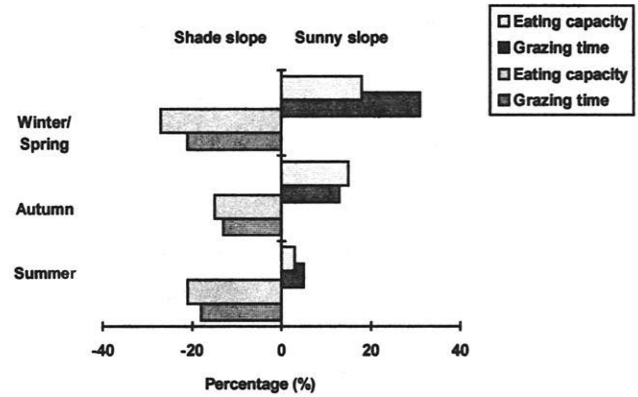

Fig 5.1. The Effects of Facing-direction of Slopes on the Grazing Utilization of Seasonal Pastures

Source: TIST, 1992:10

Design: WU NING

5.1.2 The Seasonal Dynamic of Quality and Quantity

In the high altitude area of western Sichuan, grasses start to sprout in April or May, when they are in high quality but low yield, which can not satisfy the needs of animal grazing. Grasses grow luxuriantly in July or August, when animals can eat their fill of the high qualitative forage, which is beneficial to the rapid growth and the fattening of animals. After September grasses enter the withering period, when grasses are at peak yield, but the quality falls gradually, until totally withered, grasses can not provide enough food for livestock (details see 3.4.2 of this book). Based on the observation in the high-frigid pasture, the results have explained the seasonal dynamic characters of grass yield in a year round (Fig. 5.2). Therefore, from the biological viewpoint, the period from the end of May to the end of September is the best time for grazing animals and fattening them. Two importantly varied period, from April to June and from September to October, are the key times for the migration between seasonal pastures.

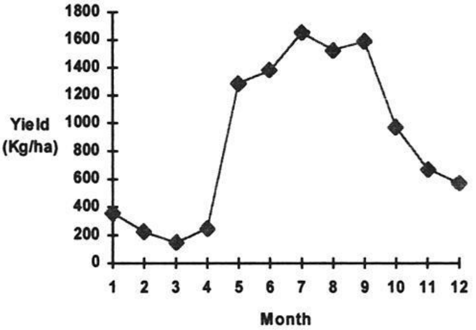

Fig 5.2. Seasonal Dynamic of Grass Yield in the High-frigid Pasture (Hongyuan)
Source: SICHUAN ANIMAL HUSBANDRY BUREAU, 1989.
Design: WU NING

After analyzing the content of crude protein and crude fiber (Fig. 5.3), man can further find that the percentage of crude protein increases after April and is highest in July. With the coming of the withering period, it decreases gradually and reaches the lowest in March. However, the content of crude fiber has not an obvious fluctuation from April to September. After that it increases by degrees with the coming of winter. From the accumulation curve of dry matter one also can find similar regularity (Fig. 5.4). Plants regreen in April, when the temperature is low; plants are hit occasionally by snow storms; the photosynthesis of grass is low and accumulation of dry matter is also slow. After June, the temperature rises quickly, with the coming of rainy season, the growth of plants enters its peak so that the accumulation of dry matter increases rapidly. From the end of August or the beginning of September, the growth of plants drops and the accumulative rate of dry matter decreases gradually. Until the end of September or the beginning of October, with the coming of winter, plants stop their growth and accumulation of dry matter. Consequently, livestock in a year round fill out in summer, fatten in autumn, thin in winter and die in spring in accordance with the sprouting, luxurious growth, withering and dying of grasses. Most damage is done during the early spring seasons, and particularly after a colder winter or during drought years when the standing biomass is declining anyhow.

Summing up, it is important to note that the duration of the growing periods per year rarely exceeds five months. Moreover, the higher the altitude is, the shorter the growing period presents. The implication of this is, that the seasonal variation of forage quality is not of an equal proportion and pastoralists have to migrate in order to adapt to it. That is the seasonal characters of high-frigid ranges in western Sichuan and even in all of the eastern Qinghai-Tibetan Plateau, which is also the limiting factor to the development of pastoralism in these areas.

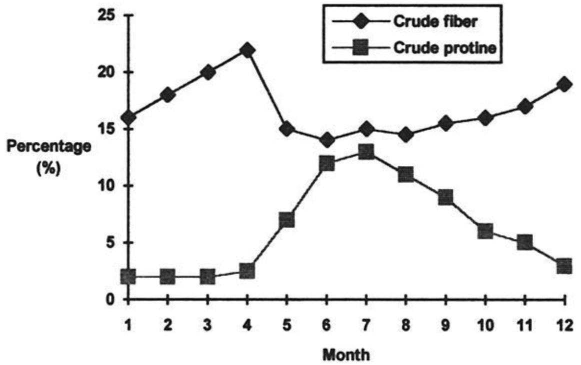

Fig. 5.3 Seasonal Dynamic of Grass Quality in High-frigid Rangeland (Hongyuan)
Source: SICHUAN ANIMAL HUSBANDRY BUREAU, 1989.
Design: WU NING

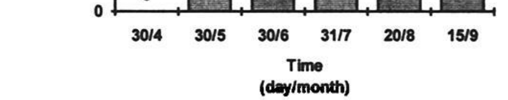

Fig. 5.4 Accumulation Curve of Dry Matter of *Kobresia humilis* Meadow
Source: ZHOU, 1982.

5.1.3 The Division of Seasonal Pastures and Their Grazing Systems

An appropriate grazing time includes the starting time, finishing time and grazing season. While determining the starting time for grazing, the height of grasses and their developing stages are always considered. The starting time in spring is confined to the time 12-18 days after grasses sprouting and greening, when the heights of grasses are about 5-10 cm (see 3.4.2). This time in the mountainous area, e.g. the semi-nomadic area, where the altitude varies from 2,500 to 3,500 m a.s.l, is late of April. In the nomadic area with the altitude above 3,500 m a.s.l the time alters from the late of May to the beginning of June. In view of the developing stage of plants, the starting time is arranged in the time when *Gramineae* grasses till, and forbs divide, during which the palability of grasses are good, nutrient values are high, and the stored nutrients exhausted by the sprouting of regressing grasses have already recovered, and consequently the grazing activity can not affect the regrowth of grasses.

The decision when to terminate the grazing in autumn (end time) will impact upon the grass yield in the next year. When the termination is too late it will reduce the storage of nutrients in plants before the following winter, and lead to a drop in production. Therefore, the last grazing activity in autumn is concluded 30 days before the stop of grasses' growth. This time in the northwest is from the late of September to the middle of October.

The grazing season is refered to as the continued period between the starting time in spring and the finishing time in autumn. The duration is changeable with the different geographical location and different type of pasture, for example, in the alpine belt it is about 120-150 days, but in the subalpine belt it last for about 140-160 days. (MANDERSCHEID, 1996)

In the western Sichuan, pasture types, stocking capacity, and utilization obviously shows more differentiation vertically than horizontally; elevation is the determining factor. Therefore, an analysis of the conditions affecting it should be made. For example, in the case studying area - Zamtang County, animals are grazed on the alpine meadows in the warm season (from May to October). In the cold season (from October to May), grazing takes place on the sheltered and sunny side of the subalpine meadows, shrub meadows and woodland meadows with elevations below 3,500 m. Pastures around the villages and at lower elevations are used to graze old, weak, and sick animals all the year round as well as for lambing and breeding.

The seasonal grazing system is refered to is that where rangelands in an area are divided into different parts and grazed according to the different seasons. In the northwestern Sichuan, e.g. the plateau area, because there is not an apparent difference of four seasons, but the cold and warm season, dry and rainy season can be distinquished easily, the natural rangelands are always divided into two parts, i.e., winter-spring pasture (cold season pasture) and summer-autumn pasture (warm season pasture), and are used in the rotational grazing system, namely "two season grazing system".

In the mountainous area or the areas with greatly varied topography, there is also the so-called "three season grazing system", including the winter pasture, spring-autumn pasture and summer pasture. In this system the migration is from low altitude to high altitude (MANDERSCHEID, 1996), a vertical direction, and the transitional belt between the winter pasture and the summer pasture support the grazing activities in spring or autumn.

5.1.4 Sufficiency and Insufficiency of Seasonal Pastures.

Tibetan nomads accumulate a wealth of experience in the utilization of rangeland, arrangement of winter housing and selection of grazing routes and sum up a series of management patterns which is adapted to the local conditions. But there are also some objective problems in this area, which express concentratively in the uneven distribution of seasonal pastures. In Garze Prefecture, for example, the area of cold pasture only makes up 28.4% of the total rangeland, on which the grass yield taking up 29.8% of the total production in this Prefecture, but the grazing time lasts for as long as seven or even eight months. Similarly, in three main pastoral counties of Aba Prefecture, i.e. *Hongyuan*, *Zoige* and *Aba*, there are 0.768 million hectares of cold pasture, which amount to 37.64% of the total available rangeland and are used for 210 days, accounting for 55% of all the grazing time in a year. The shortage of cold pasture leads to the overstocking in this area. Besides these three counties in Aba Prefecture, others are in the similar situation but only in different degrees.

The warm pastures are widely dispersed throughout the alpine area and are the largest in terms of acreage, which in generally can provide enough foodstuff and nutrients to domesticated animals. In Garze Prefecture, the area of warm pasture takes up 65.3% of the total available rangeland, and on which the grass yield making up 61.9% of the total grass yield in this Perfecture, but the grazing time is only four or five months. Likewise, in Aba Prefecture, there are 1.27 million hectares of warm pasture in *Aba*, *Hongyuan* and *Zoige*, which accounting to 62.36% of the total available rangeland in three counties, and the grazing time are 150 days, amounting to 45% of all grazing time in a year.

Now we can exemplify *Zamtang* to look into the contradiction in more details. Cold season pastures in *Zamtang* have to support animals for seven months of the year, whereas warm season pastures are only grazed for other five months. Thus, the ratio of cold season pastures to warm season pastures should be 1.4:1. However, there is a serious shortage of cold season pastures, due to the fact that there are only 132,969 ha of available cold season pasture in the County, while there are 166,511 ha of warm season pasturelands, comprising 55.6 percent of the total available rangeland. In reality, therefore, the ratio of cold season pastures to warm season pastures is 1:1.28, and this is almost the reverse of what is ideally required.

When calculated according to the carrying capacity of the ranges in *Zamtang*, pastures that are used during the cold season have almost a carrying capacity of 450,000 sheep unit, whereas the carrying capacity of warm season pastures is about 560,000. Consequently, it implies that, at the end of Autumn, when the herds are moved from the warm to the cold pastures, the utilization balance would only be maintained by reducing livestock by 24.44 percent.

In *Zamtang* about 134 hectare of ranges have been reclaimed around the river valleys, shoals, and pens lying below 3,500 m (1992 data). They have been planted with forage grasses, such as oat (*Avena sativa*), but the annual hay yield is only 800,000 kg giving a mere 0.84 kg extra for every head of livestock in the County. Therefore, *Zamtang* has a low capacity for producing complementary winter feed and livestock has to be put out to graze all year round.

Because the cold pastures are used in the period of grass withering, both the trampling of animals and snowstorms can lead to the decrease of grass availability and the loss of nutrients. At present, in some pastoral area of Aba and Garze, pastoral herdsmen prefer to mow before grazing in a cold pasture, which at least is feasible in a short time. Otherwise, the heights of grasses in warm pastures are short (only 5-12 cm tall) and vegetation covers are relatively sparse, particularly on the alpine meadows, the coverage varies from 45 to 60 percent. The amount of hay which could be mowed annually from it is very limited, which may be considered as one of the main reasons why it is only used as grazing pasture by herders.

Due to fodder shortages and the fact that the grasses are buried by snow in winter and spring, many animals die of hunger. The animal husbandry is, therefore, affected by adverse weather conditions, and it is essential that the local Administration provides substantial financial assistance and grain, feed, to supplement grazing and to protect livestock.

5.2 The Traditional Adaptive Strategies

Very different management considerations and practices apply across the livestock production spectrum from nomadism through semi-nomadism to mixed farming. It should be appreciated that ecology both influences the occurrence or choice of production system and the manner in which the system is managed. This is especially true of subsistence pastoralism, i.e., nomadism and semi-nomadism, which are both a response to environment and, in its execution, a living exercise in applied ecology. Its central concern is to maintain animal numbers and animal products, such as milk and butter yield by seeking good grazing and adequate water, avoiding predators and know foci of disease (MANDERSCHEID, 1996). As often as not its movement patterns are a direct response to the distribution of grazing and water.

5.2.1 The Traditional Grazing Management

On the Qinghai-Tibetan Plateau there is no single management system which applies to all livestock over the large area of their distribution. Because of the vital role of yak in the pastoralism of western Sichuan, the management system is mostly formed based on the yak breeding. The grazing methods differ according to the different regions, influenced by altitude, climate and other natural conditions. Proximity to centers of population or to urban centers, which provide a market for yak products, also has an effect on the pattern of management, since it determines whether products are used primarily by the families herding the yak, or whether certain products, like milk, are exploited more for the sale of, for example, butter. (CAI and WIENER, 1995)

In western Sichuan the herds are always accompanied by the male members of the families. Yak herds always vary in size. A herd of about 20 yaks is generally regarded as the minimum to support a family (CAI, 1991). Herds of 100-150 given an ample livelihood, but rich herd-owners with 300-500 yaks are certainly not unusual, while the very rich families may have a thousand sheep and yaks.

Traditionally, the nomadic way of herding yak was to keep the entire herd together, irrespective of age and sex, and to allow the yak to pasture together with sheep and horses. The herders would live with their animals and would, during the growing season, move with them as necessitated by the availability of grazing and water. Since the 1950's, the changes of management system in China have also brought a division of the herds into different categories of yak and the separation of different types of stock. According to the study of

CAI (1992) in pastoral areas, the total yak herd is usually divided into different component herds, including dairy herds, "*Ganba*" herds (the dry-cow herd), "*Yaer*" herds (the younger reserve herds), and pack herds. Herds of the different categories of yak also differ in size, for example, the dairy herd is normally tends to the number between 100 and 150 head. (CAI, 1992)

The peak period for lambing is between January and March. Lambs born in winter are suckled at the start of the day, then left in an enclosure of stones or thorn scrub. The rest of the herd is led by way of the shade side of hills into woodland or bushland. If enough herdsmen are available, the dairy animals are separated from the rest. The dairy animals, or the whole herd if there is no division, returns to the camp in the late afternoon, and the young are released from the enclosure to be suckled again. About the management of calves one can get a rough impression from following description:

> "*Young calves remain with their dams up to weaning - which is most often in their second warm season of life, when they are between a year and eighteen months old, but it can, of course, be sooner. After weaning, whenever it is, the young animals are incorporated into the 'Yaer' herd of replacement animals.*" (CAI and WIENER, 1995: 126)

The Tibetan nomads migrate from their winter regions over a transitive belt, most routes skirt the bushy valley or gully where grazing paths formed under the trampling of animals year in year out, to reach an altitude of 3,500 m, or more. On their migration the Tibetan nomads use male yaks and horses. After leaving their winter territory in mid-April or beginning of May (see 5.2.2 for details), they enter the next vertical belt, characterized by alpine meadow dominated by *Kobresia* species, and occasionally interspersed with alpine *Rhododendron* or *Sibiraea* bushland. Many nomadic families spend the summer here but send their herdsmen on to considerably higher altitudes, as far as the alpine pastures around 4,000 m. They are back in their winter territory by early winter and not usually later than November.

But nomads do not live on milk alone, and various methods of obtaining grain have been devised. Except the true nomads distributing in the northwest where the altitude is so high that it is impossible cultivate any crops, most nomads, who could be called semi-nomads, practice widely a mixed subsistence way that they sow grain - often Tibetan barley or wheat - in their fields in April or May, which always locate in the valley or foreland of mountains, pasture their herds from June to end of September or beginning of October in summer pastures, harvest grain crop in October and then migrate to winter pastures with the herds.

Nomadic herders rely solely upon natural vegetation for their livestock's fodder, and traditionally neither sow pastures nor store forage. As they live in areas whose temperature conditions preclude all-year grazing, they are forced to move their herds in search of new pastures. In the northwest, i.e. plateau area, where the landform is relatively flat and there are seasonal fluctuations in the movement of the cold high pressure from Tibetan Plateau and in winter there is northwesterly cold current from Siberia, nomads with their herds migrate in a regular northwest - southeast movements around the hillocks and select a leeward slope, always facing southeastwards, to put up their winter tents or houses. In the mountainous parts or plateaus with incised valleys, where nomadism is vertical rather than horizontal, each group of nomads follows the same route each year, although perhaps stopping at different places on the route to graze from one year to another. The route, from the low valley to the high mountain pastures, is so designed as to maximize the optimum use of seasonal variations in grazing.

5.2.2 Keeping Mobile Livestock Husbandry - A Strategy of Sustainable Utilization

5.2.2.1 The Seasonal Grazing System in Western Sichuan

As described in 5.1.3 the grazing system is the using system when rangelands are used as grazing lands, which confines the arrangement of grazing period and spacial migration, and combines livestock, grazing land and grazing time. Thus, grazing system is different from grazing technique. A grazing technique can be used in different grazing systems, but grazing systems always present the zonal difference or features. In the past hundreds, or even thousands of years until today, in most area of the Plateau, the nomadic grazing-system was and still is the main grazing system.

Meanwhile, the different grazing system mentioned above, i.e. "two season grazing system" and "three season grazing system", which are the main representatives at present in all of the Plateau region (TIST, 1992), have implied the different form of life and different economic organization. In comparison with the definitions given by SCHOLZ (1982:6; 1992:14) the term of true nomadism is approximate to the pastoralism in "two season grazing system" in the northwest, which including *Zoige*, *Hongyuan*, most of *Aba*, northern *Zamtang*, *Sertar* and *Serqu* counties, and the term of semi-nomadism or mountain nomadism is similar to the pastoralism in the "three season grazing system" or in the remaining parts characterized by mountains or the areas with greatly vertical difference. However, it should be emphasized that the division is always not so absolute and clear. Due to the vast area and complicated natural conditions, even in the same system the duration of grazing time and livestock composition is different when they occur in different area.

True nomads, in the sense of people on the move wherever their fancy takes them, are rare. Even for the pastoralists in pure pastoral areas there is rather a seasonal pattern of movement between pastures in which there are well-defined land rights, which have in all likelihood existed for as long as the State and literate civilization in this area.

The general movement, especially for the semi-nomads, is a dispersal in the summer to the high-frigid pasture (summer pasture) on the sides of the mountains, and back down the valleys in the winter to the lowest settlement (winter pasture), which can be fixed villages with houses. Current efforts at settling down pastoralists in *Zamtang, Aba* and *Hongyuan* involve building them permanent winter settlements. There are also intermediate spring and autumn sites in the cycle, and encampments can last for period of between 15 days up to five months. In *Zamtang*, as well as other pastoral areas, these areas are well-defined, with areas within the administrative hierarchy. Each level has exclusive use of a certain territory, and the "*Chun*" (village) within the same "*Xiang*" (see 6.2.2 of this book) have contiguous pasture. As far as the "*Chun*" or "*Xiang*" is concerned, these territories would appear to be roughly the same as those of the traditional land rights.

Within the territory of their own "*Chun*" they can in principle pasture their animals anywhere; but it was said that in practice the custom is that there is a subdivision of every family's grazing or family group's grazing, but we did not learn the mechanism in detail. According to the research in Tibetan Autonomous Region by CLARKE (1987):

> "*...overall in these areas there is a similarity in the manner in which rights to pasture are allocated. In law they follow the administrative structure; in practice they follow the traditional pattern of village or neighborhood allocation of pasture and boundaries. Within these communities rights fall to local extended families or herds again according partly to tradition, and partly according to an egalitarian rotation. These rights are managed by one of the elected or otherwise appointed officers of the neighborhood.*" (CLARKE, 1987:24)

a) Two season grazing system

This system mainly occurs in the northwestern Sichuan, where flat plateau surface constructs the base of rangeland and yak takes the main role in the composition of livestock.

But it can be also found in the area where pasturelands are too limited for livestock to migrate in a long enough range, such as in *Jinchuan*, *Barkam* and *Xiaojin* Counties, the mountainous region in the southern part of Aba Prefecture, yaks and other animals are confined in the limited alpine pastures since yaks cannot be driven downward too low. Considering the different landforms, there are some kinds of variety, but the typical model can be represented by *Yuto*, in *Zamtang*, which is illustrated in following paragraph, table (Table 5.1) and figure (Fig. 5.5).

Table 5.1 Two Season Grazing System Represented by *Yuto Chun*, Zamtang

Item	Warm season pasture	Cold season pasture
Grazing period	end of May - end of October	end of October - end of May
Grazing days	153	212
% of one year	42	58
Type of pasture	Alpine meadow	Valley bush meadow Subalpine meadow
Altitude	3,800 - 4,100	3,500 - 3,750
Dwelling	tent	Winter shelter

The dweller in *Yuto*, a small village belonging to *Zhong Zamtang Xiang* administratively, has only pastoralism as his or her subsistence. Due to the high elevation, there are not farmlands in the range of cold season pasture, and not even permanent winter houses. Although some winter houses were built up in the 1970's by the government, who attempted to settle nomads as sedentary pastoralists, at present only some ruins can be found. The nomads return to their winter tents or simple winter shelters, around which small patches of artificial pasture are found where nomads also plant some improved grasses for winter fodder. The cold season pastures locate mainly in a valley, which is a branch of the *Zhe-qu* River, where the altitude is about 3,600 m a.s.l., and are composted by bush meadow which are dominated by *Sibiraea, Hippophe*, and *Kobresia, Carex* meadow. The bushes provide the fuelwood for nomads during the frigid winter.

After seven months when nomads stay in cold season pasture, they move out in the middle of May (around 20th of May) and migrate to warm season pasture. The distance between two kinds of pasture is about three or four hours when the men ride horse, and the relative altitude is about 100 meters or more. The procedure is to move the livestock and the people, with their tents and belongings, all together in one move, until the new campsite is reached. Under this circumstances the animals get virtually no chance to graze on route. The warm season pastures are dominated by alpine meadow, mainly *Kobresia* meadow, where nomads will not stay until the middle of October. In this situation there are not special pastures for

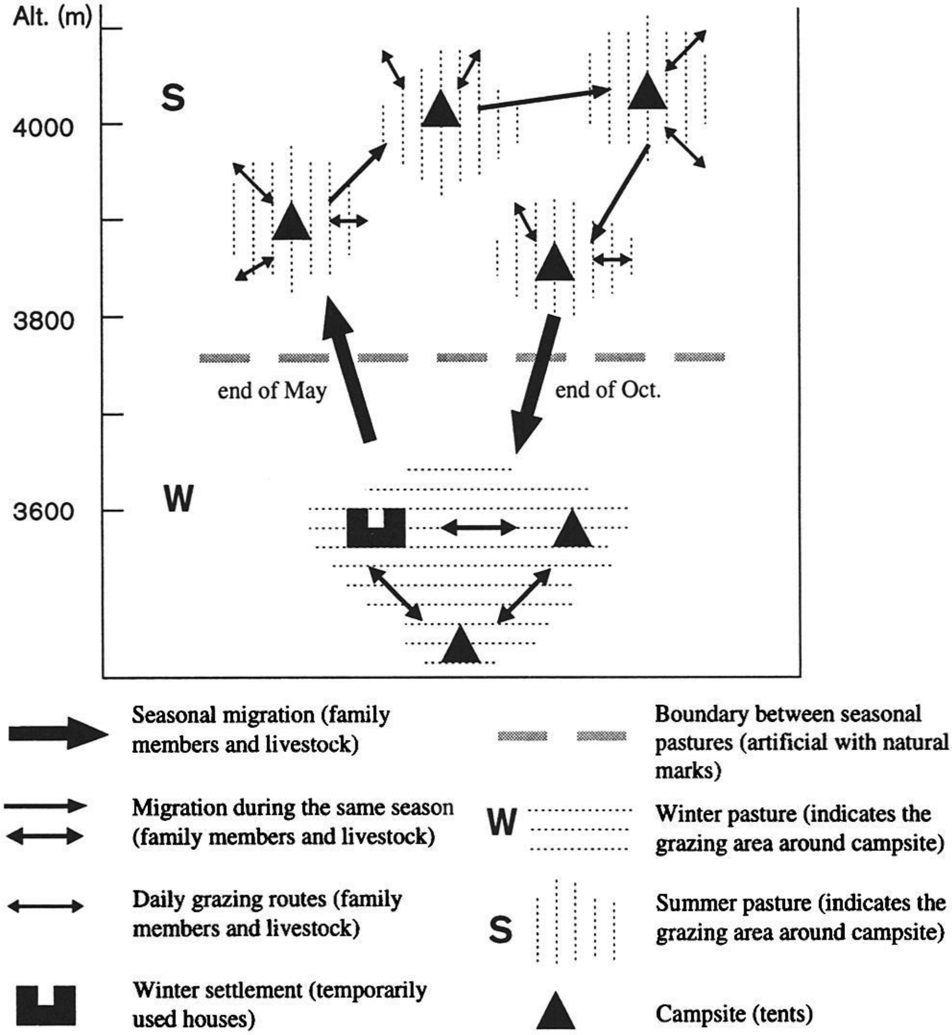

Fig. 5.5: Grazing Routes in Two Season Grazing System Represented by *Yuto Chun*, Zamtang
Design: WU NING 1995

spring or autumn purpose, but nomads always move their tents twice or three times in a summer[43], i.e., a routine from near part to further point and then to near part in terms of the relative distance with cold season pasture, so that they can return to cold season pastures gradually. The distance between campsites is generally less than 15 km. Even in a same pasture, such as in summer pasture, nomads may act to increase the breadth of land use and minimize foraging pressure is to disperse grazing routes as much as possible, by which nomads can ensure equal distribution of grazing pressure on pastures.

In general, the process of moving from cold season pasture to warm season pasture is a direct way, which is always finished in one day, but the migrating process in summer and autumn is progressive. During the cold season, movements from one site to the other are few and the routes are short.

Besides the above example, other variations can also be found in the northwestern Sichuan, in which the most apparent difference is the duration of summer campsites and the times of moving tents. General speaking the similarities of "two season grazing systems" are greater than that of "three season grazing systems".

b) Three season grazing system

This system is more popular and complicated than above one in western Sichuan. One example is in *Gamda*, *Zamtang* County, where pastures are divided into winter-spring pasture, autumn pasture and summer pasture, and which is similar to semi-nomadism because pastoralists always have some farmlands in valleys. Nomads stay in winter houses to spend the severely cold winter and starving spring until the beginning of May. After sowing barley in their fields, they migrate to summer pasture, with their tents and belongings, and graze their livestock there till the harvesting time in autumn. Meanwhile, they drive their livestock downward and put up their tents in the autumn pastures, but some members of a family, mainly manpower, will leave their livestock temperately and go harvesting in the fields. After that, they will return to their tents and stay there until the end of October or even the beginning of November, and the residues of barley are always brought by them to the winter house and used as hay in the following winter. Around winter houses artificial pastures where oat is planted for supplementary fodder often can be found. The relative altitude between winter pasture and summer pasture is always beyond 300 meters. Although the autumn pasture is only used in a short period (not more than 50 days)

[43] During the warm season, a yak herd will typically be moved every 20 to 40 days depending on the state of the grass and the size of the herd, which means that the moving times for every family are different.

in this situation, it has become the buffer zone for winter pasture (Table 5.2; Fig. 5.6). During the cold season, grazing acitivities are taken out in the valleys or beside the fringe of woodland. The spacial mobility of grazing herds are always limited by topographies. If the herd is small, or if livestock are kept in stockades or pens during most time of a winter, and if there are enough supplementary fodder (such as the families with big enough artificial pastures), there may be no move at all over the whole of the winter and early spring.

Table 5.2 Three Season Grazing System Represented by *Gamda Xiang*, Zamtang

Summer pasture				**Autumn pasture**				**Winter (spring) pasture**			
Period	Days	%	Pasture	Period	Days	%	Pasture	Period	Days	%	Pasture
Begin. of June–begin. of Sept.	90 - 95	25 - 26	Alpine meadow	Mid. of Sept.–begin. of Nov.	45 - 50	12 - 14	Subalpine meadow Bush meadow	Begin. of Nov. - end of May	210 - 215	58 - 59	Subalpine meadow Bush meadow Woodland meadow

In order to alleviate the conflict between summer pasture and winter pasture, specially lighten the grazing intensity on winter pastures, some kinds of variety based on above system should be mentioned here. One can be exemplified by *Gado*, Zamtang County (Fig. 5.7). Since the area of summer pasture is big enough to support a longer grazing time, pastures are divided into three parts, i.e. summer- autumn pasture, winter pasture, and spring pasture. Pastoralists (or in term of semi-nomads) possess farm-fields in the basin of *Zhe-qu* River, which is below the winter pasture. In the spring before they sow barley, livestock are driven downward at first and utilize the grasses, which regress earlier, along the valley or around the fields, by which the spring starvation can be mitigated to a certain extent and animals' dropping can fertilize the fields which will begin to be plowed. When plowing and sowing, livestock are driven backward onto slopes. After these farming activities, pastoralists take their animals and tents to summer-autumn pastures at the end of May. Sometimes the movement is direct between the spring pastures and summer-autumn pastures. However, if the moving distance is not too long, the procedure of movement is that the people and belongings are moved firstly to the new campsite in the summer-autumn pasture, where the site is established, and then the herds are driven gently in the course of a day's grazing toward the new site. During the harvesting period, some members in a family (always adults) return to the fields, but other members (always children) still company animals in the summer-autumn pastures. At the beginning of November all members with their tents take their livestock back to the winter house (Table 5.3).

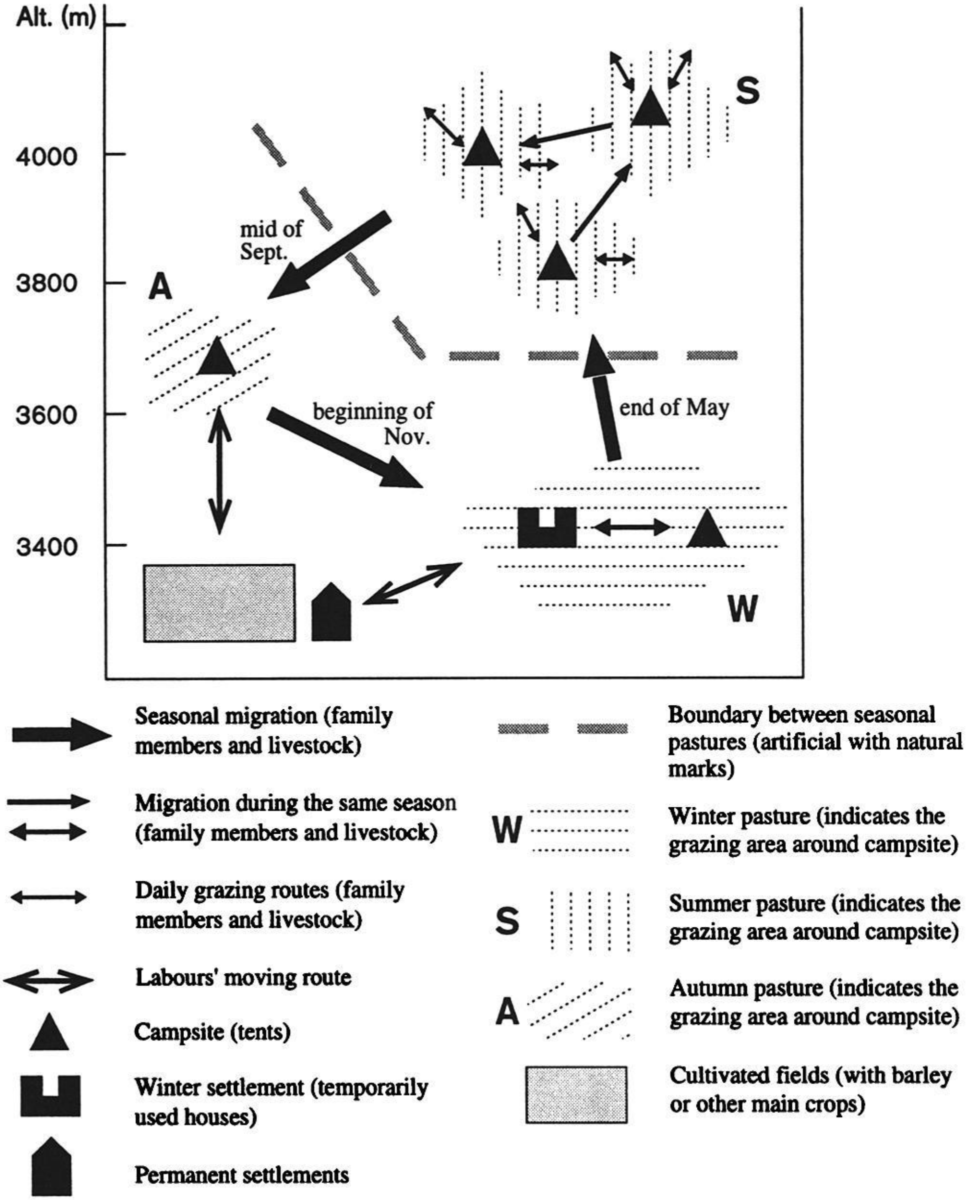

Fig. 5.6: Grazing Routes in Three Season Grazing System Represented by *Gamda Xiang*, Zamtang
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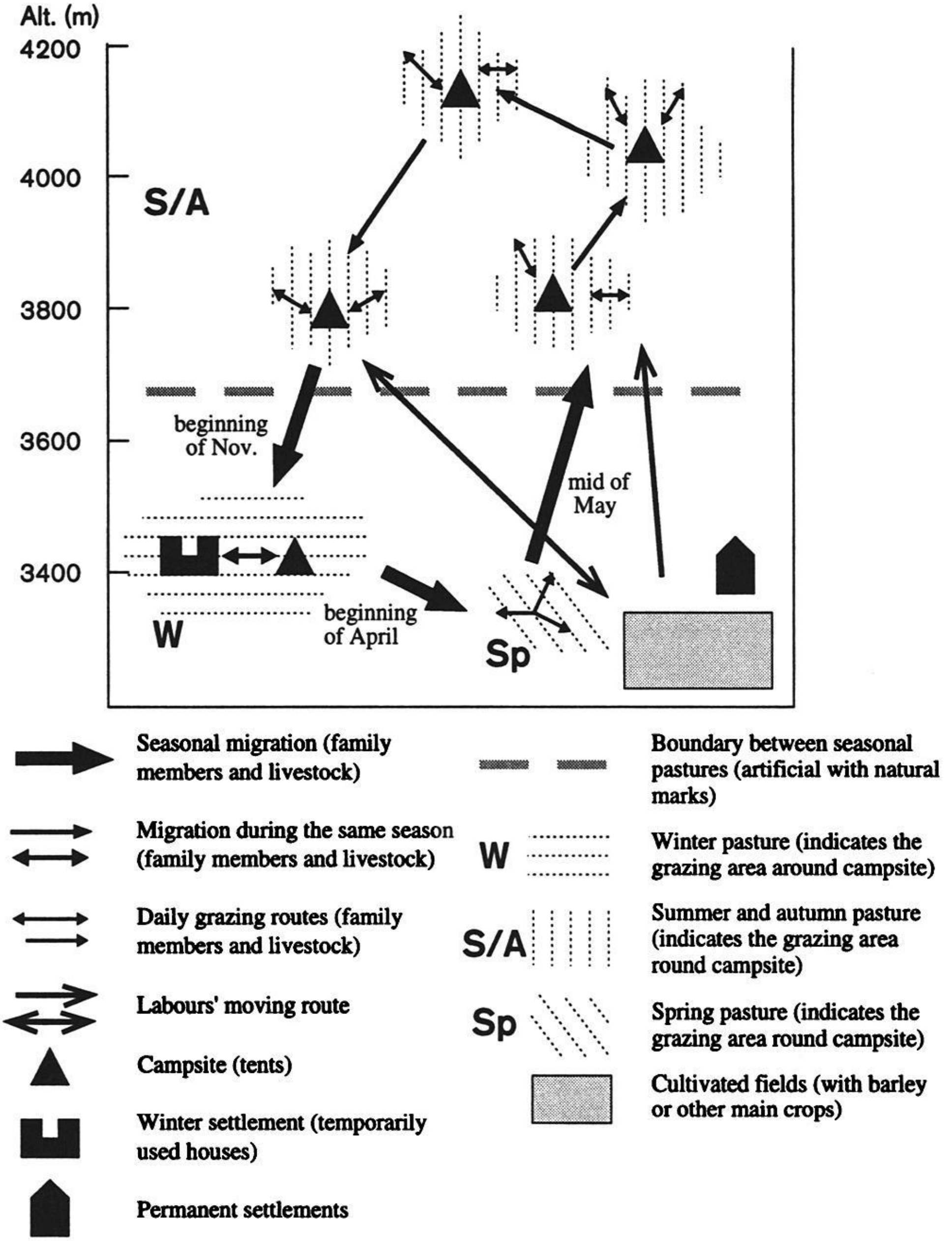

Fig. 5.7: Grazing Routes in Three Season Grazing System Represented by *Gado Xiang*, Zamtang
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Table 5.3 Three Season Grazing System Represented by *Gado Xiang*, Zamtang

Summer and autumn pasture				Spring pasture				Winter pasture			
Period	Day	%	Pasture	Period	Day	%	Pasture	Period	Day	%	Pasture
end of May - end of Oct.	150 - 155	41 - 43	Alpine meadow	Mid. of April - mid. of May	30 - 45	8 - 12	Valley bush meadow Subalpine meadow	Begin. of Nov. – begin. of April	148 - 153	41 - 42	Subalpine meadow Bush meadow Woodland meadow

The other one can be represented by the three season grazing system in *Hongyuan* County, which differentiate pastures as winter pasture, spring-autumn pasture, and summer pasture (Fig. 5.8). This type always occurs in the area where nomads migrate a long distance between summer and winter, and between two destinations pastures in this long range can be used repeatedly in spring and autumn during the two migrations (Table 5.4). Although the spring and autumn pastures are only the transitive steps, they have reduced the pressures on winter pastures or summer pastures to a great extent. In this system nomads are mainly engaged in animal husbandry and generally have no farmlands. Consequently, it could be understood that this system is developed from a "two season grazing system".

Table 5.4 The Three Season Grazing System Represented by *Wache Xiang*, Hongyuan

Summer pasture				Autumn and spring pasture				Winter pasture			
Period	Day	%	Pasture	Period	Day	%	Pasture	Period	Day	%	Pasture
begin. of July - mid. of Sept.	77	21	Alpine meadow	Mid. of Sept. - end of Nov. Mid. of May -end of June	120	33	Subalpine meadow Bush meadow Alpine meadow	Begin . Of Dec. - mid. Of May	168	46	Subalpine meadow Bush meadow Woodland meadow

In both types of migration ("Two season grazing system" and "Three season grazing system") nomads or semi-namads keep to prescribed territories, but these are by no means unchangeable. In *Hongyuan* County, for example, in order to sell the surplus milk to a milk factory, which is in the town and to collect milk daily in summer from the beginning of July to the beginning or middle of August along the main roads, nomads have to stay a certain distance from the roads, where the pastures have to be used in summer time, although most of them were just used in the last winter (Fig. 5.9). In this way, owing to the marketing force, man's impacting on vegetation leads to a greater change in rangeland. Compared with the two season grazing system in *Hongyuan* mentioned above, it can be found that the duration staying in summer pasture is two months fewer, and the period spent in winter pasture is one month more (Table 5.5). Although the spring pasture is chosen as a buffer measure, it is also unavoidable that the winter pastures are overstocked and overgrazed.

Table 5.5 The Three Season Grazing System Adapted for Milk Sale Represented by No.1 *Chun* of *Anqu Xiang*, Hongyuan

Summer and autumn pasture				**Spring pasture**				**Winter pasture**			
Period	Day	%	Pasture	Period	Day	%	Pasture	Period	Day	%	Pasture
mid. Of Aug. - mid. Of Nov.	92	25	Alpine meadow	Mid. of June - mid. of July	30	8	Subalpine meadow; Bush meadow; Swamp meadow	end of Nov. - mid. of June mid. of July - begin of Aug.	243 (for milk sale)	67	Subalpine meadow; Bush meadow; Woodland meadow; Swamp meadow

5.2.2.2 The Ecological and Socio-Economic Significance of Seasonal Migration

The sparseness and limitation of natural pastures and their geographic and/or orographic location contribute to the formation of nomadic characters in western Sichuan. In general, with the seasonal alternation, the herds repeatedly often having to cover a distance in search of food and water, which leads to the migration in seasonal pastures. Just as the nomadic features described by SCHOLZ (1992:14):

> *"The search for pasture means that nomads have to shift camp regularly and so need mobile, easily transportable or naturally available dwellings (e.g. tents, wind shelters, movable huts, caves) and other appropriate types of material goods such as household utensils, looms, clothing..."*

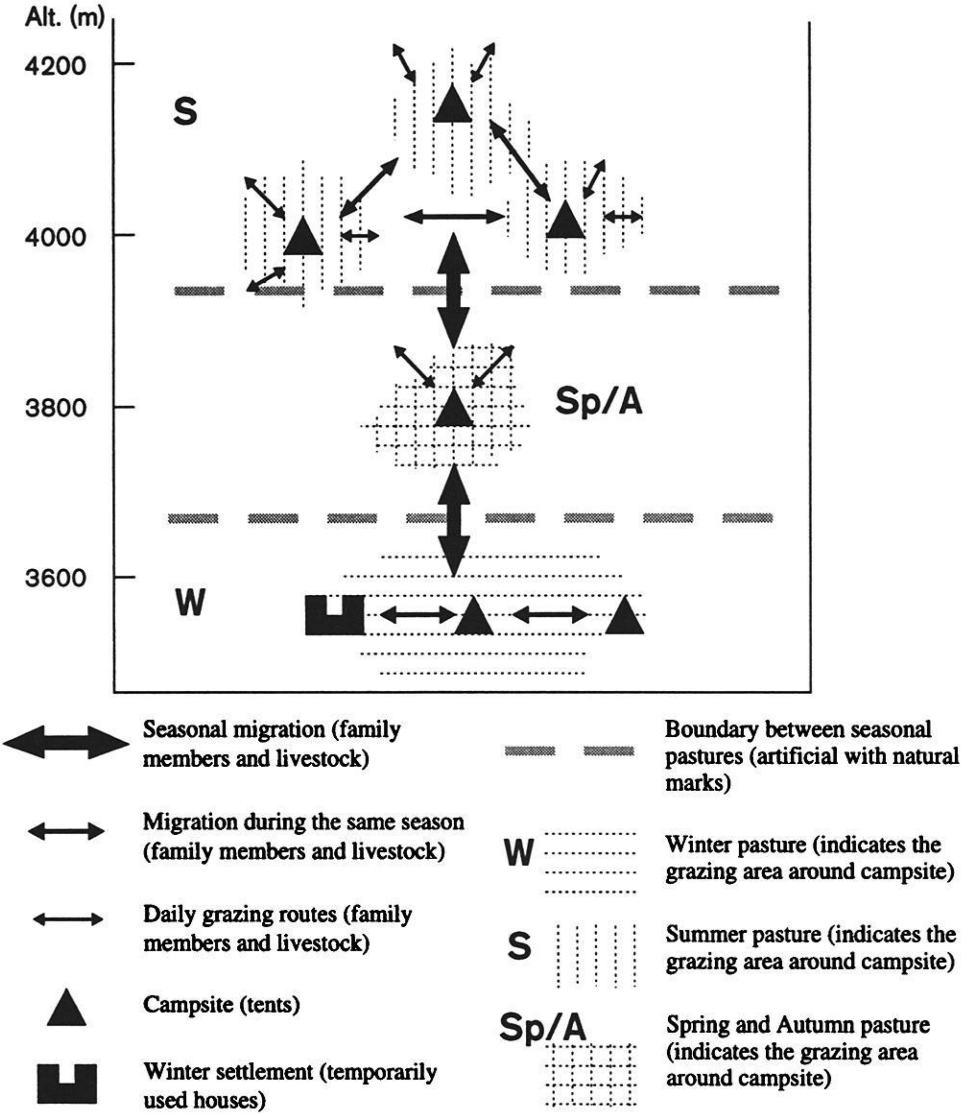

Fig. 5.8: Grazing Routes in Three Season Grazing System Represented by *Wache Xiang*, Hongyuan
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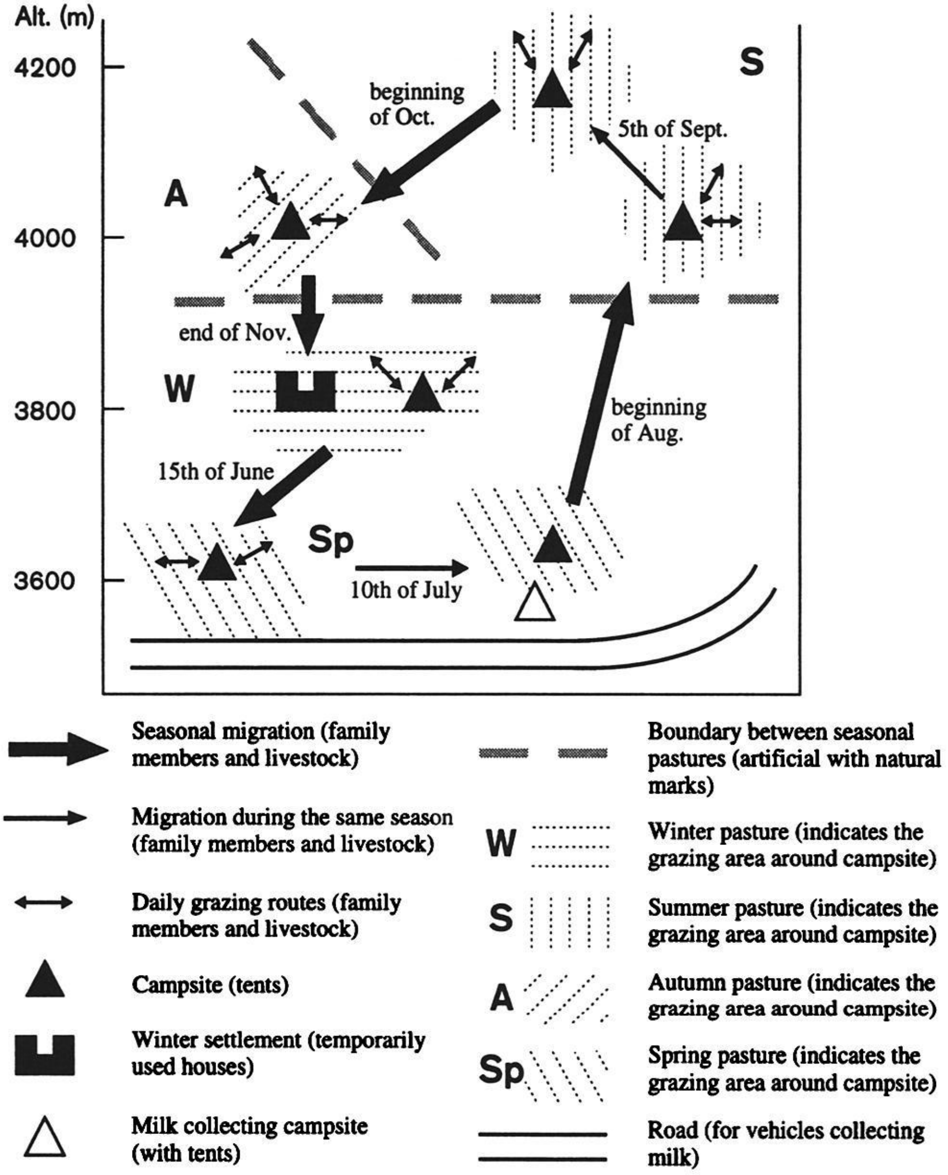

Fig. 5.9: Three-season Grazing System Adapted for Milk Sale Represented by *Anqu Xiang*, Hongyuan
Design: WU NING 1995

JAHNKE (1982) takes the position that pastoralists execute logical risk-averting strategies for livestock. Through the researches carried out in Africa (HÜBL, 1986; JANZEN, 1986; JANZEN, 1993) and in Mideastern Asia (SCHOLZ, 1981;1982), many authors take it as an undisputed fact that mobile livestock keeping is an *"optimum active human adaptation to the physical environment of arid and semi-arid areas, and is probably the only possible way of putting the barren pastures of these regions to economic use without an immense expenditure of capital"* (SCHOLZ, 1986:113). This fact is frequently not adequately recognized or taken into account by representatives of the urban elites of these countries, nor even by development experts. Instead, to suit the interests of the urban classes, priority in national development planning is usually given to costly and prestigious projects promoting productivity, industry and infrastructure. Neither government-enforced settlement programs nor technocratic pasture farming systems imported from the industrialized countries constitute appropriate development concepts for the nomadic zones of the world.

Rangelands on the Qinghai-Tibetan Plateau are ecologically heterogeneous at a variety of different spatial scales. Exploiting environmental heterogeneity could be thought of as the ecological reason for nomadic movement. MILLER (1990), in a vivid account of the rangelands of the Qinghai-Tibetan Plateau, regards the pastoral grouping and mobile keeping of yak as well-adapted responsis to different range and environmental conditions and ecologically sound and sustainable. BEHNKE stated:

> *"Locally, heterogeneity may be expressed in terms of the patchy distribution of pockets of high and low range productivity, up-slope and down-slope, on different soils within a single drainage system. At the other extreme, heterogeneity may be expressed on a regional scale in terms of soil moisture and fertility gradients which control the quality and quantity of forage production over vast areas, ..."* (1992:3)

In ecological terms, the exploitation of heterogeneity in pastoral society involves optimization of foraging through local strategies of habitat division and dispersal of grazing pressure. Quantitative and qualitative differences in grazing pressure through "space" and "time"[44] are maintained by herding strategies which take advantage of animal differences in diet and mobility, whether due to species, age or gender. These strategies do usually promote sustained-yield resource exploitation whenever land becomes scarce, and in particular when seasonal grazing sites are as far as inaccessible by any other ways.

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[44] "Time" means course and periodicity, and "space" means range and direction of wandering (SCHOLZ, 1991: 83).

It should also make more sense, on the other hand, to adapt autochtonously established land-use systems of mobile livestock keeping to the requirements imposed by changed ecological, socio-economic and cultural conditions, and to develop them further in modified form. Such strategy of exploiting variations in animal foraging behavior and local forage availability in order to maximize production itself implicates a dynamic balance in the adaptive process, and is also linked to ecological strategies that ensure future forage quality and pastoral productivity.

Although, there can be no uniform concepts that can be applied to all "nomadic regions" (the regional differences are too great), certain aspects do have supraregional applicability (SCHOLZ, 1991; JANZEN, 1993), and these should there be taken into account in development planning.

- There is the principal requirement to ensure the maximum possible geographical mobility for nomads, because the dispersal of animals limits the pressure of grazing on any one pasture at any one time and is the only way of guaranteeing the greatest degree of conservation of rangeland resources.
- For ecological and socio-economical reasons, rangelands in high-frigid regions or arid areas should be maintained or opened up by appropriate land-use practices. Although the resources are scarce, they are and still will be the available base to support local societies, and the animal husbandry potential based on these resources must also not remain unused.
- The intervention by governments in the nomads should be kept to a minimum. The fact should not be overlooked, however, that the infrastructural development of pastoral areas, for example, and the provision of corresponding services is barely possible without government financed programs.
- Apart from securing basic needs, low-cost measures aimed at promoting self-help should also allow for improving the possibilities for marketing the livestock. However, it should not be forgotten that the main factor that the migration of stock-owner was determined by the need for subsistence goods rather than marketing or economic plans, which implicate that in any development planning the problem of subsistence should be considered at first.
- Finally, one particularly important point is the preservation of the nomads' extensive traditional knowledge of their natural environment, but also of their skills in the breeding, keeping and care of their livestock. Indigenous Knowledge of nomads should be scientifically investigated so that they can be integrated in the practical planning and implementation of development projects (see 6.3.1 of this book).

5.2.3 Keeping enough Livestock - A Survival Strategy

In western Sichuan, or even all of the Qinghai-Tibetan Plateau, pastoral nomads rely for their subsistence upon their herds. Milk, from sheep and yak, provides food. Meat is only rarely eaten, when animals die or when they are slaughtered on ceremonial occasions; then hides or skins are also obtained. Wool and yak hair are important products, specially the latter is used to make tents, bags and ropes. Livestock are rarely sold, for they are the nomad's capital. About the number of animals kept by nomads, GRIGG (1974:113) argued that

> "*Most anthropologists have seen cattle numbers as giving an individual prestige and playing an important social role. But it can be equally well argued that the pastoral nomad is used to drought, and in Turkeskan and Mongolia, winter cold, destroying his herds. Thus the larger the herd the greater the chance of some surviving.*"

Although it not only limits on the Qinghai-Tibetan Plateau, but also is a worldwide phenomenon in the traditional pastoralism that the wealth of the nomads was judged by the number of animals possessed, the increasing of animal numbers cannot be only be understood as a projection of prestige or a indicator of social status. Probing further into the ecological connotation, more animals in fact provided extra insurance against deaths in times of harsh cold or drought which was also believed by many nomads.

As an insurance against constraint events pastoralists have to strive to increase stock numbers, in order to provide security in case of losses, to leave a remainder of feasible size, to rebuild his herd. Thus, the expansion of herd size in "normal" times, not stricken by cold, disease or unrest, is a survive strategy adopted by nomads worldwide, which is analogous to "*r*-selection" in bionomic strategy[45]. Although it is true, that parallel to increased numbers

[45] In terms of animal population ecology, the most dominant feature in the study of life-history strategies of a animal population has seen a tendency to divide suits of characteristics, and the environments with which they are associated, into two contrasting types: "*r*" and "*k*". Generally speaking, *r*-selected individuals attempt to maximize their fitness by improving their ability to reproduce rapidly in an uncrowded environment, whilst *k*-selected individuals maximize fitness by increasing their contribution to a population that remains at its carrying capacity. The *r*-selected population lives in an environment which is either unpredictable in time, or ephemeral, and it therefore experiences significant environmental fluctuations. In fact, yak, cattle, sheep or other domesticated animals, as a individual, belong to *k*-selected individuals rather than *r*-selected individuals. However, the term, "*r*-selection", is borrowed here to describe the strategy adopted by nomads against inconvenient nature rather than the individual adaptation. Furthermore, it mainly indicates the facts that under the harsh environment the population itself fluctuates widely in size, and juvenile and adult mortality-rates are unpredictable; The restoration of the population after natural hazards is dependent upon the number of population, which is because, with the proportion surviving remaining essentially unchanged, numbers-surviving increases with numbers-produced. Therefore, in order to keep the reproductive ability of pastoral society, nomads have to maintain the livestock number and increase it whenever possible, i.e. a number-dependent strategy.

of animals, an increased social standing for the owner will develop, this has to be seen as a favorable by product of an effort to safeguard future survival.

As the mentioned in Chapter two, cold stress is the most harmful factor to impact on the animal husbandry in the western Sichuan. Maintaining many stocks, therefore, must become an ecological strategy selected by nomads. Parallel to this, mixed herds, rather than herds of only one type of animal, also give an insurance against cold failure, which also means a traditional way to keep plant species diversity based on the maintenance of animal diversity.

Traditionally, risk-reducing adaptive strategies also include herd diversification and herd dispersion. Herd diversification is practiced as an insurance against major disease outbreaks since the different domestic species are generally not susceptible to the same pathogens. Beside this , the different dietary preferences of the various domestic species also allow for a better utilization of pastures that may not be suited for one or the other domestic herbivore species. As the mentioned above in 5.2.1, in western Sichuan yak are allowed to graze together with sheep and horses. Yak are versatile grazers, which will take a variety of different herbage and this ability contributes to a better utilization of the total grazing (CAI, 1992). Moreover, yak consumed a variety of forages avoided by sheep or goats, but these other ruminants in turn took large quantities of some types of browsing largely ignored by yak (CINCOTTA et al., 1991). With regard to the utilization of the pasture lands, care should be taken that this complementary grazing by a mixture of livestock species generally leads to a better overall utilization of the total grazing resource, and a sensible combination of various types of animals not only ensures that the vegetation is used sparingly and selective overgrazing is avoided, but also that the best possible use is made of the available biomass.

Herd dispersion is another risk-reducing strategy, which is frequently practiced in traditional systems. Stock owners in *Zamtang* separate their herds and have them herded in areas sometimes up to more than five kilometers apart; this is primarily a measure against forage shortages and raiding. If the family is large enough, the different herding units are managed by its members, and family reunions and rearrangements of the different stock sections take place during the favorable seasons. NYERGES said:

> *"The owner's function is to make decisions about herd size, species composition, sex ratios, age structure and migrations. If in a market economy the owner attempts to optimize the economic value of his herd (growth of capital and formation of a profit). If in a subsistence economy the owner attempts to optimize the ratio between human*

> *population and consumable herd products. This difference in economic goals will often be reflected in meat vs. milk production with concomitant differences in herd structure.*" (1979:10)

Curiously, in the Tibetan area the existence of the "communes" and "production teams" of earlier years is said to have maintained these attitudes more clearly than do households at the present day, both because they had no pecuniary advantage from the slaughter, and because money and markets were not the dominant force in a centrally controlled economy. In addition, CLARKE believed:

> "*In Tibet it is still held by those nomads in the remoter areas who have not been influenced to any great degree by the growth of markets in the past few years. These are people for whom the world is still constituted by goods rather than by commodities. Cash is seen by them as another item or good, rather than as a baseline medium of exchange and store of value.*"(1987:28)

It should not be neglected that there is a cultural resistance to the slaughtering of livestock, with strong Buddhist prohibitions against killing. This is admitted to have two main effects: first, the people who work on the government livestock farms try to take leave when the time comes around in Autumn for slaughter; second, the pastoralists themselves often do not cull the herd early in the season when the price is high, but hold on until much later, perhaps coming near to degradation of the pasture, and only at the end, in winter, when the price has fallen, do they slaughter the animals. However, another fact should also be remembered that live animal trade in western Sichuan as well as other Tibetan areas has never stopped (see 4.1.6 and 5.3.5 of this book) since historical times, which has become one of the mainly traditional measures to reduce grazing intensities and pastures' pressures during favorable seasons or normal years.

The nomadic group would always want to make maximum use of pastures available in a 'good' year, and to minimize the potential loss of animals by starvation during 'bad' years. Consequently, given the movement of people and animals from place to place, in fact, it is the people outside the nomadic societies rather than nomads themselves that relatively little attention has been paid to concepts of carrying capacity or dynamics of carrying capacity for various grazing grounds. A possible reason for this is that the considerable climatic variability experienced by these areas on the Plateau meant that it was never really possible to talk about a 'normal' year for a person outside local system. This, however, could be achieved by indigenous knowledge of alternative grazing resources.

5.2.4 Burning

Burning is possibly one of the oldest management tools used by farmers and herdsmen all over the world (BRIGGS and COURTNEY, 1985). Fire exclusion by man and its effect on the composition and character of the vegetation have been largely overlooked. Most ecological emphasis has been on fire-maintained vegetation such as certain rangelands, communities created by 'slash and burn' farming and on the effect of catastrophic conflagrations. (HOLZNER et al., 1983)

Today the use of fire is mainly confined to extensive rangeland, where its function includes the control of weeds, the restriction of vegetation succession and the control of woody plants. Burning is normally carried out under strictly controlled conditions and on a regular rotation. In most cases the private activity is prohibited in China.

The use of fire has a marked effect upon the vegetation in most cases. More susceptible species are eliminated directly, while others may be destroyed by increased competition from plants which are able to regenerate more effectively. In western Sichuan, it is believed that the decline of treeline and the extension of subalpine meadows on sunny slopes has been due to regular burning, which could provide more extensive winter pastures on this warmer location. When studying the deforestation in eastern Tibet, WINKLER commented the role of fire that:

> "*The deforestation of the past was not a blind destruction of resources. Moreover it was a consequent step in developing Eastern Tibet as a grazing land. Summer pastures above timberline used to be abundant in comparison to winter pastures due to the prevalence of forests in lower altitudes. Creating winter pastures through burning or using temporarily naturally deforested slopes was a prerequisite for fully using summers rich fodder availability. The sunny slope's pastures are of utmost importance to provide fodder for the animals in winter, since fodder availability in winter is the limiting factor for herd sizes.*" (1995: 6)

Forest fires are a widespread hazard in the forested region or agro-pastoral region (the transitional belt of forest region and grassland region) of eastern Qinghai-Tibetan Plateau. In *Zamtang* traces of forest fires were abundant everywhere, but seldom on the moist north facing slopes. The strongest impact of fires was on dry south facing slopes, which is similar to the situation in *Jiuzhaigou* reported by WINKLER (1994). Burning pasture land was a traditionally common practice among herders before the wave of modernization came so strongly upon them. In *Zamtang* and *Aba* local Tibetans confirmed that until recently south facing slopes were burned periodically to clear unwanted shrubs and trees which reduce forb and grass availbilities for livestock grazing. In this way, futhermore, sunny slope can provide more fodder for animals in winter, which reduces winter fodder storage to a minimum (LONG, 1994) and diminishes energy consumption for herders in the harsh winter.

Although it is known that herders used fire as a tool to create lush grazing for animals, little is known at present about natural fires in the pastoral area of western Sichuan. There can be no doubt that lightning has caused, and still causes, grassland fires. But little is known about their frequency and extent of the fires. Some data of a localized character indicate that naturally occurring fires, mostly caused by lightning, are not very frequent and usually form only a small percentage of all fires. Thus, YANG (1987) mentions that in western Sichuan 20% of the fires occur due to natural ignition by lightening and 40% due to intentional burning.

The greatest benefit of burning is probably derived from the removal of excess litter, and its conversion into nutrients provided that enough water is available. Burning at the time when least damage is done to the vegetation can thus result in stimulation of growth. LOOMAN (1983) thought that "Damage to plants is greatest when burning is practised during the early growth period, especially to those species that their meristematic tissue well above ground." (HOLZNER et al., 1983: 177) In western Sichuan where winter snowfall is important as a source of soil water in spring, burning in the fall can affect the vegetation indirectly. Burning of the stubble and standing carry-over reduces the amount of snow held, and increases drought susceptibility.

Nevertheless, the effects are not always as marked as might be expected. Several authors have suggested that burning represents an important cause of nutrient loss and might lead to a progressive decline in soil fertility and productivity. It is clear that the losses may not be rapidly replenished by inputs from rainfall or weathering, and in the absence of fertilizer inputs a gradual decline in the nutrient content of the system may occur. Furthermore, another main effect is erosion, both through wind and water run-off. Both forms of erosion can become severe and cause losses of nutrients in the form of ashes as well as soil. Whereas, DAUBENMIRE (1968) mentioned, a single burn may act as a stimulant through freeing of nutrients despite the loss of N and S as a result of volatilization, repeated burning followed by erosion depletes the soil.

BRIGGS (1985) further pointed out that the effects of burning upon the vegetation and soil depend to a large extent upon the temperature of the fire and its duration. These are influenced by factors such as the age and density of the bush, the moisture content of the vegetation and soil and the windspeed. He stated:

> *"Uncontrolled fires whose temperatures can reach 900°C or more destroys the root-stock and inhibits regeneration, and, in turn, may lead to soil erosion and extensive damage to the pastureland. However, under controlled conditions, maximum temperatures do not usually exceed 300°C, and the severity of the burn is much less; often parts of the woody stem of the bush survive along with the surface cover of lichen or mosses."*(BRIGGS and COURTNEY, 1985:150)

The key problem for nomadic society, viewed from these points, is how to control the frequency and extension of burning other than the prohibition of this indigenous action. Effects of fires in a given type of rangeland depend on several factors, such as time of season and frequency of burning, condition of the pasture, weather conditions at the time of burning and the habitat type. Each of these factors alone exerts a certain influence, and combinations of two or more factors can increase the intensity of the effect, or ameliorate it. The damaging effects can not be thought of as the direct result from burning actions of herders. Of course, the effects upon the present vegetation partten can also not be denied, specially in the shift of the natural ecotone between grassland and forest and the formation of open woodland meadow (open park-like stands).

5.3 Modern Development - Chance or Crisis?

Traditional pastoral production systems have remained stable for a long time, particularly through flexible responses to short-term variations of the climatic conditions. Today, however, numerous demographic and economic changes of long-term nature occur which trigger adaptive changes likely to transform this system significantly. The most salient feature is an emerging precedence of market oriented production and the modernization over the traditional subsistence production.

To prevent the degradation of rangeland, range managing techniques were introduced that allow desirable forage species to be grazed but not destroyed. While this can be accomplished fairly easily under private ranch conditions, it is much more difficult where the areas to be managed are vast, the range resources are publicly owned, and the animals are owned individually by semi-autonomous producers. Nevertheless, most projects in the pastoral zone are considered as a precondition that some methods could be devised for introducing collective control over range resources. This is held to be especially important when the project is designed to improve animal health and nutrition and thus potentially will increase livestock numbers and the incidence of overgrazing. Although improved marketing opportunities might result in greater off-take, and thus ameliorating the overgrazing situation somewhat, this effect is thought to be lessened to the extent that animals are held as a store of wealth rather than simply for their value in commercial production.

The governments of state and province have paid great attention to the modernization of the pastoralism in western Sichuan. Since 1960s some large scale scientific surveys and development projects have been organized and carried out in this area and much valuable data has been collected. From 1976 to 1982, some research institutes and experimental stations were established, such as the Sichuan Institute of Grassland, Animal Husbandry and Veterinary Institute of Garze, and grassland experimental stations in each county.

Since 1958 an attempt had been made to stabilize the nomads. Permanent building for livestock had already been established, and ownership of livestock had become communal rather than individual. After the 1970s, under the *Gongse* (people's commune), attempts were made to grow forage crop for winter fodder, veterinary facilities were made available, and winter livestock shelters were constructed. The livestock were also allowed to be pastured on state land, but seasonal movements to pastures were still allowed and made. In effect an attempt has been made to convert nomadism to a ranching system, or so-called "modernization" of animal husbandry, but the economy is still essentially nomadic. After 1978, mainly from the beginning of the 1980s, communal livestock were divided again between families, but the tenure of pastures still belong to the state and were not divided, which left a shadow of ecological crisis looming large in the high-frigid meadows and finally become the one of most important factors leading to the overstocking and overgrazing. Since the late 1980s has there been a move towards conservation policies and attempts to adjust stock numbers to the land's carrying capacity. But such attempts have often foundered on the refusal of the nomads to cull their herds to the level which governments hoped. From the end of the 1980s the trend to settle nomads became apparent and many so-called "integrated programs" meaning to construct the infrastructures and permanent settlements for nomads were carried out in the pastoral area.

However, modern management techniques have been employed in western Sichuan, in general, aimed at:

- Encouraging grass growth (e.g. ploughing, fertilizing);
- Controlling animal behavior (e.g. fencing, sedentarization);
- Harvesting the products (e.g. mowing, ensiling); and
- Promoting the commercial production (seasonal culling out).

5.3.1 Enclosure of Rangelands

In China, the enclosure of rangelands appeared at the beginning of the 1960s, when it was only used in cutting pastures in order to supply winter foodstuff to domesticated animals. In the last two decades it has been utilized to delimit the pasture's boundary, enclose degraded pastures or abandoned fields for forage cultivation, divide pastures for rotation grazing and defend it from the invasion of wild predatory animals.

In western Sichuan, as well as in all of the Qinghai-Tibetan Plateau, the enclosure, as a managing technique, was introduced in the end of 1960s. At that time pastures were mainly enclosed with the fences which consisted of local materials, such as soil wall, turf wall and stone wall. From the beginning of 1970s, thorny iron-wire (barbed wire) has been used gradually in this area. In the 1980s, since the manufacturing line of netted fence was introduced by Inner Mongolia from western country. (TIST, 1992) Netted fence consisted of iron wires was rapidly popularized on the Plateau. The following paragraphs will describe the main kinds of fence which are commonly found in the western Sichuan.

a) Soil Wall

This kind of fence mainly appears in the nomadic area of Northwestern Sichuan, such as *Serqu*, *Serta*, *Zamtang*, *Aba* and *Hongyuan* counties, and requires the soil without too much sand, which can be used for about 5-10 years. Its advantages are that the material can be collected nearby and fence small areas, such as the stalls, pens or artificial pastures around winter houses, and can preserve heat in winter. Owing to the excavation of soil on the pastures, it led to the direct destruction of the vegetation cover of pastures, which further led to erosion easily by wind or rain. Thus it has been abandoned in most areas, and only in the remote areas where other material is difficult to collect. Based on the measurement in *Shang Zamtang Xiang*, Zamtang, generally, the height of the wall is about 140 cm, base width is 80 cm and top width 40 cm (Fig. 5.10).

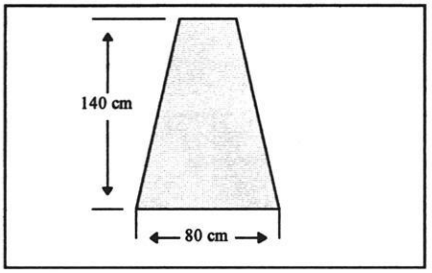

Fig. 5.10 Schematic Structure of Soil Wall
Design: WU NING

b) Stone Wall

This kind of fence consisted mainly of stone and pebble can be found easily in agro-pastoral areas, which was used by herdsmen to built up winter shelters for livestock. Not only its materials can be collected easily, but also stones or pebbles scattered on the pastures can be cleaned out through this activity. Soil or peat are always mixed with stone or pebble, so its duration is as long as about 20 years. The height of wall is about 140 -160 cm, base width 80 cm and top width 40 cm (Fig. 5.11).

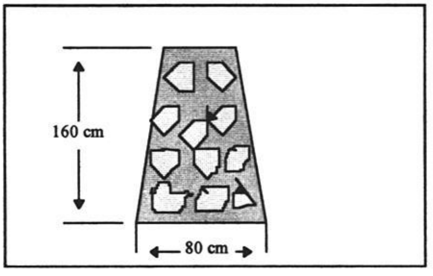

Fig. 5.11 Schematic Structure of Stone Wall
Design: WU NING

c) Turf Wall

This kind of fence constructed with turf is mainly found on the alpine meadow, such as in *Hongyuan* and *Zoige* counties. Because roots of herbaceous plants in turf can develop abundantly into a complex net again, this fence will become very steady and can be used as long as 15 years or more. However, the collection of turfs from pastures always led to barren patches on the rangelands, which need at least 20-30 years to restore again, and in the end result in the heavy destruction of the range vegetation, thus it has been objected to by scientists and its use stopped in many places. In *Hongyuan*, for example, turf wall was used to enclose pastures on a large scale in 1970s under the encouragement of governments in order to sedentarize nomads and promote the "modern" management of rotation grazing. In the end this led to the waste of remote pastures and the overgrazing or even degradation in the fenced pastures. At the beginning of the 1980s, centrally collective management collapsed, these walls were abandoned and now only the relics can be found in this County. At present this kind of wall is still used by herdsmen occasionally as the fence of winter stalls, where other material is difficult to find, but it is always combined with stone or soil (Fig. 5.12).

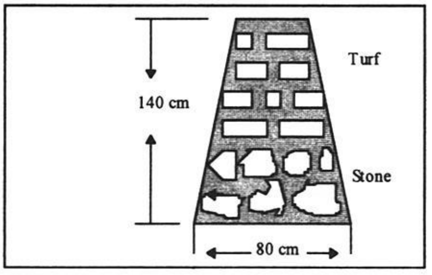

Fig. 5.12 Schematic Structure of Turf Wall Combined with Stone
Design: WU NING

<u>Barbed Wire Fence</u>

This kind of fence constructed by barbed wire and cement or iron pole has been mainly used by governments or administrative units to enclose pastures for purpose of artificial pastures building or forage cultivation since the 1970s (Fig. 5.13). With the introduction of netted iron-wire fence in the 1980s, it has been substituted and only some, which was built up years ago, can be found.

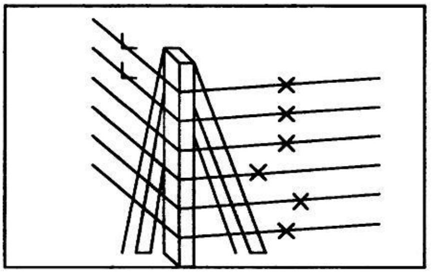

Fig. 5.13 Schematic Structure of Barbed Wire Fence

Netted Iron-wire Fence

This kind of fence has been popularized in western Sichuan, as well as other pastoral areas on the Qinghai-Tibetan Plateau, which mainly used to replace the old thorny iron-wire fence. It was made and assembled by the manufacturers and installed by purchasers themselves. It is easy to be installed and can be used for a longer time (Fig. 5.14). However, it also mainly used by administrative units rather than local herdsmen, owing to its cost, techniques, and mainly to its impracticability in the nomadically grazing styles.

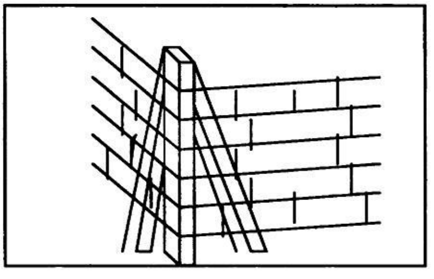

Fig. 5.14 Schematic Structure of Netted Iron-wire Fence

Increases in the pastoral population and the simultaneous losses of communal pastures are leading to a reduced mobility and the closing pastures. *Zamtang* County, for instance, has 1,000 hectare of fenced grassland, most of which are the pastures enclosed on cold season grassland. These measures were introduced in the 1970s. Following the introduction of the right to use cold season pastures, many herdsmen have been encouraged to re-build these fences with state subsidies.

From a biological standpoint, the construction of fences is undoubtedly beneficial to the growth of grasses. After the regeneration of grass, the fenced pastures were greatly improved in the physico-chemical characters of soil, the quality of grass and vegetation structure. Furthermore, if the enclosure of rangeland is only on a small scale, such as fencing the winter pastures on the bottom of valley as hay meadow, it will be helpful for the aleviation of the shortage of winter fodder. In the field work of 1992, we chose a fenced grassland, which closed by the Grassland Experimental Station of *Zamtang* County one year earlier, as our working plot. With eight quadrats of 1 square meter inside and outside fence separately, the grass yield and the variations of plant composition were measured and analyzed (Table 5.6).

As the Table 5.6 shows, the grass yield in the first year was greatly increased and was 32.34% higher than that of the unfenced grassland. The content of legume increased by 57.10%, *Graminae* grasses by 6.7%, *Cyperaceae* grasses by 49.1% and forbs by 37.0%, but poisonous weeds decreased by 44.6%.

Table 5.6 Comparison of Fenced and Unfenced Pastures in Zamtang

Kinds of Grasses	**Fenced Pasture**			**Unfenced Pasture**		
	Coverage (%)	Grass yield in quadrat (g/sq. m)	Grass Yield (kg/ha)	Coverage (%)	Grass yield in quadrat (g/sq.m)	Grass yield (kg/ha)
Legume	4.0	33.0	330.0	3.0	21.0	210.0
Gramineae	9.5	95.0	949.5	7.5	89.0	889.5
Cyperaceae	39.5	317.5	3175.5	35.0	21.5	2125.5
Forbs	40.5	264.5	2644.5	34.0	193.1	1930.5
Poisonous	1.5	20.0	199.5	2.5	36.0	360.0
Total	95.0	729.9	7299.0	82.5	551.6	5515.5

Another example was observed in the alpine meadow and pastures in the wide valley in *Hongyuan* (Table 5.7). From this table we also can find the changes in the community structure and plant composition.

Enclosed range areas, although there are slightly higher potentials than the open range, are not immune against diminishing range condition, specially in the practical grazing management or enclosing on a large scale, since stocking densities are rarely matched to the carrying capacity but rather to the needs and demands of the stock owners, which often results in overstocking. Additionally, erratic spatial distribution of precipitation or unpredictable snowstorms during certain seasons or years may reduce forage growth in some enclosed areas and lead to temporary but severe overstocking and irreversible degradation. This may be aggravated if the breakdown of traditional resource-sharing attitudes in the pastoral system prevents emigration of herds from fenced lands. For example, in the 1970s large scale fences were set up in *Aba, Hongyuan* and *Zoige* counties, with a closed area of thousands of hectares, which not only were not beneficial to the rangelands in the long run, but also finally led to the degradation of pastures and partly to the denudation in these counties.

Table 5.7 Comparison of Fenced and Unfenced Pastures in Hongyuan
Date: Aug. 17, 1991; Site: *Longzam Xiang*

Type		**Plant Composition**	**Coverage (%)**	**Height (cm)**	**Grass yield (kg/ha)**
Alpine Meadow	Unfenced	*Kobresia setchwanensis* *Carex sp.* *Potentilla anserina* *Oxytropis ochrocephala* *Rumunculus brotherusii*	65	3 -5	1,275
	Fenced	*Kobresia setchwanensis* *K. capillifolia* *Roegneria nutans* *Festuca ovina* *Koeleria cristata* *Elymus nutans* *Poa pratensis* *Anaphalis flavescens* *Polygonum viviparum*	95	15 - 20	3,375
Subalpine Meadow	Unfenced	*Kobresia setchwanensis* *Poa pratensis* *Anemone geum* *Laminophlomis rotata* *Stellera chamaejasme*	60	14 - 35	1,169.6*
	Fenced	*Kobresia setchwanensis* *Roegneria nutans* *Koeleria cristata* *Elymus nutans* *Festuca ovina* *Anaphalis flavescens* *Leontopodium sp.* *Taraxacum dissectum*	95	15 - 45	7,728.6

Key: * The yield of poisonous or unavailable plants is 469.5 kg per hectare, which accounting to 40.14% of the total.

Furthermore, enclosed pasture involves heavy capital investment in landed improvements, as BEHNKE (1984: 264) stated, which are attractive only if rangeland is privately owned in a ranch system. These capital investments make possible technical innovations (such as fodder production, pasture rotation, improved watering facilities, etc.) which are required to meet the higher standards of husbandry demanded by high-yield breeds of livestock. In return, the higher productivity of these breeds is able to pay for the expense of their rearing. Although fenced pasture has substituted commodity production for in-kind production and heavy capital investments for pastoral investments in human labor, it hardly established effectively in a nomadic system the first aim of which is subsistence.

5.3.2 Sedentarization

Sedentarization indicates a changing process from a more nomadic to a less nomadic way of life, from a nomadic to a more sedentary way of life. (SALZMAN, 1980) Although it is a process occurring with varying frequencies in virtually all contemporary nomadic groups, there is every indication to suggest that sedentarization processes are of great historical depth, that nomads, singly and in groups, have been repeatedly drawn into non-pastoral activities. In fact, nomads have been settling and resettling themselves repeatedly throughout history. (ARONSON, 1980)

On the Qinghai-Tibetan Plateau nomads also settled themselves or were settled by other nationalities during historical periods when they constituted the dominant military or political force in this region. It is possible, of course, that the relative political or military importance of nomadism to the sedentary society into which some nomads, for one reason or another, decide to settle has no significant effect upon the social and economic forms of being settled. Sedentarization of nomads accompanied almost all of the their developmental history. The earliest record of settled themselves could be traced back to the sixth century (SHI, 1994) During the seventh and eighth century, when the first Tibetan kingdom "*Tubo*". expanded from the Plateau to the peripheries, nomads began to settle themselves in the contacting area with the sedentary society and this phenomenon was not suspended afterwards. However, it should be added that this kind of sedentarization was never present on a large scale and did not constitute a uniform social phenomenon in historical times. It seems more than likely that the different circumstances of nomadism in earlier times produced still more varieties of sedentarization. The first historical record about which nomads on the Qinghai-Tibetan Plateau were forced to settle on a large scale, could be found in the first half of eighteenth century. When Qing Dynasty in 1720 - 1724 conquered the rebellions in Qinghai, nomads were settled and the boundaries of migration were delimited. (SHI, 1994)

However, do the historical examples of sedentarization illuminate modern examples? In fact, the reason of modern sedentarization is not similar to the historical, which always forced by the market orientation of government. The modern sedentarization, with regard to its scale and depth, is much more significant than the historical in the effects upon environment and socio-economics. In western Sichuan the modern sedentarization of nomads occurred at the end of the 1950s, but mainly was popularized in the 1970s. It can be further divided into: 1) sedentarization, i.e., stabilizing nomads in permanent settlements in order to build up a ranching system, such as some examples in *Hongyuan*; and 2) semi-sedentarization, i.e., in the cold season (winter and spring) nomads (excluding semi-nomads) with their grazing animals settle themselves in cold season pasture where there are fixed winter houses, but in warm season (summer and autumn) they migrate to pastures which are always far away from the winter settlements, which in fact is a kind of change from nomadism to semi-nomadism, and more popular than the former in this region.

In semi-sedentarization the grazing system with seasonal rotation is preserved, and pastures are divided into different sectors, which means that it is easier for administrative units to control the utilization of communal pasturelands and nomads' seasonal migration. In this way they try not to destroy totally the mobility in a certain extent. The main merits are shown in the following:

a) Improving the livestock productivity

Under the traditional pastoral management, a great number of the environmental constraints are known and various means to reduce the effects of these constraints are well tried. However, the productive potential of herds is rarely fully utilized due to private ownership and individual management. After semi-sedentarization routine animal health programs are more easily applied.

With the construction of settlements in cold season pastures, there is a strict line between two kinds of pastures, and the cold season pastures are prohibited to be used in warm season, this protects the regrowth of grasses there. Around winter houses artificial pastures are developed, in which herdsmen can plant some grasses or other forage with high quality and high yield so as to provide foodstuff to animals in winter or spring.

b) Beneficial to livestock surviving during cold seasons

The winters are so cold on the Plateau that a yak of 250 kg will lose 87.8 Kcal of heat energy if it travels one kilometer. (CAI, 1990) To offset this hazard, wintering and windshields were built up to reduce heat loss and improve the survival rate of the newborn.

In practical terms in Western Sichuan, there have been fences, stalls, pens or shelters for livestock in almost all of pastoral areas, which provide safeguard against the severe cold and great snow for domesticated animal in winter, and diminish mortality in spring. An example is sheep breeding in spring. Before the sheep give birth, they are driven to specially prepared pastures, which are assigned on the leeward and south facing slopes, on the terraces, or flat valleys with luxuriant grasses, in February, March or April. It has been found that in *Hongyuan* County the experienced herdsmen in a family or a productive group are always appointed to manage and utilize these particular pastures due to their importance in the sustainable use for livestock's reproduction.

c) Promoting the infrastructure and raising the living standards

It is common practice to talk about carrying capacity in connection with grazing animals. In a pastoral economy where animal numbers should be in a stable proportion with the number of people whose subsistence requirements have to be met, the same term has to be applied to the human population. At present the human support capacity on the Plateau is grossly exceeded (see 1.2 and 4.1.1 of this book). Since neither primary productivity (pasture) nor secondary productivity (livestock) can be easily improved, it is of the highest importance to relieve the pastoral systems by developing alternative means of livelihood in the non-pastoral sector of the national economies. After the sedentarization, the infrastructure can be improved greatly, such as hospital, entertainment facilities, schools and shops, which further raise the living standards of nomads.

Generally speaking, sedentarisation may offer opportunities for improved land management, permanent investments in land productivity and the application of innovative technologies. Small favored areas in the range lands such as run-on areas and drainage lines may be used for forage and/or food crops, agricultural by-products may become available in increased amounts to stabilize feed supplies during the cold seasons, deferred grazing systems and small scale harvesting schemes may be feasible for specific groups such as enclosure herders and range livestock associations.

On the other hand, the changes from a long ranging and highly mobile herding system to a short-range and semi-sedentary one bears the potential for both negative and positive effects. Amongst the most obvious negative effects are:

- Increasing risk of environmental degradation

Sedentarization is always accompanied by the enclosure of pastures. The emerging trends toward short-range herding systems have definitely deleterious effects on range vegetation and soils. Severest impacts are found around permanent water sources and in the immediate vicinity of permanent settlements, though they are limited spatially to a small section of the total range at beginning. Grazing pressure on the residual open range is becoming exhaustive, and migrations have to be rerouted. Some migration routes may be closed permanently, thus increasing pressure on others. Furthermore, since areas with higher potential are usually enclosed first, the residual open range areas possess lower support capacities and are prone to faster degradation.

- Increasing production risks for the individual herd owner as well as for the industry as a whole due to disappearance of traditional adaptive management strategies

One of the main purposes of settled nomads is to maintain adequate stocking rates and to practice some form of grazing rotation. If pastoral areas are sparsely populated and include access to reliable cold-season pastures, this presents no problem. Neither of these two conditions can be met at present. Under the condition of centrally controlled economics, long-term protection of larger range areas is impossible to achieve without a large police force. However, compulsory destocking, which has been suggested frequently in the past, would further reduce the already narrow base for subsistence of the pastoral population and reduce the enthusiasm of nomads, specially when they have survived in a traditional social structure.

It should be stressed again that pastoralists are nearly all engaged in multi-resource economies and pastoralists' economic strategies are geared not just for current production but for the long-term security of that production through quite severe environmental fluctuations. The lessons that nomads have learned through bitter experience in hard lands will not be abandoned easily. Consequently, since pastoralists have their own systems of health control, breeding, insurance coverage, range and water conservation and the like, there can be little doubt that improved methods will find acceptance among them as long as they are compatible with ongoing schedules and routines. Until now, in fact, very little solid information is available as to whether such inputs can be paid for with the anticipated increases in pastoral production.

- Accelerating the breakdown of social structures which previously served as a form of social security system within herding communities

To understand sedentarization, one must view it as a particular kind of change, defined by its substance, but exemplifying a more general process, the process of socio-cultural change (SALZMAN, 1980). After all, left to their own devices and the vagaries of their environments, societies change all the time, self-initiating even quite profound transformations. Traditional mobile livestock keeping is founded upon a traditional social system, which secure the realization of multiple goals that pastoralists pursue rather than only economic goals.

Governments have thought, perhaps, that they could trade a stabilized feed and water supply for their pastoralists through sedentarization in order to improve the output of pastoral products. However, it oversimplifies the diversity of real situations and undoubtedly neglects some of that diversity in a pastoral society. Nomadic economics requires distinguishable strategies for short-term productivity and longer-term insurance. Moreover, pastoralists also use their animals to acquire prestige, influence in their societies and other purposes. All of these are not strictly justifiable on economic grounds alone. A nomadic society responds in its entirety to the change of environment and the availability of resources. Every attempt by which only part of a system is changed will lead to unbalance in whole system.

5.3.3 Cultivation of Forage Grasses and Supplementary Feeding

Shortage of fodder in winter and spring grazing is one of the main constraints on increasing the production of livestock. In order to realize the appropriate location of animal husbandry and to construct the production bases, the germ plasmas of grasses have been taken as a very important factor for animal production. In western Sichuan, research on forage breeding for the environment of high altitudes is continuing, with indigenous and exotic species. Since the 1960s, more than 200 varieties of forage plants, belonging to 16 families, 49 genera and 98 species, have been collected or introduced, and tested in the pastoral areas of Sichuan (DU, 1986). As mentioned by scholars (HEADY, 1975) the best forms of production are coming from the optimum combination of the germ plasmas and the ecological environments. In the light of problems care has been taken about the following measures that can be designated in western Sichuan (1) introducing; (2) protecting, and (3) improving.

Since the 1960s introductions of valuable grass have been carried out in western Sichuan, and many grasses have been selected and identified suitable in this area, such as Smooth brome (*Bromus inermis*), Wildrye (*Elymus nutans*), Siberian wildrye (*Elymus sibiricus*), Common oat (*Avena sativa*), *Trifolium pratense,* Alfalfa (*Medicago sativa*) and Turnip (*Brassica rapa*), etc. Of Smooth brome, with the long green period (225 days) the grass yield is as high as 22-37 tons per hectare, and with good quality, ratio between leaf and stem being 1:1 and high nutrient content (10-13% of crude protein), palatability for ruminants is very good. Its mature seeds are very difficult to collect in the area with the altitude above 3,500 m, but its roots can be used for propagation. In the area where the altitude is about 3,000 m, its mature seeds can be harvested. Therefore, a seed base has been established in *Shua-jin-shi* District of *Hongyuan* County, the only one agro-pastoral district of this County, in order to supply seeds for the pastoral area. The cold resistance of Siberian wildrye is strong and its mature seeds can be collected in many areas. The seed production is about 600-1,100 kg per hectare. This kind of grass was planted in *Zoige* County in large areas with the grass yield of about 19 tons per hectare. The weight of its leaves accounts for 37.37% of the plant's total weight. During its flowering period, the crude protein content is 9.3%. It has been mainly used for the artificial cutting pastures in northwestern Sichuan.

Some indigenous grass species has also been improved for this purpose, such as *Elymus breviaristatus*, which is mainly suitable for the artificial cutting pastures, and Red fescue (*Festuca rubra*) and Sheep fescue (*F. ovina*), which have been used for the rehabilitation of degraded pastures. The yields of these grasses are generally more than 15-22 ton per hectare and their mature seeds can also be collected in the high altitude areas. Turnip (*Brassica rapa*) is a kind of indigenous and popularized succulent forage in pastoral or agro-pastoral area, which is always planted near the winter houses and provided for winter fodder. In *Hongyuan* and *Zoige* its yield is as high as 22-30 ton per hectare, or in temperate areas, i.e. agro-pastoral areas, its yield is as high as 50 ton per hectare. In Aba Prefecture the seed production is concentrated in the area of below 3,000 m.

Generally speaking, under the adversely climatic conditions and due to the rugged terrain, it has been difficult to replant pastures or to establish new ones. However, it is possible to take advantage of micro-climates in certain localities to plant forage grasses. Common oat (*Avena sativa*) (simply called oat in the following text), the fresh yield of which on average can get as high as 58 tons per hectare, was introduced to *Zamtang* in 1978. Having been tested for a long time, it has been planted popularly in this County and accepted by herdsmen progressively. In the autumn of 1991, 40.5 tons seeds and 200 tons oat hay were harvested in the 30 hectare trial pastures of the Animal Husbandry Bureau of this County.

Among these, 21 tons seeds provided to pastoralists for the purpose of winter forage planting and some hay present to *Romda Xiang*, resulting in only 8% grazing animal deaths from the cold in the spring of 1992 (comparing to the mean 13.5% of whole county). Consequently, with the increasing of participating enthusiasm, the county government in 1992 encouraged every family to plant 0.2-0.35 hectares oats around their winter houses for the animal feed in winter.

In *Zamtang*, as well as other counties in this region, *Cao-si-zhan* (grass and forage station)'s principal role is, of course, grass introduction, seed multiplication and extension work. Even in 1985 none had been distributed due to the nomadic traditions. In 1987 and 1988, 10 tons seeds were distributed free by the staffs of this station and even brought to some voluntary families. Through the cultivation around the winter houses or in winter pastures, especially through several strikes of snowstorm in the following years, the pastoralists who have sown oats got the benefits from this activity, and the pastoralists who have not saw its advantages. After 1990 more and more pastoral families bought forage seeds voluntarily from this station. People's participation further improved the introduction and distribution of forage plants. From 1993 onwards, owing to the demand of so many pastoral families to enlarge the cultivated area themselves, county government had to purchase seed from Gansu and Qinghai provinces to supply the shortage locally.

Having finished the discussion of grass introduction and distribution, some problems concerned with them should also be mentioned here. In *Zamtang* around thirty hectares of trial pasture in 1993 were to be planted with improved seeds from the Animal Husbandry Bureau of the County or directly from the prefecture seed multiplication unit in *Barkam*, using an ammonia based fertilizer. But the costs of fertilizer make the benefits of its use on pasture debatable. Furthermore, in conditions of drought the present hybrids either die or revert to their original natural form; they tend not to breed true above around 4,000 to 4,500 meters, but degenerate back to their natural form. The indigenous species, while of course they do not die in seed form and will germinate in the following year, they can not grow without water, and their seeds are difficult to collect and to improve on a large scale. Although many efforts have been made in western Sichuan to introduce legumes, it must be said that none has been successful. The broad leaves of legume are susceptible to harsh climate, specially to hailstone, which can even strip all of the leaves from a plant during its growing period.

Supplemental feeding is another important practiçe particularly when animals receive feed below the requirment for maintenance during the long cold season. Crop residues are locally available either in the mixed crop-animal operations by the semi-nomads or neighboring settled cultivators. However, this strategy requires much improvement in order to minimize competition for human consumption. Traditionally, hay-making has not been adopted by nomads in pastoral areas, although it has been the main method of conservation in agricultural or even agro-pastoral areas. In the last three decades, however, with the promotion of local governments, this practice has been popularized in some pastoral and most semi-pastoral areas. In pastoral areas, where there are not enough arable fields for crops cultivation, hay mainly comes from the cut natural grasses and the cultivated forage grasses. On the contrary, in the semi-pastoral areas (agro-pastoral areas), where there are cultivated lands near winter houses, hay is mainly composed of planted forage and crop residues. The market exchanges of fodder between agricultural areas and pastoral areas have taken place occasionally, but most of them are tinged with governmental influence.

This method describes, in fact, a situation in which farming and pastoralism are closely integrated, either through market exchanges or mixed systems of agro-pastoral production. With the exception of improved supplies of purchased feed supplements, the management improvements suggested here require to be controlled by livestock keepers of high potential in areas which will respond favorably to intensive management. In this case, pasture development involved a concentrated investment of labor and capital on small but very productive sites, rather than the dispersal of resources and management over large grazing areas of relatively low potential. All of these, in fact, also imply that supplementary feeding or forage cultivation is difficult to be carried out in whole pastoral area of western Sichuan. Moreover, it should not be forgotten that the artificial maintenance of high stock numbers may have long-term deleterious effects on the condition of the natural range.

> "*Policy makers and administrators may instead strive to maintain the ability of herd managers to 'track short term swings in feed supply by responding quickly and flexibly to unpredictable events. Effectively tracking fluctuations in rangeland productivity would require the ability to rapidly destock and restock rangelands, the provision of feed supplements to cover temporary shortfalls in forage production from natural rangelands, ... which will dampen the economic impact of unavoidable environmental fluctuations.*"(BEHNKE, 1992:3)

It should also be considered that conservation as hay requires drying of the grass to a moisture content of 25 percent or less in order to suppress fungal or bacterial decomposition. When drying is carried out in the field , this process is highly dependent upon weather conditions and labors in a family. Thus, in most cases, only the residues of barley are stored as hay. In additions, silage-making practices have been seldom used by local people until now due to its complicated techniques, only in *Hongyuan* some examples can be found which were guided by government experts.

5.3.4 Strengthening of Veterinary Services and Disease Prevention

Improved animal health conditions are especially critical among young animals. Owing to the importance of yak in the pastoral production of western Sichuan, many researches in the diseases of yak have been carried out since 1960s. Yak are prone to most of the diseases recorded for cattle world-wide (CAI and WIENER, 1995). However, information on the losses of production from disease are not readily available, though the consequent economic loss could be high. Some records are kept at animal husbandry and veterinary stations of annual mortality, and clinical cases are recognized by herdsmen.

In *Zamtang*, veterinary services and epidemic prevention program have been improving gradually since 1959. In 1970s veterinary stations were set up in every commune, which at present are kept continuously by every *Xiang*, and some nomads were trained as veterinarians. Cattle plague and anthrax have now been eliminated. The current problems include internal and external parasites such as liver rot, mange, and warbles. These affect the health of the stock as well as the quantity and quality of animal products. For example, 70-80 percent of the yak hides originating in *Zamtang* have holes caused by cattle grub. Currently, the County offers antihelmintic treatment for all animals in spring and autumn each year.

Although some successes have been obtained in disease control, it appears that the incidents of some of the diseases may be also high in western Sichuan and this is attributed mainly to lack of economic incentive for prevention and treatment in many cases. Meanwhile, vaccines and other prophylactic measures, as well as curative treatments, are not widely used even when they are indicated and are known to be effective (CAI and WIENER, 1995). Looking into the reasons, one could find that several factors, including the remoteness of much of the grazing territory, the low-cost effectiveness of treatment (especially as treatment costs may often be relatively high) and the traditional nature of much of mobile livestock keeping, contribute to the general paucity of treatment of disease. After the economic reformation carried out in China at the beginning of the 1980s, specially the privatization of livestock in pastoral areas, veterinary system was affected to a certain extent. It can not be denied that successful seasonal vaccination campaigns and disease control measures by the veterinary authorities have resulted in an explosion in the number of animals in some areas. Therefore, the improvement of veterinary system should be accompanied by the more rapid rotation of livestock and more effective marketing system.

5.3.5 Marketing of Animal Products

It should be kept in mind that the traditional strategies which modify herd structure include trade, capital accumulation, and the production of secondary animal products such as wool and skins. Therefore, the owner also tries to track and exploit major regional, seasonal and year-to-year fluctuations in resources in order to optimize herd productivity through strategies of maximizing potential reproduction and optimizing potential mobility. On the other hand, if in a market economy, the owner's attitude towards conservation of renewable resources may be (but is not necessarily) that short-term degradation through overstocking is permissible if a profit can be made and rapidly converted into other capital. However, in a subsistence economy, managers will be more likely to track environmental variations closely without serious overstocking being a frequent occurrence, because under these conditions it may not be possible for a herd owner to reap a profit and then convert stock into other equally usable resources. Close tracking of resources may equally be due to mechanisms such as animal starvation, disease and theft.

The situation in Tibetan nomadic area is as same as that in other places, such as in Africa (HÜBL, 1986), that nomads are always said to hoard livestock, being reluctant to exercise normal herd off-take; and they keep more animals than the family needs to live on. Most of these actions are unjustified, people misunderstand the reality. When looking at the prevailing composition of nomadic livestock herds where female animals largely predominate, one can easily conclude that male animals have been previously taken off. In addition, according to relevant experience and knowledge, recently confirmed, there is no known pastoral system on the Qinghai-Tibetan Plateau in which the number of livestock units kept per person exceeds the minimum required for subsistence.

In fact, the trade of animal products in western Sichuan, which is functioning in a traditional way, has almost never been broken off since ancient time. In the sixteenth and seventeenth century, when *Ming* Dynasty conquered Mongolian in the north of China, horses from Tibetan area became the main source for war horses. Meanwhile, owing to the shortage of tea on the Plateau, the famous "tea-horse" trade reached its climax. An big market with fixed tea storage was built up by *Ming* in *Ya-zhou* city (now called *Ya-an*), which further became one of the most important places for the *Ming* Dynasty using tea to exchange for horses with Tibetan nomads. In the following centuries the pastoral areas of the eastern

Qinghai-Tibetan Plateau with a high livestock population have continued to maintain a close livestock trade with their neighboring areas, specially with the hinterland of China. Another example can be found in *Shongpan* County, which is not only the mixed area of ethnic groups, such as Tibetan, *Qiang*, *Hui* (Chinese Muslim) and *Han*, but also the pivot of products' exchange between Tibetan Plateau and neighboring areas. Trading live animals which represents a traditional form of meat trade is mainly operated by *Hui* People in *Shongpan* and *Aba*, who consume some products themselves on the one hand, and sell some out to northwestern China, such as Gansu and Ningxia Province where *Hui* People congregate, and the neighboring urban areas.

Traditionally the trade of animal products or live animals is always a private entrepreneurs' business. Although it was prohibited in the 1960s and the 1970s and replaced by communal trade, private trade was still functioned in a "black" market. From the 1980s onwards the private business has been restored very quickly and become another main trading channel besides the communal trade. In *Zamtang* County, for example, the traditional barter system between pastoral and agricultural areas is still dominant in the market. As far as livestock traders are concerned, the private marketing sector has performed well during the past 40 years (due to skilled manpower, long experience and inherited knowledge).

At present the dynamic of the trade has been driven by market forces and not dictated by or largely dependent on government authorities, although in recent years the State has stepped up its purchase of animal products and supplies of grain to pastoral areas. Due to the private nature of trade, it is difficult to get a precise statistics about this trade from official reports. Currently, in western Sichuan, animal products are also roughly processed. Only in Aba Prefecture, besides the slaughter-houses in *Hongyuan*, *Zoige*, *Aba* and *Barkam*, a new slaughterhouse in *Zamtang* has operated since 1993, and a small deep-freezing storage facility was set up. The total production of beef or mutton in these five houses can get to 2,500 tons yearly, where products are mainly sold to the hinterland and part is exported to the Middle East and killed and processed by muslim butchers.

However, it is unfortunate that market prices of animal products are always relatively low in China, and the unfavorable geographic locations of nomadic pastoralism areas often have few market outlets. Railways and good roads are lacking and transporting expenses are high, such as Chengdu, the nearest big city of *Zamtang*, being about 600 km away from it. Since most of the grazing pastures are situated at distance from the market, they are burdened with heavy transportation costs. On the other hand, livestock trade in the private sectors, which is carried out mainly between the agricultural area and pastoral area, is functioning in an economic way with fewest extra expenses. Regional price differentials and traders' margins are mostly reasonable and consistent with transportation and transaction costs.

There is an obvious trend that the market-pricing process has made people more aware of the possibilities inherent in slaughtering livestock earlier in the season. Pastoralists now in effect own the livestock themselves, and in the hinterland of urban areas there clearly is an open market in livestock. Livestock can be converted into an income above and beyond that contracted with the state, and this does appear to alter people's attitudes towards breeding for market. For the Qinghai-Tibetan Plateau the spatial structure of trading routes follow a peripheral-central pattern, leading mainly from economically weaker areas in the west to economically wealthier areas in the east or hinterlands of China with higher levels of urbanization. It is obvious that the trade of animal products is carried on mainly in a zone in close vicinity to the latter and hardly affect the market in the hinterland, which may be considered as one of the reasons why the authorities in urban areas always underestimate this economy.

In fact, there are indeed a great number of problems confronting the marketing, which hindered the marketing potentials being brought into full play and include:

- Lack of a market intelligence system in order to evaluate trends, to anticipate supply, demand or price changes etc.;
- weak communication linkage;
- too many individual traders with weak management and financial capability;
- concentration on a few markets in the past;
- the failure to gain a presence in other rapidly growing markets.

In addition to these constraints in the socio-economic system, limited factors also occur in the ecological environment of livestock breeding and the sustainable marketing. Exemplifying the milk trade in *Hongyuan* (see 5.2.2 of this book), one can find that livestock rearing for marketing is generally characterized by short-term profit-seeking production strategies which tend to promote inappropriate land-use practices.

> *"The process of sedentarization is encouraged, because the market-oriented livestock breeder tends to settle near roads, settlements and watering places, where livestock can be easily sold to traders. Another consequence is the decrease of the pastoral migration distances, resulting in higher stocking rates and also, often, in longer periods of grazing*

in the vicinity of settlements. This ongoing concentration of man and beast implies a heavy burden for the natural environment." (JANZEN, 1995:284)

Consequently, an important prerequisite for sustainable marketing is the establishment of favorable conditions for living and production in the mobile livestock sector. The main aims of national development policies should be not only the improvement of the quality of the animal products and the better marketing strategies, but also the conservation and rehabilitation of rangeland as well as other environmental resources. For this purpose one principal prerequisite which should be fulfilled by governments and development agencies which is the incorporation in integrated rural development concepts of the living space of the mobile livestock keepers in order to minimize negative environmental, economic , social and cultural effects. (JANZEN, 1995)

5.3.6 The Promotion of Seasonal Animal Husbandry

In the Qinghai-Tibetan Plateau region, seasonal animal husbandry was proposed by some scientists in the 1970s according to the practical situation of the spatial unequilibrium in the distribution of seasonal rangelands, and promoted by governments in the 1980s, which was thought as a technique that can correct the imbalance in the productivity between cold and warm season pastures, and increase the output of animal products. Its basic contents are the utilizing the characteristics of young animals, such as higher utilizing rate of forage grass, higher digestive and assimilating efficiency of nutrients, and growing quickly, more animals are raised during the growing period of grasses in order to use the surplus forage grasses to the large extent on the one hand; before they are driven back to cold season pastures, the weak, old or wounded animals are in time eliminated on the other. In the transitional regions, i.e., agro-pastoral areas, some of thin and weak animals are carried to the farming area to be fattened and slaughtered.

During recent years, the counties in western Sichuan have experimented with different techniques for fattening, slaughtering, and marketing yearlings. In *Zamtang*, for example, three month old lambs raised on warm season pastures had a carcass weight of 10.19 kg, i.e. 75 percent of the weight of an adult (13.5 kg) (tested by the County Animal Husbandry Bureau in *Cao-si-zhan*). Since the lambs were fattened at a much lower cost, by the optimum use of warm season pastures, lambs and calves can be fattened for marketing in a short time. With the accelerated turnover rate of livestock, its significance is obvious:

a) Alleviating the pressures on the cold season pastures and reducing the loss of "spring death":

On the Plateau the offerings of grass in 88.9% counties are in surplus during the growing period of grass, but during the rest time forage grass is in shortage and 48.6% counties there is a serious lack.

b) Reducing the waste of forage grasses and increasing economic returns:

In this physio-geographical region herbaceous plants are short and sparse. If they can not be used enough during the growing period, they are difficult to mow and process in autumn as hay, which leads to waste. The seasonal animal husbandry carried out in the warm season can give an impetus to the changes of the surplus grasses into animal products.

c) Optimizing the herd composition, accelerating the turnover of livestock, and increasing the productivity of animals:

A good herd composition kept in rangeland not only should adjust to the climatic conditions, but there should also be a balance between the number of animals kept and the fodder yield of the pastures grazed. This will vary according to the differential productivity of cold and warm season pastures. For instance, the total carrying capacity of warm season pastures is greater than that of cold season pastures, and the forage grass from warm pastures is too short to mow for winter storage. Hence, to make optimum use of warm pastures, enough animals have to be bred during the warm season.

The reason for low productivity of livestock on the Qinghai-Tibetan Plateau was usually ascribed to the irrational composition of livestock and the slow turnover of animals (TIST, 1992). In the nomadic area of western Sichuan the proportion of the female animals in the proper bearing age is low, but that of old and non-producing animals high, which inevitably affects the rate of elimination and net rate of increase of animals, and the consumption of foodstuff. For example, in *Zamtang*, only approximately 33.7 percent of all animals were female and of bearing age, and in 1988 the increasing rate of all animals was only 8.17 percent. From 8-10 percent of all animals are left to free graze until they die of old age. Moreover, due to the difficult traffic conditions, pack animals take up a large part. Therefore, 40-45 percent of the total composition of livestock are pack animals and other unproductive animals, which further results in a slow turnover and poor profits.

By the seasonal animal husbandry the composition of livestock can be regulated, the survival rate of reproduction rise, and the turnover and elimination of livestock increases, which in the end leads to the increase of the carrying capacity of rangeland in a unit time. Therefore, under the present situation this measure is always thought of as an optimum way to use rangelands rationally, which can not only alleviate the pressures on cold season pastures but also compromise the contradiction between nomads keeping their traditional types of grazing to some extent and the governments requiring the modernization of pastoral production.

In fact this method can be corresponded ecologically to the "tracking strategy" described by BEHNKE (1992). In this system pastoralists or livestock owners attempt to compensate for fluctuations in forage supply by quickly and deliberately adjusting stock numbers. As in the migratory strategy, livestock leaves the local grazing system, in this case primarily through disposal or death rather than relocation. Development options open in this situation include (BEHNKE, 1992: 7):

> *"...the retention of indigenous stock breeds which can withstand fluctuations in feed availability; stock mobility; the development of livestock marketing systems which can absorb massive shifts in levels of throughput; and producer credit or insurance schemes or post-drought restocking programs"*

However, due to the influence of practical constraints, such as the lack or imperfections of markets, securing system for natural disasters, and social serving system, the practice in some places has not, as yet, been widely accepted. For herdsmen, the number of animals they keep is not only an indication of their wealth, but also a survival measure against natural disasters (see 5.2.3 of this book). Meanwhile, some potential risks in this system also should be considered:

- With the fluctuation of climate, the carrying capacity of rangeland is dynamic rather than static. This implies that one cannot assess with certainty how many animals should be culled, which then do not disturb the reproduction next year (specially if followed by a unpredictable snowstorm in the spring) on the one hand, and satisfy fully the carrying capacity in the following summer on the other;
- When livestock prices, marketing capacity and rangeland carrying capacity collapse simultaneously, more serious impoverishment will strike on producers;
- Encouraging the slaughter of livestock does not necessarily reduce the pressure on pasture if people are specifically breeding them for marketing. In fact, some cases in

western Sichuan have already suggested that breeding for beef or other commercial aims with the current structure of incentives implies a greater number of grazing animals on the pasture than previously;

- Owing to the rapid change of physical and marketing situations, it is very difficult to make a priori assumptions about what raising livestock for beef production is actually going to do to the total numbers grazing, the rate of slaughter, rate of birth, and number of years to maturity being the critical parameters.
- Economic self-interest in the urban hinterland may reinforce the traditional attitudes towards accumulation in remote areas, and against slaughter in the state-controlled sector; it may also increase the number slaughtered privately for market, all of which may be incentives to increase the number of grazing livestock.
- The intention that carry some of the thin and weak animals to agro-pastoral areas and fatten them would be obstructed by the remoteness, inaccessibility and poverty of nomadic areas, if the present infrastructure could not be improved.

If these constraints are removed seasonal animal husbandry would function in a more effective way, and mobile livestock keepers and/or the pastoral system in western Sichuan would have a fair chance of survival. In many areas of the Qinghai-Tibetan Plateau their contribution to the market in the hinterland and even to national economics will then certainly be of more importance.

5.3.7 Fertilizing Pastures

It is clear that in the last two decades the use of fertilizers in rangeland systems has increased markedly, specially in artificial and/or semi-artificial pastures. Grass has been found to respond well to large inputs of fertilizer nitrogen, even on relatively fertile soil. Innumerable studies have examined the response of grassland yields to fertilizer nitrogen (BRIGGS, 1985), but here I do not want to review these experiments, adversely but only to concentrate the utilizing status of this technique in the pastoral areas.

Fertilizing pastures began to appear at the end of the 1960s in western Sichuan. Fertiliser was applied in the field for forage cultivation or in artificial pastures, and only dung and urine of livestock, and ground manure or mud from the stalls and pens was used at that time. In recent years it was also used in the winter pastures or fenced degraded pastures for its rehabilitation. With the different animals the amount of excrement and its fertility varies greatly. According to the measurement:

"The daily amount of excrement and urine drained by an adult sheep is about 2 kg, in which the ratio between excrement and urine is 3:1, and yearly amount is about 560-750 kg. Adding the sheepfold manure, thirty sheep can provide fertilizer for the requirement of one hectare qualified pasture. The sheep's manure not only contains nitrogen and potassium, but also its urea nitrogen amount to 53.4% of all nitrogen, which is the highest in all of animals' manure."(TIST, 1992: 130)

The amount of excrement and urine drained by yak is the biggest in the domesticated animals, with the daily amount of 25 kg per herd, yearly amount of 9,000 kg and in the ratio of 3:2 between excrement and urine. The fertility of horse's manure is medium, which daily amount of excrement and urine is about 15 kg and the ratio of them is 2:1, thus the yearly amount is about 5,000 kg. (CAI, 1992; TIST, 1992)

An important function of the grazing animals is the cycling of nutrients within the rangeland ecosystem. The nutrient content of dung and urine and the volume returned to rangeland depends on many factors of which the following are most important: type and age of livestock, quality of herbage being eaten, water content of herbage and weather conditions. After DUFFEY et.al. (1974) studied this function, they stated:

"It is clear that most of the nitrogen and potassium returned to the pasture is present in the urine, while all of the phosphorus and calcium is present in the dung. The pattern of dunging and urination in a pasture may therefore have an important effect on the redistribution of nutrients within a rangeland." (1974: 210)

Areas favored as dunging sites often have the effect of animal droppings on the yield and botanical composition of pastures has been examined by WATKIN (1954, 1957). He found that both dung and urine, applied separately, increased the productivity of the pasture, resulting in a clover-dominant sward with dung and a grass-dominant sward with urine.

The abundant livestock provide ideally organic fertilizer for rangelands. However, due to the lack of manpower, the weakness of technical capabilities and the restrictions of traffic conditions, at present in western Sichuan, as well as in other areas of Qinghai-Tibetan Plateau (TIST, 1992), naturally fertilizing pastures is the dominant method, i.e., fertilizing pastures by means of grazing animals and moving their location in rangelands. The greater the mobility of pastoralists, the more evenly the excrement and urine of grazing animals can be scattered over the pastures.

Besides the fertilising naturally pasture, sheepfold or yak-stall manure is also used by semi-nomads to fertilize the field for forage cultivation near winter houses or the crop production. Chemical fertilizers, however, have been rarely applied by pastoralists until now due to its expense, and it has only been used by administrative units for the production of grass seeds or for the experiments in collective pastures.

Lack of technical capabilities, uncertainty of rain and vastness of the rangelands also prohibits fertilizer application on a wide scale. However, if limited scale artificial pastures are established, range fertilization as well as herbicide application may be successful. Fertilizer applications result in significant variations in processes of nutrient cycling, though the effects depend upon the timing of the applications and the management system. While the grass is actively growing, most of the applied nitrogen is taken up by the pasture and leaching is slight. When the grass is harvested, however, the nitrogen is removed, with the result that little is available to subsequent growth. In the case of field-grazing, of course, losses of nitrogen are far less, for much of the fertilizer taken up by the grass is returned in the faeces.

Repeated applications of nitrogen fertilizer not only stimulate growth, they also alter the composition of the pastures. It is apparent that nitrogen applications can result in significant increases in grass yield, and these may be translated to higher output of animal products either by allowing more rapid live-weight gain or milk yield, or by permitting higher grazing intensities.

However, it should be remembered to that the application of fertilizers, particularly high rates of inorganic nitrogen, cause rapid changes in floristic composition leading to a sward dominated by grasses and with a few other species. Broad-leaved herb may be completely eliminated after two or three years of heavy nitrogen applications (DUFFEY, et al., 1974). Meanwhile, it is undoubted that in the pastoral areas of western Sichuan as well as whole Qinghai-Tibetan Plateau the maintenance of a high degree of spatial mobility for the mobile livestock keepers with their herds is the most available and convenient way for fertilizing pastures under the current economic and technical conditions.

5.3.8 Improvement and Rehabilitation of Rangeland

In some cases the degradation of natural grassland is so great that grasses and other fodder plants can no longer recolonize it without positive human intervention rather than mere protection. It is then very often necessary to turn over the upper layers of the soil by discharrow, or even to plow them up, so as to destroy the thick mat of inedible plants that has formed over the surface. In *Hongyuan* County, for example, attempts to rehabilitate a very degraded pasture overrun by a sedge mat with its tight network of rhizomes and roots have had encouraging results. At the end of the 1970s, after mechanical working of the soil, several tens of hectares were sown with the annual grasses, such as Common oat (*Avena sativa*) and Downy brome (*Bromus tectorum*), and the perennial grasses, such as Common wildrye (*Elymus nutans*) and Siberian wildrye (*E. sibiricus*) (WEI and WU, 1988). These methods greatly improve the grassland quality and its productivity. It is even possible to envisage the reconstitution of the "original" vegetation[46] by reseeding with a suitable mixture of native species.

In order to improve the inferior and degraded pastures, governments have taken the integrated technologies which were mainly introduced from developed countries to construct "artificial" or "semi-artificial" pastures since the 1970s. Until 1981, it was said that about 20,000 hectare artificial pastures and 700,000 hectare of semi-artificial pastures had been built up (SICHUAN ANIMAL HUSBANDRY BUREAU, 1989). For example, in *Hongyuan* County it was reported that more than 30,000 hectare of rangeland was degraded because of water shortage and overgrazing. From 1977 onwards County government started to encourage pastoralists to construct artificial pastures or improve the natural pastures into semi-artificial pastures in order to raise the yield of grass, increase the storage of winter fodder and rehabilitate the degraded pastures. They mainly use the following methods:

a) Plowing, harrowing pasture and planting herbage

In 1989, for example, about 35 hectare of land was plowed. The land was first tilled 18-20 cm deep with five-share disc plower. 11,000 kg of sheep manure was applied per hectare. Then the land was harrowed three times. The period between plowing and harrowing was more than 30 days. But the harrowing was not well done and large pieces of sods were left on the land surface. In 1990, Common oat, Downy brome, Common wildrye and Siberian wildrye were planted (98 kg seeds/ha for the annuals and 38 kg seeds/ha for the perennials).

[46] "Original grassland" or "virgin grassland", in the sense that it escaped man's influence altogether, probably does not exist anywhere and certainly not in the Qinghai-Tibet Plateau. On the other hand, in how far natural grasslands in their present floristic composition resemble the vegetation prior to man's influence cannot be determined. Changes in climate and soil as a result of man's actions may have resulted in the extinction of many species, and even the loss of entire vegetation types. It is not likely that species or vegetation types which have disappeared will ever return (HOLZNER et al., 1983).

b) Harrowing, manuring land and planting perennials

Heavy toothed harrowers were used to break the sod layer for the surface improvement. There are two ways for manuring and planting, namely 3,800 kg/ha, 6,000 kg/ha application of sheep manure and planting Common wildrye of 23 kg/ha.

c) Fertilizing pastures

In order to increase pasture productivity, in July of 1989, about 4 hectares of natural pastures were fertilized with urea (23 kg/ha). The vegetative leaves of the grasses were greatly increased and all the grasses grew very well. At the end of September, the grass yield was tested 12,900 kg per ha, and was 204% higher than that of the control pastures.

The results of these methods are as follows:

- Compared with the control pastures, the plowed pastures were greatly improved in the physico-chemical characters, such as soil porosity increased, water-holding capacity increased, water permeability increased and soil heat conductivity increased. Furthermore, the activities of aerobic bacteria were increased. The aerobic bacteria can decompose organisms well and increase soil fertility.
- The improvement of vegetation structure by planting grasses. The different species of the annual and perennial herbage have different biological characters. In the two year's experiment, the planting of different plants produced different results. As for the plowed and mixed planting artificial pastures, the grass yield of first year was greatly increased and was 10 times higher than that of the control grassland. The content of poisonous grasses decreased by three fourths (from 200 kg to 50 kg). In the second year, the pastures were dominated by the perennial herbage. Though the production of edible grasses was not as high as that in the first year, the growth of poisonous grasses was inhibited.
- The economic benefits are quite different between completely plowing and surface improvement of degraded pastures. Based on the comparison between the two, the investment of the former was only twice higher than that of the latter, but the benefit of the former was 20 times higher than that of the latter.

However, it should be remembered that this kind of newly improved grassland and newly constructed artificial pastures or semi-artificial pastures are always mainly used as cutting pastures at the beginning, and could be gradually grazed in a sustainable way. Furthermore, it is advisable to construct artificial pastures in the areas with lower elevation, because at the lower elevation higher grass production will be obtained; a thick and humid soil layer can be found; land is easy to plow, cost will be low and economic benefits will be apparent. In addition, the sites for the artificial pastures are always in the areas with good water and soil conditions and on the really degraded pastures. For the convenience, the pastures were constructed near the winter houses.

The plowing is very important for the construction of artificial pastures and its time will greatly effect the quality and cost of land preparation. According to our investigation, plowing is done in the rainy season. Having compared the plowing carried out in the rainy and dry seasons respectively in *Serqu* County, it was found that the cost of that done in the rainy season is 90 Yuan per hectare, which is cheaper than that in the dry season, and also the quality in the former situation is much higher. (LIU, 1984)

In *Serqu* County, the artificial pastures have been reconstructed in different ways with annual grasses and perennial grasses. The tested results show that the grass yield is very low when pastures are colonized by single species, and even the pastures with the perennials (Common wildrye) can only be used for 5-7 years. However, if two or three species are mixed planted in a pasture, the grass yield will be 13-33% higher and the pasture can be used for a longer time.

The artificial pastures must be improved in time after their construction. Of the pastures with the perennials in *Serqu* County, the grass yield in first year was very low, that in the second or third year was the highest, and then gradually decreased. Therefore, the yield has to be improved by applying fertilizer and loosening soil. When the yield was decreased to as low as 5,000 kg (generally 5-6 years), the pastures need to be rehabilitated again.

In many parts of the Qinghai-Tibetan Plateau forage species that have proved valuable elsewhere have been introduced. These species have been used to replace native rangeland by sowing in monocultures or simple mixtures, e.g., annual-perennial mixtures and grass-legume mixtures. This has been extensively practiced in western Sichuan where thousands of hectares of native rangelands have been broken and sown to introduced forage species. Overgrazing of artificial pastures is rather uncommon because the forage is mostly cut in autumn or used as early grazing and plants recover rapidly in summer. If overgrazed, however, the pasture is usually destroyed and must be resown as above described. In the moister parts of the rangelands or the sites with lower altitude, such as in the subalpine meadows or open woodland meadow, sowing of smooth brome (*Bromus inermis*) and legumes into native grassland has been successful in some areas.

It appears that, if properly grazed, these pastures can be maintained in a semi-natural state. However, it should not be denied that the construction of artificial pastures on a large scale only can be operated by governments or development agencies rather than individuals under the present economic capacity. Moreover, it will present the unsustainability without continuous inputs from outside, which indeed will affect its practical availability, specially in a nomadic area where vast grazing pasture and a high degree of spatial mobility reduces its feasibility.

5.3.9 Extermination of Rat and Pest

a) Reduction of Rat-damage

It has been mentioned in 4.2.3 of this book that the damages caused by rats and pests to the rangelands are very serious in western Sichuan. The studies on exterminating rats in this region began in the end of the 1950s. Under the guidance of many experts from various institutions, who collaborated with the staff in rangeland experimental stations of Garze and Aba, chemical raticides were studied to kill the mouse hares. At the beginning of the 1960s, zinc phosphate was used to kill mouse hares. Some information about its production and preparation, as well as how to use were obtained. In the end of the 1970s, rangeland work teams were set up in each prefecture and county, who were in charge of the grassland protection and considered the rat's extermination their main work. In the 1980s the work teams organized the herdsmen to use zinc phosphate. At the same time, they introduced a new raticide and applied it in large areas, and also carried out the studies on the extermination by liquid ammonia and cement. Furthermore, biological extermination through the protection and utilization of rats' natural enemies began to be recognized and promoted. Since the 1980s the exterminations have been conducted once every few years in Aba or Garze Prefecture, such as in *Zamtang* recently this work was carried out in 1982, 1988 and 1993 separately, the financial support came from the Animal Husbandry Bureau of Sichuan Province. The major methods which have been adopted include the following:

- Physical extermination

Some traps are used to catch marmots (*Marmota himalayana*). Local people use stone board, wood set, slingshot and water filling to catch mouse-hares. Recently, electronic instruments have also been used to kill rats.

- Chemical extermination

This is the major method used in western Sichuan. During the last 20 years zinc phosphate was widely applied and now it is still used in large areas. The proportion of its preparation is that 50 kg of wheat mixed with 4 kg of zinc phosphate and some rape seed oil (LIU, 1984). People in *Serqu* and *Serta* Counties also applied some new raticides in large areas. Besides that, the rat glue, liquid ammonia and cement were studied and applied. However, some chemicals badly affected the ecological environment due to their long-term residue, and are no longer used.

- Biological extermination

Since the middle of the 1960s, the studies of biological extermination have been paid special attention to. In 1967, the Grassland Station of Garze first conducted the research on biological extermination. They planted the grasses of wildrye (*Elymus nutans*) on the rat-damaged land. The vegetation was recovered and rat density was decreased. Since the end of the 1970s, the research on the rat-damaged land improvement has been changed in application. In some areas, vegetation is artificially recovered on the rat-damaged land and rats' habitat is changed. In addition, the protection of rats' natural enemies has been carried out in the whole region. In 1985, the Government of *Serqu* County issued an announcement calling for the protection of rats' natural enemies. Actually, this is an administrative measure to promote the biological extermination.

The serious rat-damage, certainly, is caused by comprehensive factors, but it is a popular belief that the proliferation of all these rodents has been further encouraged by the elimination of their natural predators, such as wolves, fox and eagles. By some survey data, one natural enemy eats more than 1,000 rats each year. Ecologically, the fundamental way to eliminate rats is to protect and utilize their natural enemies. Because of the increasing of human activities in recent decades, however, the natural enemies are getting rare. Since the 1970s large amounts of chemicals have been used to kill rats, because of their serious residual toxicity, large number of rats' enemies are also killed simultaneously. Therefore, before the natural enemies are effectively protected and resurrected, it is at least necessary to use chemicals in a sustainable way, i.e., only the chemicals with low residual toxicity can be used in order to avoid environment pollution.

After extermination, in many places the vegetation was allowed to recover naturally. In this way the vegetation recovered very slowly, and it may not have changed into that which people desired. Under the natural recovery, the rat-damaged land would be slowly covered by secondary weeds and developed into inferior pasturelands. This caused a great waste of land resource. Under the natural conditions, it is estimated that the rat-damaged land needed 30 years or more to be recovered into that with its original vegetation. If it was artificially improved, it only needed 2 or 3 years with low investment. In 1976 about 50 hectares of the rat-damaged land was artificially improved by planting wildrye (*Elymus nutans*) and Common oat (*Avena sativa*) in *Serqu* County (ZHU, 1984). Based on the test of 1981, the fresh grass production was increased from 40 kg to 4,500 kg per hectare; the vegetation coverage increased from 30% to 75%. In 1985 and 1986 about 15 hectares of the rat-damaged land was artificially improved again. The grass production was compared with that of the control group, the grass production of the improved land was 1,900 kg per hectare in the second year and 4,600 kg in the third year. The grasses grew much taller and the dominate plants were changed from the various weeds into the more available grasses.

b) Control of Pest-Damage

As early as in the 1960s scientists paid attentions to the insect pests, and did some research of their control. In the 1970s some studies were also conducted for the control, but all the studies were not complete and systematic. In *Zamtang*, pest damaged land occurs frequently in overgrazing or overgrazed pasturelands, such as in *Namqi* summer pasture. We were told that almost every other two years the government invested specially in the integrated control of pests. The major ways applied for the control are as following:

- <u>Biological control</u>

The most effective way for pest control is to change the ecological environment of these pests. The pests of *Gynaephora spp.* and *Acrididae* like to eat the grasses of *Kobresia* and short grasses of *Gramineae*. Also these grasses are favorable for them to climb and jump, suitable for the pests of *Gynaephora* to become chrysalis, lay eggs and suitable for the hibernation of their larvae. Owing to the shortening of grasses, the hibernation conditions of *Gynaephora* have been built up and their density can increase sharply.

- <u>Protection of natural enemies</u>

The protection of pests' natural enemies is an important way to control the pests on the rangeland and maintain the natural ecological balance. In the recent years, the natural enemies have increased, which has inhibited the growth of the pests and prevented great plagues of stick flies and bees. The parasitic rate of *Gynaephora* is very high on the parasitic flies and bees. This artificial reproduction is of great use to control the pests of *Gynaephora*. Since 1986, Sichuan University made some success in applying virus pesticides to control *Gynaephora*.

- <u>Chemical Control</u>

Now the biological control and the control by using the natural enemies can not completely inhibit the growth of grassland pests and prevent their plagues from taking place. Chemical control was and is still the main method to be used in western Sichuan. In the 1950s BHC powder was experimentally used and the rate of killing the insects was more than 90%. After the middle of the 1970s, some chemicals, such as DDVP, dipterex and oil dipterex were used. Since the 1980s, about 14,000 hectare of rangeland have been chemically controlled with low toxicity, such as oil dipterex and pyrethrums. The techniques and instruments of these controls are being further improved to reduce the residual toxicity.

However, herbicides are unlikely to be widely used on rangelands managed for the purposes of nature conservation, partly because they would destroy many of the plants of conservation value, and partly because the long-term effects on the rangeland ecosystem are unknown. In a few exceptional circumstances when the use of herbicides might be necessary on nature reserves (for example to control an aggressive grass 'invading' an area where a nationally rare species occurred), great care should be taken to ensure that they are applied only where needed. As a general rule it is best to avoid the use of herbicides on rangeland managed for nature conservation.

6. SUSTAINABLE USE OF RANGELANDS ON THE PLATEAU AND ITS APPROACHES

The rational utilization could retard the progress of degradation, otherwise it could accelerate its progress. The rational utilization of range is in a sense an important measure of cultivation, which could conserve the resource in a sustainable way.The essential conditions for a grazing land utilized rationally are that

- an harmonious community structure should be kept in the range of vegetation, which can sustain the high productivity of domesticated animal for a long time;
- the grazing land should maintain a relatively stable carrying capacity which can be grazed by a certain number of animals; and
- the forage grasses should have a good proportion of nutrients during the grazing season.

In order to meet the requirements of sustainability, the determining of the indicators of unsustainability and the sustainable potentials and constraints in this special ecological region should be done first.

6.1 Indicators and Assessment of Unsustainability in the Rangeland Ecosystem of the Plateau

The above negative changes (see Chapter 4 and 5), treated as indicators of unsustainability, may relate to (1) resource base (e.g., rangeland degradation); (2) production flows (e.g., persistent decline in grass yields and livestock outputs); and (3) resource management/use systems (e.g., increased unfeasibility of seasonal pastures). More importantly, for operational and analytical purposes, the indicators can be grouped under the following three categories on the basis of their actual or potential visibility (Table 6.1).

a) Directly visible negative changes

These can include increased dunes on pastures and pest/rat damage, prolonged fall in the yields of grasses in pastoral areas, reduced diversity of plateau pastoralism, abandonment of traditionally productive systems, and reduced extent of seasonal migration of pastoralists.

b) Negative changes made invisible

People's adjustments to negative changes often tend to hide the latter. In plateau areas such changes can include substitution of improved livestock for yak, sheep or other traditional animals; be putting up of fences and grass planting around permanent settlements or winter shelters; the replacement of yak by small ruminants due to permanent degradation or reduced carrying capacity of grazing lands, introduction of public food distribution systems, due to the increasing inter-seasonal hunger gaps (local food production deficits), nomads or semi-nomads leasing out their lands or herds to concentrate on wage earning, and the shift towards increased external inputs in cropping or grazing due to the decline of locally renewable resources.

c) Development initiatives with potentially negative consequences

A number of measures are adopted for meeting present or perceived future shortages of products at current or increased levels of demand. Some of the measures (changes), while enhancing productivity of pastoralism in the short run, might jeopardize the ability of the system to meet the interventions' insensitivity to specific conditions of plateau areas.

These can be illustrated by any management technology that increases plateau pastoralism's crucial dependence on external inputs (e.g. supplemental feeding, fertilizing pastures) as against the locally renewable input resource, or adds to mass production of high-weight, low-value products with a largely external market ignoring inaccessibility and related problems. Similarly, any measures that disregard the fragility of plateau, ignore linkages among diverse activities at different elevations, such as the unified construction of artificial pastures nearby winter shelters, and promote mono-variety of herd may not prove sustainable.

Under categories (b) and (c) above, there may be served changes that might bring positive results in the short term but obstruct the sustainability of pastoralism in the fragile areas. To separate them from negatively oriented changes, one needs a fairly detailed analysis of the components involved. This involves examination of the implications of interventions in terms of their compatibility with the relevant plateau specificities.

Table 6.1 Negative Changes as Indicators of the Unsustainability of High-frigid Pastoralism

Visibility of change	**Changes Related to**[47]		
	Resource base	Production flows	Resource use/management
Directly visible changes	Increased dunes and other forms of pasture's degradation; per capita reduced availability and fragmentation of rangeland; changed botanical composition or structure of pasture	Prolonged negative trend in yields of livestock, etc; increased input needed per unit production; increased time and distance in food, fodder, fuel gathering; reduced capacity and period of grazing; lower per capita availability of pastoral products	Reduced extent of mobile pastoralism, recovering duration of rangeland between migrations; diversified resource management practices; extension of grazing to sub-marginal lands; sanctions for resource use by legal measures; unbalanced and high intensity of input use
Changes concealed by responses to changes[48]	Replacement of yak by sheep and natural rangeland by artificial or semi-artificial ones; shift to non-local inputs; Replacement of water flow by fossil fuel for grinding and manure by chemical fertilizers.	Introduction of externally supported public distribution systems (food, inputs); intensive cash cropping or animal on limited areas	Shifts in grazing pattern and composition of livestock; reduced diversity, increased specialization in intercrossed; promotion of policies/programs with successful record outside, but without evaluation
Potentially negative possibilities[49] due to development initiatives	New systems without linkages to other diversified activities; generating excessive dependence on outside resources; (fertilizer/pesticide-based technologies), ignoring traditional adaptation experiences.	Pastoral measures directed to short-term quick results; primarily product-centred (as against resource-centered) approaches to pastoral development	Indifference of programs and policies to the Plateau specificities, focus on short-term gains, high centralization, excessive, crucial dependence on external advice, ignoring wisdom

The above discussion on unsustainablility indicators, when related to the mainstream debate on sustainability, has two significant implications. Firstly, judged from the complex of negative changes in many parts of the plateaus, under the present patterns of resource use, the threshold limits to maintenance or enhancement of the system's performance, even by using the inter-regional linkages, seem to have been reached. Further efforts to improve output levels imply over-exploitation of their biophysical resource base and the initiation of

[47] Most of the changes are interrelated and they could fit into more than one block;

[48] Since a number of changes could be for reasons other than unsustainability, a fuller understanding of the underlying circumstances of a change will be necessary;

[49] Changes under this category differ from the ones under the above two categories, in the sense that they are yet to take place, and their potential emergence could be understood by examining the involved resource use practices in relation to specific plateau characteristics.

the irreversible process of resource degradation. These areas represent crisis zones, where the unsustainability, usually conceived at conceptual or philosophical levels, has become an objective reality. The production prospects and output levels, on a per capita basis and in most cases on a per production-unit basis, have declined. Thus, in these habitats, one can observe the emergence of the inter-generational inequalities. Accordingly, compared to past generations, the present one (unless supported externally) seems to have lower production prospects. The links between short-term intra-generational issues (poverty, ineqality, etc.) and long-term inter-generational issues (emphasized by the sustainability debate) are quite apparent in these areas. This may help inject some relevance into the sustainability debate in the developing country context (MELLOR, 1988; JAIN, 1989).

Secondly, since the unsustainability indicators are a product of mismatch between resource characteristics and their use pattern, the reestablishment of a match between the two is an important step in enhancing the sustainability of plateau resources and the activities, including pastoralism, based on them. At the conceptual level, the above reasoning implies a change in the perspectives on the sustainability question. Accordingly, for identifying and operationalizing the components of sustainability for a given system, one needs to examine the unsustainability phenomenon first and then proceed backwards to understand the factors and processes contributing to it. This can help in identifying practical measures to reverse the process leading to unsustainability. A practicable step towards implementing the above approach is to prepare an inventory of the indicators of unsustainability in a system and then look into the 'why and how' behind them. This approach has some merits. It can help to improve the understanding of operational aspects of the issues involved in the sustainability debate. This also helps to relate more easily the involved issues to the real world situations in which the causes and consequences of unsustainability are felt. It can also help to identify concrete steps to modify the current approaches towards development and resource management. Such steps may relate to macro- and micro-level policies and programs as well as to 'farm-level' decisions and actions.

6.2 Sustainable Potential and Constraints

UEXKULL defines the environment as "*the entirety of all its relations to the surroundings*" (NEUMANN, 1991). The environment can give a number of services to an ecosystem: It can support the production function through the supply of resources, it has carrier functions for activities, communication and production. The environment stabilizes system functions through protection, compensation and cleaning services. As a carrier of signals it allows for the orientation of organisms. The use of the environment can impinge on the performance of environmental functions. As a general rule, one can say: "*The more an environmental function is used to its full capacity, the greater will be the danger that certain levels of environmental quality are affected.*" (NEUMANN, 1991:127)

The human use of the environment is primarily shaped through an economic rational. In our modern societies with their immense capacities of alteration of the natural environment this economic rationale seems to be particularly rigid and little consideration of the environmental impact of production-systems has existed until recently. This is also true of pastoral production systems. The main environmental impacts are:

- the destruction of original vegetation and the related fauna;
- degradation of soils and water-systems;
- alteration of macro and meso-climate; and
- imbalance in landscape ecology.

The underlying problem might become clearer if one looks at the conflicting paradigms of economy and ecology. FREDERICHS and BLUME (1990) consider the classical discipline of economy as being based on two basic categories: scarcity and needs. The economic world view sees relative scarcity (of resources and capital) going along with absolute needs (goods and services). This allows for the unlimited substitution of means and makes a quantitative growth of economy necessary. Ecology, by contrast, regards needs as relative and the scarcity of resources as absolute, thus demanding controlled growth. Therefore, the so-called unsustainability or the degradation of environment always results from the different opinions in utilizing natural resources.

6.2.1 Status and Trends in Pastoral Production System

The pastoral production system is "*based on the use of natural and semi-natural vegetation via domestic animals, in particular ruminants*" (HÜBL, 1986: 61). The main economic activity of the pastoralists is the raising of livestock, making use of the rangelands by a variety of opportunistic pastoral strategies.

Nowadays, a large variety of livestock production systems can be found on the Qinghai-Tibetan Plateau. Production of milk and meat and the use of animal traction for subsistence purpose as well as with market orientation are practiced with indigenous and improved breeds. Generally, five livestock species are reared: yaks, sheep, horses, goats and cattle. Having referenced SCHWARTZ's summary about Somalia, Table 6.2 summarizes some key descriptors of present pastoral systems in western Sichuan. Common to all systems is the use of communal land as pasture, whereas they differ in the degree of mobility of herds and households. With increasing altitude, specially transferring to plateau inside, mobility increases and reaches the extreme in the opportunistic migratory pastoralism, which utilizes the most marginal areas in the region.

Table 6.2 Descriptors of Pastoralism in Western Sichuan

Agro-pastoralism	Combining crop production and grazing of domestic stock on individually owned and on communal land in the immediate vicinity of a permanent homestead for subsistence and marketing
Sedentary pastoralism	Grazing individually owned domestic stock on communal land in the vicinity of permanent homesteads throughout the year
Semi-sedentary pastoralism	Grazing individually owned domestic stock on communal land in the vicinity of a permanent homestead for part of the year and long-distance movement of the herds during the warm season
Migratory pastoralism	grazing individually owned domestic stock on communal land and moving herds and homesteads as seasonal forage supply demands

Source: Wu Ning 1995

In western Sichuan constraints on livestock productivity in the systems could be divided into three different categories: normal constraints, disasters and long term irreversible changes such as increasing population pressure and constant loss of pastoral lands. The first two have always been part of the systems and adaptive strategies have developed to compensate for their effects. The third group is of more recent origin and largely beyond the control of the pastoralists. Normal constraints are seasonal, annual and spatial variation of thermo-conditions and, accordingly, seasonal, annual and spatial variability of quantity and quality of the available forage.

The nomadic livestock productivity seems to be low, as demonstrated in the following Table 6.3. In Europe the birthweight of the dual-purpose cattle is 50 kg; adult weight is 600 - 800 kg; and the milk yield in lactation period is as high as 5,000 kg (HÜBL, 1986). The relatively low productivity of nomadic yak is, of course, a result of numerous constraints prevailing in the hostile and frigid habitat of the Qinghai-Tibetan Plateau.

Table 6.3 Productivity of Yak in Western Sichuan

Parameters	Nomadic Yak
Birth weight (kg)	11.8 (female) - 13.8 (male)
Adult weight (kg)	281.5 (female) - 575.6 (male)
Carcass weight (kg)	158.13 (female) - 331.78 (male)
Carcass dressing percentage (%)	56.17 (female) - 57.75 (male)
Carcass dressed weight (kg)	136.63 (female) - 275.63 (male)
Milk yield (kg/yr.)	176.5 - 227.5
Butter-fat content (%)	5.62 - 7.83

Source: CAI, 1989.

Firstly, there is a serious nutritional problem. The pastoral system does not allow a regular, balanced food intake because of great seasonal variation of the vegetation resources, in terms of availability and nutritive value. Whereas, during the warm season, a surplus offer of fodder occurs there is usually shortage of feed during the cold season causing malnutrition and its negative consequences with respect to health and fertility.

Secondly, the supply of fodder in winter is problematical. While in summer, grass can be found almost everywhere, serious problems arise during cold season period. Animals have to stay on the snow covered grounds supplemented by hay (if nomads have kept it in stock) or migrated on the remaining grazing grounds. At the end of the cold season, most of the scarce feed intake will be consumed by this exercise.

Thirdly, the nomadic livestock rearing system does not allow efficient husbandry measures and control, and this is not because of lack of knowledge by the pastoralists.

Normal herd off-take in accordance with biological herd increase is frequently disturbed because of insufficient marketing facilities. Cold periods cause excessive herd size reductions due to emergency mortality, sales in late autumn and reduced fertility rates. However, after making allowance for all these obstacles and environmental hardships, the nomadic livestock system proves in fact to be quite efficient and productive. The International Livestock Center for Africa (Annual Report 1983) has compared an East African pastoral production system, the Borana system, with a modern cattle ranching system in Kenya (Laikipia) and ranches in the northern territory of Australia. The results synthesized the practical situation of nomadic production system on the Qinghai-Tibetan Plateau were that:

- the pastoral system seeks to optimize the number of people supported per unit area of land and to offer these people a maximum food supply security;
- the nomadic tradition is a multiple goal system where production and consumption of milk are far more important than consumption and sale of meat;
- compared with ranchers, pastoralists are poor people, not because of low productivity, but because their numbers per unit area are high;
- pastoralists try to optimize the number of people supported per unit area, ranchers aim at optimum economic returns;
- the pastoral system in Western Sichuan directly supports to 6.5 people per square kilometer of rangeland, Kenya ranches no more than 0.5 people/km and the Australian ranches 0.002 people/km.

These findings and the awareness that the pastoralists have perfect knowledge of their production system including pasture and seasonal management, animal health care and the like has induced JAHNKE to state:

> "*Human development ... does not mean teaching pastoralists better methods of stock raising, but making them fit for occupations in other zones and sectors, so that the arid zone can be used within its capacities and continue to be a valuable resource for the economy.*" (quoted from HUBL, 1986:63)

Pastoralists exercised in the past an effective control of their environment. However, according to current legal definition, rangelands are property of the state with no clear demarcation of responsibility. In spite of purely private animal ownership, land tenure is usually communal. Many attempts or suggestions are made in order to regulate range use, such as dividing rangelands between families and setting up new responsibility systems. Under present circumstances, pasture or range management measures become very difficult or even impossible. Technocratic intervention to stop degradation has not met with much success. Pastoralists hardly participate with their experience in the development of appropriate range management technologies.

6.2.2 Political and Socio-Economic Sustainability

By definition, the principle of sustainability poses the question of the time factor of the development process, which meets human needs and is capable of maintaining economic growth and conserving natural capital. Instead of probing into the difficulties and complexities of the concept, here it is only attempted to outline what sustainable development in the Tibetan pastoral livestock sector policy would require during the 1990s in terms of political accommodation, participation of and incentives for the livestock owners, and the shaping of the future of pastoral people and consequently the pastoral livestock system.

6.2.2.1 The recent transformation and administrative institution

After 1978 the government of China recognized the need for corrective measures and made a major shift in policy. It slowly moved away from state control and ownership (planned economy) towards a more market-oriented economy and the policies to encourage private sector initiatives and investment. From the beginning of the 1980's various major economic policy changes were introduced which significantly improved the performance of the pastoral sector. A series of economic measures signaled the government's willingness for a more liberalized structure. Such measures included the disbandment of the livestock marketing organization, the considerable reduction of marketing organizations for animal products as well as and more particularly, the release of control over prices.

The trend towards a mixed, more private economy combined with a liberalization of the marketing of locally produced animal products, and also a reduced role for public sector institutions has proved successful. Thus, the very fact that the change in state-stipulated basic conditions led to the production increases mentioned, proves again that it was not – as is a common complaint – exclusively a lack of mechanization or pastoral inputs which was responsible for the too-low harvest yields.

The failure of collective pastoralism carried out before 1978 and the great changes due to the "Responsibility System" since then has also proved that family should be a relatively stable and basic productive unit under the present circumstances in China, which not only suits the present level of productivity in these areas, but also is paralled by the social organization of nomadism in the World. The family has always been the central production institution in any nomadic society, because of the economics needed roam in small groups, and it is impossible to feed and water all the livestock on a limited territory. Numerically larger groups could band together for only a fraction of the year, except in times of natural calamities. So, as a general rule, the roaming unit usually consisted of a small community, such as "*Zhu*" in the case study area. KHAZANOV also pointed out:

> "*One should also remember that a nomadic economy is comparatively labor-unintensive. ... on the whole labor consumption in cattle breeding was far smaller than in plow or irrigation farming, which was one of the reasons why the nomads were reluctant to give up their traditional way of life and settle down on the land.*" (1978: 122)

Besides human and animal organization on the pasture, the form of managing livestock also depends to a degree on the wider administrative order of which the community is a part. For example, the allocation of rights to pasture between two communities may reflect internal factors, such as descent; but it is not a putative descent backed up by some competitive display of arms, but by the existence of the state. This is a traditional truth for Tibetan areas; it is even more true, perhaps, today, when there is a modern infrastructure and appointed posts in the administration that reach down to the sub-county level.

In *Zamtang* the basic administrative unit is known as "*Chun*", which are coextensive with the old "*Dui*" ("production teams" or "production brigades"), and in which the local people are elected and serve as official leaders. Below "*Chun*" there is a further divided sub-unit, namely "*Zhu*" (group), which is constituted by a group of families or even campholds, and is a productive unit rather than an administrative unit. As in most areas, in principle some "*Chun*" constitute a "*Xiang*", which is in general equated with the old "*Gongshe*" (People's Commune); "*Xiang*" make up the county, for example, in Zamtang there are 11 "*Xiang*" which include 61 "*Chun*" and 130 "*Zhu*".

The commune was a unit for governance and production in a single chain of command, however, in the current system production and governance are separated (CLARKE, 1987). Whereas the old communes had a role of regional economic cooperation, especially for land use, the present function of the "*Chun*" and "*Xiang*" officers is the collection of data for forwarding upwards for collection at the county level, and internal management of primarily rural issues among the households of the "*Chun*". Rights in land and livestock are now held within households under the Responsibility System and are not accounted for collectively. It is from the "*Xiang*" office that demands for fertilizer are forwarded upwards, and through it that agricultural inputs, grass seed for herbage planting, and extension work come down to the "*Chun*". In the same way, veterinary care, services for health and education are coordinated.

The introduction of individual or household contracts evidently does raise problems about collective resource management. One has to ask whether the present structure gives enough incentive to preserve this resource, or whether it is 'rational' for pastoralists to maximize their immediate return and that the creation of markets may serve quite literally to clear the ground in a "tragedy of the commons" scenario.

Recent research studies have shown that intra-community wealth differences among the pastoralist families or household groups in western Sichuan do exist. This implies that producers vary considerably in the size of their livestock holdings, in their access to essential elements of production, and in income and expenditures, in resulting different sales numbers and marketing strategies. Greater wealth opens increased possibilities of access to purchased livestock inputs (veterinary care, medicine, water, etc.). In contrast small stock owners must struggle to provide the minimum necessary for subsistence. This dilemma of a limited resource base among the poor pastoral families is further aggravated by the threat to herd survival by cold conditions.

6.2.2.2 The role of governments in pastoral sectors

Comparative studies of "traditional" and "modern" systems, the quest for indigenous technologies and resource management are necessary to understand in what way sustainability is in contrast to short-term benefits and targets in households. The statement that it is mostly the government that has to take the responsibility for the long term consequences regarding sustainability problems, was strongly denied by international experts recently (FOOD-2000, 1987). In contrast, governments tend to adopt short-term views often including those unsustainable effects. But the herdsmen household, which is much more interested in a long-lasting, sustainable security for its household members, is limited by resources. It depends on the level of control regarding property rights, management of the pastures, etc.. It was mentioned once more that very often the changes are too fast for pastoral people to react to or to foresee all the implications. But the awareness is there, and also the awareness of a need for change in the mode of reaction on the part of the household.

Furthermore it was commented that there can be situations in which the long-term reproduction of the household is indeed aimed at although a lack of sustainability through degradation takes place simultaneously. In a similar way, the view that sustainability is not a technical problem was challenged; there is a demand for technology that is compatible with sustainability. As an answer, the close interrelations of all the mentioned aspects should be once more emphasized here, on one side, the fact that many political issues influence ecological sustainability and, on the other, that we are aware of the fact that the general poverty problem leads to environmental degradation: poverty forces people to do things that increase their poverty contra-sustainability. Within this context, employment and income generation are necessary to relieve the pressure on the environment.

In order to realize the sustainable development in western Sichuan, a development plan must be worked out according to the principles of ecological-economic and the practically socio-economic situation in pastoral areas, and the plan must be implemented in practice. To make the plan in practice, first of all human behavior must be efficiently regulated. That guarantees that social regulation functions better.

Government is the main body to carry out social regulation on human behavior. In fact, the social regulation of government is mainly to restrain and induce human behavior through issuing a series of policies. Whether the regulation goals can be achieved depends on the feasibility, efficiency and coordination of the policies concerning nature, economy and society. To make these natural, economic and social policies play their parts coordinately, they must be drawn up in an integrated system, which including natural, economic, social sub-system. By means of the integrated system, the government regulation will be more efficient. The integrated system can not only make these policies in coordination, but also make them promote each other. Government regulates the ecological-economic system by the integrated system, and improves the integrated system according to the practical feedback results, which forms an optimum feedback regulatory function and realizes the sustainable development of the ecological economy. Just as the description of SANDFORD in his paper about organizing government's role:

> "*... I will take a situation in which government has two major aims: to maximize, for the benefit of urban consumers, the long-term average output of meat from a pastoral area; and to increase the economic security of the poorest groups of pastoralists in the area. One policy (variable) being considered by the government is whether or not to control livestock numbers to alleviate pressure on grazing.*" (1981:271)

The government's role in the development of pastoralism would seem to be unavoidable, which not only occurs in the macro policy-making level, but also in some detailed technical aspects. Corresponding to the analyses in western Sichuan, government's functions in pastoral sectors have included:

- the provision of social services and the construction of the infrastructure necessary, such as communications, education, and health, to satisfy the growing personal needs of pastoralists and the requirements of their whole economic system;
- the provision of animal health or breeding services in the form of mass vaccinations, improved yaks, or artificial insemination;
- the management of pasture through adjustment of the length, season, or intensity of grazing use or by land shaping and forage planting, in order to prevent and repair the ecological damages;
- the provision to individual pastoralists of production inputs such as capital, technical advice, fencing material, or of consumption goods such as grain;
- the maintenance of acceptable price levels for the livestock products of the nomads, so that it remains economically attractive to them to keep livestock and produce livestock products.

However, opinion on how far government should go in planning and managing the development (or to what extent government should be trusted) differs greatly among environmentalists and environmental economists. Due to the promotion of the market economy in China, namely "socialist market economy", and privatization of a part of common property in rural societies, such as arable land and livestock, it is unavoidable that policy conflicts may occur between exponents of the market establishing and the economy developing rapidly on the one hand, and advocates of sustainable development. This phenomenon not only occurs in China, but also has become the worldwide problem since the 1980s (MIKESELL, 1992). Therefore, concerning the government's role in the sustainable development, economists thought:

> *"Environmental protection and resource management for sustainable development requires government regulation, which to some degree conflicts with modern trend in development economics in the 1980s toward market freedom and deregulation. Most environmental economics believe in competitive markets and favor economic incentives over 'command and control' instruments for achieving environmental and resource conservation goals. Nevertheless, requiring producers to internalize the social costs of their pollution, or preventing private owners of natural resources from depleting or degrading resources required by future generations, necessarily entails some government intervention in markets or interference with private property rights. ...To a considerable degree, sustainable development expands the role of government in regulation and in directly controlling the use of natural resources. ... Government intervention is not designed to promote economic growth, but rather to prevent*

economic activity from overwhelming the pollution absorptive capacity of the environment, or depleting or degrading the natural resource base." (1992:5)

Sustainable pastoralism and environmental improvement on the Qinghai-Tibetan Plateau will depend heavily on the decisions that policy makers formulate about highland animal husbandry. The role of these important lands in the total scheme of pastoralism and human development has been neglected. More importantly, the environmental dimension has been neglected in most development programs - the challenging questions of sustainability. A good understanding of the resource economics of livestock production systems and livestock development is essential in estimating whether economically, socially and ecologically a profitable system can be established and sustained or not. However, one key challenge for the governments administering these areas is to establish policies which reward conservation efforts; policies which create an "incentive to conserve" as well as an "incentive to produce". Land-use planning, land settlement problems, restrictions on the cultivation of marginal lands, strategies to prevent overgrazing of rangelands, and indiscriminate use of fire also need attention.

In the discussion on an adequate development strategy for the pastoral sector in developing countries, the main question is usually how to achieve an increase in production which will ensure a sufficient and steady product supply for the population. Adherence to old production techniques is regularly interpreted as the main impediment to progress in this respect. However, the causes to the -supposed or real – retarded developments are manifold. Thus, strategies to overcome them must be equally multifarious and flexible. MIKESELL's opinion (1992: 102) must be endorsed, when he states that "development...is a comprehensive process of change, in which economic growth (increase in production), technical modernization, social change and cultural development combine as inseparable and interdependent parts of the whole." Nevertheless, when a transformation of existing production methods takes place, it is not a seldom occurrence that new methods are introduced with no consideration of the formerly existing basic conditions.

In general, the scope for developing pastoral systems is extremely limited. With time, institutional changes and technical improvements may one day provide a more ample subsistence and income base but hardly adequate for all today's pastoralists and their progeny. It must be recognized that there are too many people dependent on range resources and livestock industry at present, while the population is rising and resources are shrinking. As the logical consequence, the human carrying capacity of the land must be optimized and the excess people drawn away from the sector (a planned redundancy scheme). This must be accompanied by destocking. From a socio-economic viewpoint, land degradation and the collapse of the existing traditional pastoral system can be viewed as a consequence of human decision-making as applied to land use and control (ABDULLAHI, 1993). Decision-making is influenced by perceived incentives and disincentives within differing time horizons in the framework of the existing policy to another. ABDULLAHI (1993) stressed that human development does not mean teaching pastoralists better methods of stock-raising, but making them fit for occupations in other zones or sectors, so that marginal zones are not overexploited and continue to be a valuable resource in the national economy.

In fact, it is necessary to keep in mind that pastoral nomads are very sensitive to the carrying capacity of the land. The pasture is not yet wholly monopolized by individual or group management units, and the self-regulatory nature of the system of pure pastoralism keeps the system of production in action. Conceptualizing the situation as such, integrated development plans which have a more positive approach to the improvement of the existing systems of crop and livestock production, will lead to real development which would have a positive impact on the quality of life of the indigenous people.

Macro-economic policies are not only an important instrument in influencing the pace and pattern of development but also in conditioning the micro-level activities that have sustainability implications. On the Qinghai-Tibetan Plateau, most of the negative trends, including the stagnation or decline of high-frigid pastoralism in several areas, can be partly attributed to macro-level economic policies. The missing plateau perspective is an important gap in these policies, because most of the macro-level policies are not designed for the high-frigid pastoral context but accord with the conventional practices or experiences in non-plateau areas or even farm areas.

There is no clear-cut policy involving all the various aspects of pastoral livestock existence. The pastoral livestock sector's lobby or representatives lack the necessary experience enabling them to influence change. The situation might become very difficult if herds continue to increase at their present rate, if profit does not increase and the carrying capacity continues to decrease, and if no controlled system of land use and pasture management is produced by the government. It is important to note here that the profit from these herds was never very high and still is not. However the profit to be gained from livestock herds, whether owned by pastoral nomads or other groups, has not yet approached zero. Until that happens herds will continue to grow in size. Planning in this area is in chaos and needs reconsideration, starting with basic issues like the concept of development itself.

It has been made clear that ecologically maladapted forms of landuse have led to a severe degradation of the natural resource base in parts of the nomadic living space during the past two decades. This is due to mistakes in development policy, such as the direct and indirect promotion of sedentarization of nomads and the one-sided preference of development measures in animal production. Some dimensions of macro-level policies seem to have hindered sustainable development in the pastoral area .

Notwithstanding the recent focus on the welfare of nomads and on the need for reducing inter-regional inequities, historically speaking, the goal of macro-economic policies in the pastoral areas has been directed towards the extraction of animal products. The additional short-term consideration has been revenue maximization. The regeneration and the sustainable use of resources have seldom been major considerations. Similarly, product pricing and compensation mechanisms are guided by conventional yardsticks, rather than on the basis of the intrinsic worth of products and the sustainability implications of the pace and pattern of resource extraction.

As a result of this policy, a process of massive displacement of pastoralists from ecologically favorable locations to less advantageous marginal areas can be observed. The negative impacts of high concentrations of livestock combined with reduced spatial mobility which can arise for the natural environment as well as for the quality and the states of health of the animals are well known.

Consequently, the main challenge for development policy has to be the elaboration of a development strategy for the nomadic habitat which should focus on the rapid attainment of sustainability in all fields, and the consistent consideration of regional variations of the political, judicial, social, economic, and ecological circumstances. The pastoral economy cannot be treated as an isolated subject, but has to be considered as an integrated part of a comprehensive regional development strategy based on basic needs and a self-help oriented approach.

6.2.3 Land Use Systems and Ecological Sustainability

Sustainable development consists of two opposite and auxiliary ecological and economic aims: high efficiency - high efficiency of resource using and rapid developing speed, harmonious relationship – harmonious social relationship and high ecological vitality. The former is a positive feedback process, emphasizing the speed of development, while the latter is a negative one, emphasizing the stability of development. These two are either contradictory or consistent. The task of ecological regulation is to promote a harmony among the social, economic and environmental development by means of exploring opportunity, raising efficiency, decreasing risk and improving function.

Sustainability, as mentioned above, is a dynamic phenomenon, as reflected through the system's responsiveness to changing requirements. In the more concrete context of pastoralism on the Qinghai-Tibetan Plateau, this dynamism translates into the capacities of production factors, mainly biophysical resources, to accommodate the increasing pressure of demand without damaging their long-term potentialities. The long-term productivity and health of the natural resource base are in turn affected by the pattern and intensity of its use. Thus, devoid of finer definitional differences, in essence, the sustainability/unsustainability is an outcome of match/mismatch between (1) basic characteristics of the natural resource components and (2) patterns and methods of their utilization. The latter can change (with the changing needs or perceptions of the community), but the former is normally difficult to change unless the whole resource base is transformed.

Given its inherent characteristics, the natural resource base of a system (e.g., plateau pastoralism) suits only some uses (and use intensity levels). Other uses (unless the resource base itself is modified) cannot be productively maintained without either a high degree of artificial support (e.g., subsidies in chemical, biological and physical forms) or damage to the inherent capacities of the resource base itself. In either case, inappropriate use of the resource base is a definite step towards long-term unsustainability. This problem is more specific to regions with fragile and marginal land resources such as the plateaus and the arid areas. In such habitats, the unsustainability situation emerges more quickly and in a more pronounced manner. In the natural state in these areas, the range of options ensuring a proper match between resource characteristics and resource use is very narrow. However, due to human ingenuity over the generations, the range of options has been widened. Features of traditional nomadic systems in these regions corroborate this. However, these options, having evolved in the context of low demand on fragile resources, are generated by population growth, market forces, and public interventions. The consequent measures, adopted to meet the situation, such as the extension of cultivation to more fragile and sub-marginal locations, or the steps leading to overstocking of grazing lands and deforestation to compensate for the falling incomes, often fail to match well with the constraints and potentialities of the fragile resource.

There is increasing evidence that the environmental degradation was produced not only by pastoralists but also by land use for development and change associated with modernization.

Furthermore, the condition of the range was widely attributed to a combination of desiccation and overgrazing, but evidence exists that in many cases the results of grazing were reversible and that the sense of crisis was produced – at least in part – by the improvement of monitoring techniques and the unprecedented attention given the problem. Without underestimating the environmental factor, one must ask what forces contribute to the extraordinary emphasis placed on ecological factors in the absence of firm, longitudinal evidence. The ecological perspective is itself an ideology, which must be understood as such and is as much deductive as based on evidence. The diverse motives of those who would circumscribe pastoral practice and resource control find a ready framework in the ecological model, which undermines the pastoral privilege of livestock production in the service of a higher ethic: the perpetuation of natural heritage.

In the past, in the agricultural-pastoral areas, many grasslands were changed into farm lands, which damaged the grassland resources and caused low agricultural production. Recently the production principle of "putting forestry and animal husbandry first" has been implemented in western Sichuan (WEI and WU, 1988). Large areas of farm land that was originally grassland before have been returned to pasture and forested land. This has greatly improved the conditions for animal husbandry production, and also improved the ecological environment of the grasslands.

The type of land use practiced on the Plateau or its margins depend on the life-styles developed by the peoples occupying the area. In this section attention is focused on pastoral activities, though the interaction between the pastoralists and the cultivation is of growing importance. Given the variety of environmental conditions, it is not surprising that different life-styles are followed by these peoples, depending on where they live. Some groups are entirely nomadic, but the majority are semi-nomadic.

One question emerges clearly from the pattern of change, and many problems associated with it, that is: what role does the mobile livestock keeping play in the land use pattern? SCHOLZ thought that mobile livestock keeping is all about an

> "*...optimum, active form of symbiosis between the people and the physical environment of arid, or semi-arid, areas, and offers the only way of realizing a sufficient economic return from the sparse grazing land found in such regions without incurring immense expenditure.*" (1986:113)

After analyzing the developing history of nomadism, GRIGG (1974) also took the same opinion and commented that in the areas with extreme natural conditions, such as arid or cold,

> "*...it is likely that pastoral nomadism is the best use of the land. Certainly it would be prohibitively costly to cultivate these areas: and the conversion of the nomads to ranching has proved difficult. After a long history of expansion, nomadism is now the optimum method of exploiting the arid steppes and the desert.*" (1974: 122)

One can observe, not only from the Qinghai-Tibetan Plateau but also Somalia (JANZEN, 1986) and other parts of the World (SANDFORD, 1981), that the harsher the climatic conditions, the higher the proportion of total land area that has been opened up; and the more it has been either allocated land in very big blocks for management purposes or had a land tenure and management system in which flexible arrangements are possible for moving livestock between small blocks. What follows is the issues which were included in the discussion of JANZEN's suggestion for the Sahel countries, and which approaching to develop an ecologically sound system of resource use:

> "*Livestock rearing must remain as mobile as possible, because the more mobility there is, the more the long-term preservation and renewal of resources is guaranteed. It should be brought to the attention of the development planners that the livestock owners are uninhibited in their movements and that the peripheral grazing grounds could be used much more intensively. It is vitally important that, as arable farming spreads, the space needs of the livestock keepers are properly taken into account.*" (JANZEN, 1991:17)

Under common property ownership rangelands can yield no rent, and consequently nobody has an interest in maintaining their quality as if they were an income-earning asset. This can be accomplished only by turning them into private or public property subject to an unified directing power. Future solutions, in order to be applicable, will have to take into account the differentiation of environmental and socio-economic characteristics of the local pastoral societies.

How do we keep range use within its carrying capacity? The definition of carrying capacity is not immutable, but for instance, capacity changes if the time during which it is permitted to use a certain resource is limited so as to allow regeneration; also land tenure regulations have a role in limited overuse of natural resources. Finally the increase of carrying capacity has a cost which needs to be covered. The problem is how can users be brought to contribute to these costs and have larger livestock owners equitably contribute to range production, e.g., through payment of fees according to number of livestock.

STRYKER (1984) thought that it is important to distinguish between two economic concepts involved in this discussion. The first is the notion of negative externalities, i.e., social costs associated with the deterioration of the rangeland that are greater than the private costs incurred in using that land that is taken into account by the individual herder. The second concept is that of economic rent. This is defined as the value of the benefits resulting from use of the rangeland after all returns to capital labor, and other costly inputs, whether private or social, have been deducted. If rangelands belonged to individual landowners instead of being exploited in common, this rent accrued to the owners, either explicitly if the land was used by others, or implicitly if used by the owners. If there is a market for land, the economic rent is reflected in the sales value of the land so that herders can move into or out of the livestock sector without gaining or losing; any loss in rent is compensated by the sales price received, and vice versa. The allocation of resources is thus unaffected. Most important, all social costs are counted as private costs in determining the net return to land, and users of the land are so charged by the owner. If the owner uses the land, that person's perception of these costs, including those associated with overgrazing, influences how resources are allocated.

In the absence of a sales market for lands, allocation of resources is still efficient as long as there is a lease market and private property rights are guaranteed so that social and private costs are identical. However, once the owners of land see their property rights threatened, so that they cannot be assured of retaining the land or of continuing to receive rent from its users, social costs might diverge from private costs and over exploitation of the land might ensue.

The approach, which has been tried over and over again in recent decades in China, has been an attempt to conserve and/or rehabilitate the open range by controlling livestock numbers and regulating livestock movements through government interventions. This has not only not been a success, but it has been counterproductive in all those instances where and when it was done in conjunction with enforced sedentarisation.

In addition, the implementation of policies involving the creation of fenced pastures and a reduction in animal population would cause problems that make the active participation of the governments concerned absolutely essential. Among other things, support would be needed for marketing prices so as to encourage the sale of the extra livestock, and there would be a need for increases in forage production through improved methods of cultivation.

The primary aim should above all be the preservation of the resource base of existence and the conservation and rehabilitation of the vegetative cover, soils and water resources. Only through this it will be possible to combat the latent process of desertification and to maintain the basis for existence for present and future generations. For this purpose the negative circumstances for living and the constraints on production have to be eliminated, or reduced in order to reach risk minimization for the pastoral sector. This can be attained by fast improvement of the living standards and through efficient livestock production. As far as the political and judicial circumstances are concerned, existing laws and the judicial insecurity of range utilization and possibilities for migration resulting for a large part from the expropriation of all state-owned grazing land should be examined. If necessary, they should be in accordance with spatial needs of the nomads. This would facilitate the preservation or reintroduction of ecologically adapted landuse systems.

6.3. Sustainable Approaches and its Perspectives

The following are prerequisites for a sustainable development of the pastoral livestock sector, which permits people and their animals live into harmony. Development of the livestock sector can only be successful in the long term, if development projects are economically, socially, politically and ecologically sustainable and if the appropriate scheme is to substitute the existing social structure. Otherwise it is doomed to failure before it begins.

6.3.1 The Research Imperative for Indigenous Knowledge

Over the past decade, the environmental changes and economic development on the Qinghai-Tibetan Plateau have accelerated, creating a serious impact on natural resources and landscapes. The natural resource base in this Plateau is deteriorating more rapidly than many other global ecosystems (IVES and MESSERLI, 1989). On the other hand, industrial and economic development are still going on without hesitation or reflection. If we realize the need for a commitment to implement conservation and development during the era of economic globalization, then development trends, due to rapid transformation from subsistence to market-oriented economies, can be supported. The need for socially and environmentally responsible action also applies to development agencies and calls for a better understanding of indigenous perceptions on the natural environment.

Traditional attitudes and behavior in pastoral societies reveal a deep-rooted pastoral culture. Traditionally, pastoral people perceive and manage their environmental resources in their habitats for their needs. Rangelands are the most important resource system and landmark on the Qinghai-Tibetan Plateau. High-frigid pastoralism, both nomadism and semi-nomadism, are directly supported by high-frigid rangelands. High-frigid rangelands also provide varied products, and environmental protection to the cultural needs of pastoral people in the areas.

In the traditional societies of this Plateau, the management of natural resources, including land-use protection, wandering and grazing, and distribution practices, is based on the perception of a man-environment relationship. Traditionally, rangelands and grazing systems are managed by pastoral societies as multiple-use systems to meet the needs, namely, food, fodder, fuel, leather and wool, and medicinal products. The indigenous people of the Plateau have a long tradition of practice in maintaining the rangelands as sustainable resource systems which are characterized by the management of mobile livestock keeping.

Since the early 1980's, political administration and formal sector organizations have shown an increasing will to invest in environmental research, development of appropriate technologies and to revise instruments of planning and decision-making in order to accommodate concerns for sustainable resource use. However, since the carrying out of "production responsibility" in China, small-holder agriculture including small-holder pastoralism on the Qinghai-Tibetan Plateau has become one of the new factors of environmental destruction, which is similar to the situation in the Tropics (WRI, 1985). Can small-holders become agents of environmental conservation? The answer to this key question will depend largely on the implementation of environmentally sound land-use systems. Eco-range-technologies gave encouraging results under research conditions, promising to stop environmental degradation and limit substantially the external input needs. But those who put lots of energy into the development and extension of sustainable range-systems in the field have often been utterly disappointed how little has been adopted by nomads. NEUMANN (1991) said:

"*...it seems that technological solutions and/or implementation methods are still too unspecified for the particular farm-household situation....the requirements of the ecological and of the social system may be so specific that planned approaches are likely to fail.*"(1991: 129)

Encouraging effects have been observed in programs that allowed for an open group-process, which was self-determined by herdsmen with regard to work-contents and speed and where long-term and qualified outside support was guaranteed without outsider domination. Support organizations left the herdsmen complete freedom in decision-making but surveyed and backed up their field personnel. Mostly the herdsmen's own practices were taken as the base of further pastoralism development, i.e. a step-by-step transformation of range systems. NEUMANN (1991) thought that it has normally posed no problems to make environmental questions in local people's groups and it can provide a stimulus for the phasing-out of counterproductive and ecologically hazardous practices. For this undertaking, professional people are needed with the capacity of communication and of integration into social processes, with good experience in the basic aspects of the pastoralists' life and their animal husbandry.

On the other hand, it should be well understood that the destruction of the environment through small-holder pastoralism is not a problem of the availability of technologies. Today there are enough innovative technologies available that increase productivity based on the use of local resources and are environmentally sound at the same time (GLEISSMAN, 1989). The problem is much more that these approaches have to be integrated into the local social and economic context.

It was soon apparent that the current notion of pastoralism as a traditional, simplistic and somewhat static, low-input/low output system, which could be corrected rigidly and generate short-term's successes were outmoded. The opposite is true: taking the terms 'traditional' as a starting point and 'modern' as a temporary final point within a transformation process of a society, then no 'readditional' sector exists in western Sichuan. All aspects of nomadic live are affected by 'modern' conditions and thus are modern. Various internal and external factors have led to a loss in grazing areas, local high stocking densities, an increase in the number of settlements and increasing integration in the national and international markets. At least a partial transition from a purely subsistence to a commercial system has taken place as an autochthonous response to external stimuli. Nomads are today faced with new sets of problems resulting from these changes. As subsistence pastoralism is not only a particular mode of production, but embodies the complex features of a total social system, including production, consumption, distribution and exchange in interactive ways, changes in production orientation towards producing live animals for sale and having to pay for some imputs, like fodder, formerly free, have caused the entire system to react.

Finally, the prevalent view, influencing development planning for pastoralists, is based on an ecological model of relationships between land, the means and methods of pastoral production and consumption, and forms of social organization and cultural values. This view assumes that pastoralists have adapted to their environment and that rapid change disturbs the adaptive equilibrium and may result in institutions and values inappropriate to their environmental and economic bases. For example, mortality in the pastoralist society has decreased because of improved health services and decreased warfare, but the economic strategies and organizational forms have not changed to meet the demands produced by increased human and animal populations. People who take this view believe they must accomplish what "natural" evolution cannot achieve: a rapid change to a new equilibrium through modernization of the pastoral economy and society. In particular, this model asserts that "traditional" forms of land use and tenure and strategies of population growth must be changed, and, to that end, they prescribe specified land rights, responsible land use and market involvement that will limit numbers of livestock and that will make accessible to pastoralists. All of these are based on an opinion, which mainly prevails in government officials and development specialists, that pastoral nomads are often regarded as "backward and irrational people, a burden on the state and inevitably destined to be changed into something more modern." (KONCZACKI, 1978)

Although the vast majority of the population of the Qinghai-Tibetan Plateau still reside and make a living in pastoral livestock areas from which comes a very large part of the national wealth, past development strategies in fact have given inadequate support to the rural areas, resulting in a deterioration in the quality of rural life. It should be said that even during the previous "Cultural Revolution Phase" enforced settlement of pastoralists was undertaken with the aim of transforming their production into that of a "modern sector based on scientific production and management". This policy, however, entirely, was not supportive to pastoralism in the long term, which, furthermore, encouraged the prevalence of above opinion.

There is no doubt that traditional pastoral production systems had reached a very high degree of adaptation to marginal environments which they were utilizing. The driving motive behind the species diversity and the high mobility that are characteristics of these systems is risk avoidance. These strategies have worked exceedingly well for many centuries, otherwise the system would have fallen to the risk of disappearence recently. However, faced with rapidly changing conditions, such as increasing population pressure, land losses to other competing economic activities, accelerated breakdown of traditional social assurance systems, reduced mobility due to political and administrative restrictions and widespread political and ethnic strife, this adaptation does seemingly no longer suffice to protect the pastoralist from hunger and destitution.

However, viewing the facts of pastoral development in retrospect, what can we find? Livestock numbers in western Sichuan are stated to exceed the carrying capacity of the rangelands by two to three times, a biological impossibility, as herds above the size that experts call the maximum thrive and continue to expand. Some of these contradictions are explained by differences in the definition of the term "carrying capacity". Demographers define it as the population size at which the population stops growing. Range scientists have borrowed the term but have given it a different meaning or rather a range of meanings which imply an optimal stocking density rather than a maximum (MACE, 1991). However, population dynamics of pastoral herds may not follow the ecologically oriented concepts of demographers or range scientists concerning the "carrying capacity" of the range population biologists or range scientists. Such concepts often assume that herder's self-interests will cause them to overuse common grazing land, rendering this form of pastoralism unproductive and ecologically damaging. Programs based on this premise are not addressing the real problem. If highly annual variable thermo-conditions rather than absolute livestock numbers is the main factor that controls the dynamics of the ecosystem, then measures which focus on vegetation management, communal projects like group ranches, grazing-control, rotation schemes and reduced herd sizes do not address the actual problem. If livestock population dynamics are governed by climate, then measures seeking to establish stable stocking density through vegetation management alone will fail. Herds which are rebuilt by traditional pastoralists as fast as possible after a drought or snowstorm and are inevitably knocked back again in subsequent cold years use range most efficiently in this case. Livestock numbers only temporarily reach a level that will seriously harm the range. Theoretical models of livestock economists support this notion of optimal use of range in years with "average" range conditions. Common property grazing systems by property rights will be stocked more heavily than those with closed access; higher stocking rates thus will not achieve an economical optimum but produce a maximum output (JARVIS, 1984). It is possible for pastoralists to produce in these years more per hectare than commercial ranches without contradicting the overgrazing argument. This is not to say that no overgrazing occurs; in fact, overgrazing is likely to occur in most communal range systems and it would be irresponsible to claim that no long-term damage is being done.

In line with the statements of GRIGG (1974), we can find the general characteristics of pastoral nomadism:

> *"Pastoral nomads rely for their subsistence upon their herds. ... Most nomads try to maintain as many stock as they can, regardless of their condition or the grazing available. Most anthropologists have seen cattle numbers as giving an individual prestige and playing an important social role. But it can be equally well argued that the pastoral nomad is used to drought, and in Turkestan and Mongolia, winter cold, destroying his herds. Thus the larger the herd the greater the chance of some surviving. Mixed herds, rather than herds of only one type of animal, also give an insurance against drought failure."*

Although this description did not mention Tibet and yak nomadism, it still can be found that the complexities of nomadic systems are far beyond general imagination. Furthermore, all points of argument indicate that our knowledge of range ecology is too incomplete to justify in the name of development aid the use of unproved interventions to forcefully change a system, perhaps to the point of no return, – a system that may be more efficient and less damaging than any planned alternative (ZESSIN and FARAH, 1993). In addition, local conditions on the Qinghai-Tibetan Plateau are so variable that development and conservation decisions need to be made on the basis of micro-level information. However, at present, not enough is know about this unique rangeland ecosystem to make informed decisions about altering traditional, pastoral production practices.

Sustainable development has been defined as a phenomenon, whereby meeting the needs of the present generation does not jeopardize the ability of future generations to meet their own needs (more details see 1.5 of this book). In traditionally pastoral communities, one still finds a stronger sense of community and social responsibility than presently experienced in many developed societies where individual rights and freedom take priority. Villages and communities in western Sichuan have conserved biodiversity in the ecosystems surrounding their habitats over centuries with the help of their lifestyles, religion, and interdependent relationships established with nature. The challenges of maintaining a sustainable livelihood for pastoral communities are varied, complex, and difficult. However, issues that have been analyzed by many scholars[50] and are closely related to sustainable lifestyles for traditional societies in the Old World Dry Belt have put forward as a good basis for further discussions.

Sustainable plateau pastoralism, as a goal of scientists and development workers, can only be achieved through a proper linking of the macro- and micro-perspectives of the plateaus. Scientists can provide a great deal of generalizable knowledge about highlands which can help predict the possible outcome of natural and social forces. However, science in the end has its limitations, particularly at the local level. I have argued that technologies are location-specific and can only be adapted by pastoralists (who may, however, use information provided by scientists). This means that nomads must be elevated to the position of 'experts' in their own right and brought into the process of highland sustainable development.

For this purpose, formal scientists and non-indigenous technologists (those who make a profession of promoting technologies among rural people) must come to appreciate "informal" science and the knowledge of indigenous technologists (e.g., those who actually farm). Nomads and their forebears created a great storehouse of technical knowledge and tools for highland pastoralism, and much of this dates back thousands of years before the first scientists were ever born. An understanding of this indigenous knowledge from one plateau location could be extremely useful in another distant highland region of a similar structural type. Highland nomads themselves, over the globe, by the weight of their numbers, have more to give each other than most scientists have to give to them.

Natural resources' management systems are localized systems which form a basis for decision-making for pastoral people. Since the majority of grazing systems on the Qinghai-Tibetan Plateau just as all productive land systems in the developing areas operate under indigenous knowledge systems, therefore indigenous knowledge systems are not only of value for cultures from which they evolve, but also for scientists and planners striving to improve conditions in rural societies.

The term indigenous knowledge has been defined as "*systems that are generated by internal initiatives within a local community itself*". "*An indigenous system may be a new development*" (FISHER et al., 1989). Therefore, it should be carefully studied, assessed, and incorporated on a case by case basis into rural development for the improvement of rural livelihoods and environmental conservation. Although indigenous knowledge is becoming increasingly important, even today, the danger of losing this traditional knowledge

[50] For a collection of nomadism in the Old World Dry Belt see SCHOLZ 1992.

concerning diverse biospecies, mobility and land-use practices increasing. The need, at present, is to seek various approaches to sustainable pastoral and rural development in which indigenous knowledge will play the major role.

6.3.2 Developing a Long-Term Approach for the Environmental Dimension

As in many other areas, environmental degradation, as well as overgrazing of rangelands stems mainly from the pressure of the socio-economic structures of pastoral societies. Such societies, such as in western Sichuan, are always associated with a nomadic way of life and they certainly permit the exploitation of ecosystems whose plant production could not otherwise be used. However, it is a way of life incompatible with excessive growth in population and incompatible, too, with the literacy needed to make human progress possible. In the end, the management systems for conservation, production, purchase and marketing need to be integrated, which would be the basic guarantee to protect natural rangeland. The only way of ending the degradation of natural rangelands in western Sichuan, or even in the world today is through a new type of the socio-economic development in pastoral area based on environmental conservation.

However, the major problem facing western Sichuan, and even all of the Qinghai-Tibetan Plateau, is that every group pursues aims which have only short-term effects and which are often incompatible with long-term needs. Almost none of the groups or persons involved will be able to evaluate the importance of a task realistically, if it means placing legitimate immediate development interests of a region in second place to long-term ecological requirements, however urgent the latter may be. The nomadic Tibetan, using different biotopes at different altitudes, can contribute considerably to the affluence of the state; their future will depend on the willing cooperation and readiness to compromise of the individual interest groups and institutions, and on whether the efforts needed to stabilize the plateau ecosystem can be undertaken without delay.

On the other, developing adequate techniques to monitor the impact of agricultural or pastoral programs on the environment may be one of the more difficult tasks for all development agencies. The most commonly used indicators of progress in pastoral development projects have been increased production and/or changes in income. While these economic measures are important, they are not adequate as indicators of sustainability, environmental degradation, or resource conservation. Economists must find a way to place an economic value on the resource base and assist with the contrasting choices between individual short-term gains as opposed to the long-term contributions to society as a whole by conservation approaches. Although the science of ecology can contribute substantially to the evaluation process - particularly through the examination of ecosystems, it alone is far inferior to satisfaction. The challenge is to involve all of the scientific disciplines in the development of environmental criteria as they provide professional input into the development process.

Adding an environmental dimension to pastoral development programs will require a much longer time frame than has been used in the past. The short-term perspective of development programs has long been a problem, especially in identifying and planning to avoid consequences that do not appear for several years. Many environmental and natural resource degradation problems are of this nature. Formulation of long-term sustainability goals cannot be attained with a 2- to 5-year project planning horizon. Although a minimum of 10 years was recommended with rolling horizons for extensions (THOMAS, 1988), it also seems not to be enough for those fragile ecosystems in western Sichuan.

Development of pastoral production systems is intertwined with environmental protection goals as expressed in the International Convention on the Protection of the Environment. However, the maintenance and sustainable use of the environment cannot succeed without planning and cooperation between the decision makers, on the one hand, and livestock breeders, on the other, according to functional mechanisms to be recognized by concerned governments. This should make it possible to determine production goals, an accurate knowledge of life conditions of pastoral populations, as well as the prevalent patterns of grazing and herd movements. They should also permit improving conditions and preparing development plans to counteract drought or frigid pressure through effective food security programs as well as providing services for herders, both mobile and permanent. Nor is this all, for a government it should be also aware of the importance of sustainability for a long-term plan, and in which the main aspects would include:

- Major changes in appropriations, budgeting, and forward funding;
- compilation of comprehensive base-line data to describe the existing natural resource situation, the cultural setting, and the points of environmental stress;
- and formulation of long-term strategies for pastoral development and natural resource protection into which individual programs or projects would be placed. The continuity of individual projects would be more likely if they were identified with long-term goals.

6.3.3 Participatory Approaches for Natural Resources Management

The natural resource scene of the Qinghai-Tibetan Plateau's pastoralism is made up of harsh climate, high altitude, scarce water and the hardy livestock grazing the degraded rangelands. The central figure in the management of these resources is the pastoralist himself who is the primary user. The grazer on the range should be the decision maker in utilizing and conserving the rangeland. His attachment to the land and the customs should govern his decisions with respect to maintaining the long-term utility of the grazing land. Technological developments should supplement his conventional wisdom.

It is now widely recognized that a major barrier to sustainability in the high-frigid region is social factors in nature rather than technical factors, as long believed. Problems in rural development programs for community rangeland, pasture management, and soil and water resources' management are often related to a lack of strong local institutions capable of managing these resources and peoples' active participation on a sustained basis. There is also a lack of decision making leading to their own self-reliance rather than perpetual dependence on outsiders for ideas, linkages, and support. The strengthening of these local organizations and motivating people's active participation must go hand in hand with the introduction of new practices and technologies in order to have a long-term impact on the lives of mountain rural (ICIMOD, 1993). Consequently, I want to emphasize that pastoral management programs will only succeed if they are based on a participatory approach. Many experts have come to the conclusion that the failure to realize this is the reason why many range management projects have miscarried. (SWIFT, 1977)

It should be also attended to that accurate planning of the sequence of range improvement projects is a problem. Herders are often against range improvement projects which oblige them not to use resources for some time. Only when they participate from the start to program planning can they propose appropriate measures such as for instance short term relief. For the same reasons, for instance subsidies in terms of feed fodder can only be reduced or in the end possibly eliminated, according to a careful timing taking into account the speed of effective natural range regeneration. Therefore, the planning and implementation of development projects must include the active participation of the different social groups of livestock keepers concerned, as well as the involvement of institutions in which they have confidence, and those sedentary groups with whom they live in close contact.

Fundamental to development is the strengthening of pastoral self-responsibility for the conservation and the rehabilitation of degraded ecosystems, that is utilization and guarding of range reserves should for example be the exclusive responsibility of local people. The development of mobile livestock keeping must not be viewed in isolation; it is an integral part of the overall process of development in these areas and must be viewed as such. Therefore it should be part of a self-sufficiency, - target group - and self-help-oriented concept of development.

Following these comments, it is apparent that the collaborative research mode should be used to the maximum extent feasible, especially for programs concerning the environment and natural resources management for sustainable pastoralism. Although a large number of scientific publications on pastoral nomadism/mobile livestock keeping are available (SCHOLZ, 1992), it must be mentioned that interdisciplinary research has to be extended. Only through intensive research in the fields of natural resource management, human resources, social structure, economics, political and judicial circumstances, health etc. may mistakes in development planning be avoided. Furthermore, only when the extensive capability of nomadic herdsmen with respect to breeding, keeping and caring for livestock, as well as their knowledge of the natural environment, have be utilized in the planning and implementation of projects, the sustainable development of pastoralism in the remote nomadic society could be possible.

In conclusion, I wish to propose a few urgent needs if sustainable pastoralism on the highland is going to be more than just another development fad.

- At the present stage of (regional) land degradation it is urgently necessary to collect a more detailed data base on regional and even local level (FAO, 1987), which can serve as a starting point for detailed range management planning. The adaptation of the animals to the natural environment has to be considered, as well as the changes in the seasonal fodder supply, which may vary greatly within short distances as well as between different range or management units.
- With regard to the cold season fodder resources it is an important task to support the economy of mobility, as this is the only way to use these resources adequately in the long term without immense financial investments. Of course, investment in range is not cost effective in the short or medium term. It has a long term productivity dimension as well as an environmental defense one. However, politicians are often not paying the necessary attention to range because of the desire for short term effects of policies. Furthermore, infrastructural measures should be adapted to the needs of mobile livestock

keepers in order to facilitate living and working in the pasture lands and to counteract out-migration and further depopulation. It is necessary to create or expand not only the stationary and mobile health care network but also those educational facilities adapted to the mobile lifestyle of nomads, in order to reduce the present inequality of opportunity between the urban and nomadic environments (see JANZEN, 1991).

- The number of grazing animals must be taken into account in the production of foodstuffs (especially herbage). The basic principle for resolving the disequilibrium between fodder and animals is that the kinds and the levels of production must be determined by the quantity of foodstuffs, especially herbage. That is to say, in the light of what types of grassland or foodstuff we have, we can then determine the suitable species and breeds of grazing animals accordingly; in the light of how much grassland and fodder we have, then we can decide the number of animals accordingly may be allowed, but this does not mean increasing the quantity of livestock linearly and continuously.
- For future developmental planning, the aforementioned qualitative aspects of range utilization should be taken into account. The attraction of an increasing market economy has to be weighed against the risk of land degradation. Today the system of production is still more or less balanced, but it is already being used at close to its maximum intensity and is therefore highly vulnerable. For this reason it should not be submitted to the uncontrolled and continually changing market interests which follow from an increasing demand for cattle milk and meat.
- Mechanisms must be developed to ensure a more meaningful dialogue between scientists and technologists. These two perspectives (basic and applied) have long suffered from an inability to communicate with each other (even within disciplines – e.g., 'pure' economists do not understand 'applied' economists). One way to overcome this is by bringing together scholars and development workers within interdisciplinary teams to work on common problems. Such efforts, however, must have a field base where science meets reality.
- The highland perspective must be brought into both science and technology development. Science that advances by piling up isolated case studies which offer no synthesis or general principles are hardly science (it is more like stamp collecting). A science of the highland must, in turn, be made palatable and understandable to those who work in the highlands but who are not highland scholars. The highland perspective - how it works and why it is unique - must be politically and practically driven home to the point that no technical development project will receive funding without its incorporation into their plans and actions.

To achieve all of these aims, projects should be carried out as comprehensive package of measures, employing experts from different disciplines. A component which solely addresses range conditions and the development of the range resources should be considered imperative for projects dealing with rangelands. Both modern technical means as well as traditional knowledge from the target groups should be considered basic to constructive development.

6.3.4 Improvement of Rangeland Management and Policy Reforms

Degradation of rangeland ecosystems is a global problem, and the Qinghai-Tibetan Plateau constitute one of these threatened ecosystems. Environmental degradation on the Qinghai-Tibetan Plateau as well as the Himalayan region is basically a product of human intervention for the use of various natural resources, namely, land, forests, pastures, water, and minerals. The scale and dimensions of disturbances and the consequences of disturbances are often irreversible. The rangelands on the Plateau, which make vital contributions to pastoral production, are threatened by overgrazing due to an expanding population and misleading policies.

The impact of rangeland degradation extends very deeply into the economy and environment, which directly affects food, fuelwood, fodder, and water supplies. Further, through changes in production of land-based activities household livelihoods are influenced. It was these trends that had to be reversed so that the pastoral people could sustain their livelihood in full harmony with the environment. The concern of rehabilitation of degraded ecosystems by halting further degradation and restoring, and restocking vegetation cover is one of the prioritized issues in this area.

The rehabilitation of the vast stretches of natural rangeland degraded by overgrazing is now becoming an ever more urgent problem. In practice, the highest priority should be given to a more rational exploitation of pasturage that still exists and that is not yet irreversibly degraded. This would involve a reduction in the density of herds to a level below the carrying capacity of the rangeland, and in some cases its partial protection to allow the regeneration of grasses and other species suitable for fodder: overgrazed herbage is prevented from producing and disseminating its seeds. To achieve this, the administrative authorities responsible for rural development should create controlled zones of limited extent to allow the vegetation to reseed and also to demonstrate to local inhabitants the restorative effects of such a practice on a degraded pasture. Proof that such a policy has a beneficial effect on the land would certainly encourage herdsmen to reduce the density of livestock and thus alleviate the pressure on the vegetation.

High-frigid pastures are and will remain a marginal resource. Light, sporadic and opportunistic exploitation, like the traditional migratory pastoralism, is the only sustainable land use system. The only conservation technique applicable is the carefully considered use of such lands. This implies that the pastoral economy is not able to sustain an indefinitely growing number on a finite resource base. Range improvement will only be possible by reducing grazing pressure, which ultimately means a reduction of the number of people which remain dependent on livestock. Although there may be other chances, the overall need to find employment opportunities outside the pastoral sector will remain a constant challenge. Until now it should be clearly shown that in a region with a natural resource basis and physical circumstances such as that of the Qinghai-Tibetan Plateau, mobile livestock keeping based on an extensive utilization of the rangelands and a high degree of spatial mobility can be considered the most efficient economic source of subsistence and cash income.

The success and failures over decades bring out the experience that the improving livestock productivity should be based on the conserving, rehabilitating and improving the feed base by better pasture management. Basically this avenue was tried in both approaches: strengthening of potentials and removal of constraints.

Strengthening the productive potential of livestock usually entails genetic upgrading of indigenous breeds with high yielding exotic stock. This has failed so far, both biologically and economically, in almost all cases where it has been tried under pastoral production conditions. Removing constraints, on the other hand, has worked quite well in the case of animal health programs, at least in biological terms. Economic feasibility of animal health programs in pastoral systems still needs to be determined. Certain tasks in the field of animal health, such as communicable diseases and public health risks, will remain a government responsibility, whereas other veterinary activities which do not present a public risk but rather an economic risk to the producer alone, will have to be covered by the producer. Here one has to mention the control of internal and external parasites and the reduction of rearing losses. Gains in animal productivity might be considerable if the relevant measures can be applied, whether the increased productivity is sufficient to support the necessary inputs financially, remains doubtful in many instances.

The available scientific knowledge on natural resources and their management in this region is insufficient, due to historical reasons and the inaccessibility of geographical conditions. More and more scientific research activities have been conducted in the region by scientists from within and outside the region over the last two decades. However, the research is so expansive in nature and scientific knowledge can only be accumulated in a dynamic way from diverse activities conducted from time to time. Ecological processes include the interactions of various natural elements, including, water, soil, vegetation, geology, and climate, within the ecosystems and their dynamic interactions with human societies. The interactions of mountain systems and plain systems, the potential of natural resources in the rangeland ecosystems and technologies for sustainable management are some of the fundamental aspects of research needs. An integrated and holistic approach to the research in and monitoring of rural development and environment are recommended (ICIMOD, 1993). Capacity-building for balanced pastoral development and conservation at all levels is needed.

In order to carry out the rehabilitation effectively, macro-policies for sustainable resources use in highland areas should be given priority. Many of the present policies on credit, prices and access to resources have been designed and formulated with the needs of the organized urban-industrial and larger land-owning groups in mind. These policies have almost completely overlooked the needs of the rural groups, including the need for protection and conservation. Very few policies, in fact, provide any benefits to or incentives for conservation. Loss of local control over natural resource use has been a major factor behind the tragic wastage of land resources through uncontrolled degradation, and some policies seen to support these trends rather than enforcing corrective measures (ICIMOD, 1993). Therefore policy reforms at all levels must take into account the basic needs of the local people, particularly for women and children, and provide direct economic benefits to the local people. Incentives for rural development must be oriented to improving households' livelihoods and environmental conservation.

The overall role of policies in the case of natural resources managed on the Qinghai-Tibetan Plateau requires greater systematic professional attention than in the past. Government policies, particular land tenure systems, resource ownership, common property, resource management, and grassland rules, can strongly effect highland natural resources.

China has already issued the "Grassland Law". This law is the administrative means for grassland management. The implementation of the Law has prevented the unreasonable uses of grasslands to some extent and protected the grassland resources. The first task in applying the Law is to determine the right of using pastures and to definite the boundaries of grazing ranges for different regions and units. Although the pasture boundaries and the right of use were determined before, many disputes on how to use the pasturelands still took place in some places, such as between counties, between prefectures and even between provinces. The major reasons for the disputes were the contradiction between the traditional grazing movement of nomads and the present administrative boundaries.

Another important prerequisite for a development policy would be a change in the political and administrative order. Not centralization but decentralization would better facilitate nomadic interests and needs. As long as all important decisions concerning rural development policy are made, there will be no real chance of participation by pastoralists. Although there is no doubt that state intervention should be kept be to a minimum, there are cases where the involvement of the government and/or development agencies might be useful in order to carry out development activities. Infrastructural development projects are of particular importance for the remote areas of the country. To a certain extent they can also be considered as an indicator for progress and honest interest in the development of the nomads' habitat.

The improvement of social infrastructure is of major concern. The construction of sports and leisure facilities may contribute to slowing the exodus especially of young people to the urban areas. However, major efforts should be undertaken to build up educational and health services. Not only school education and vocational training should be strengthened, but also mobile medical and veterinary services should be provided in order to improve the harsh living conditions. At present the State has exempted the *Zamtang* County from animal husbandry taxes in order to help the sector develop. It has also introduced science and technology for animal husbandry by setting up a pasture station for grassland management and selecting or improving of grass and livestock; and eleven veterinary stations in every *Xiang* for the prevention and cure of animal diseases and epidemics. It has also introduced cashmere goat for cross-breeding and experimental purposes.

At the strategic level, diversification of the pastoral economy is seen as a viable solution for meeting the increased needs of pastoral societies, achieving economic growth, and alleviating poverty. Highlands in western Sichuan have rich biodiverse resources and varied ecological locations. Indigenous communities in this region have developed specific knowledge on the use of natural resources for their subsistence economies and some mountain products were traditionally exported to other regions (medicinal and aromatic plants, mushrooms, honey, wild fruit, animal products and others). These forest-pasture-based natural products should be further developed for mass production, while developing rural industries for the market. The resource potential and opportunities for marketing highland products should be fully used for income and employment generation.

The construction of small industries for manufacturing of local products in district and regional centers may improve the development of oriental pastoralism and reduce unemployment. Only through diversification can the economic future of rural areas be attained. In China, the recent rural economic growth and structural adjustment have resulted in diversification of the rural economy, and rural industries have been extensively developed. Although in pastoral areas the level of development is relatively lower, resource-based industries have also been developed, such as that in Zamtang, a slaughter factory was built up in 1993 and mainly processes beef and mutton; and a beverage factory was constructed in 1994 and takes up the production of seabuckthorn (*Hippophae*) juice as its main products. This has provided more employment opportunities for the surplus labor in rural communities and has increased appreciably rural incomes though exploiting local resources.

Strategies for range management and pastoral development on the Qinghai-Tibetan Plateau should aim to promote sustainable livestock production, rehabilitate degraded ranges, protect and enhance biodiversity, improve incomes and create employment, and contribute to economic development. Developing such strategies requires a much better understanding of range ecosystem dynamics, increased knowledge of pastoral production practices, more thorough analysis of the issues and opportunities facing pastoralists, and modifications in policies and current approaches. It is becoming increasingly clear that solving pastoral problems will require greater knowledge of pastoral production systems. Understanding the aims, purposes, and goals of the pastoralists is the key to sustainable pastoral development. Development programs must be socially as well as ecologically appropriate, and this calls for a much better understanding of the social dimensions of the rangeland ecosystem, including the social values attached to livestock and livestock management practices, land tenure, and community interactions.

The fact that prosperous pastoral cultures remain to this day on the rangelands of the Plateau bears witness to the remarkable diversity and resilience of the highly unique ecosystem, as well as the sustainability of its resources if wisely used. New perspectives regarding the assessment of range ecosystems, pastoral production practices and conservation development provide a valuable framework for studying high-frigid rangeland ecosystems and suggest fresh approaches for designing pastoral development in ways that complement environmental conservation efforts. Pastoral development programs will need to take into account local resource possibilities and constraints and the sensitivities of pastoralists. Development programs should be flexible enough to take into account new information as it emerges and to support activities based on technologically and socially accepted options. Only thus will the long-term viability of the Qinghai-Tibetan Plateau rangelands be protected and enhanced.

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APPENDIX

List of Seed Plants Occurred in the Context[51]

Gymnospermae

Pinaceae

Abies fabri (Mast.) Craib
Abies faxoniana Rehd. et Wills.
Abies georgei Orr
Abies squamata Mast.
Picea asperata Mast.
Picea balfouriana Rehd. et Wils
Picea likiangensis (Franch.) Pritz.
Picea purpurea Mast.
Picea wilsonii Mast.
Pinus densata Mast.

Cupressaceae

Sabina pingii var. ***wilsonii*** Cheng et L. K. Fu

Monocotyledones

Araceae

Arisaema flavum (Forsk.) Schott

Cyperaceae

Carex atrofusca Schkuhr
Carex digyne (Kükenth.) Tang et Wang
Carex enervis G. A. Mey
Carex kansuensis Nelmes
Carex moorcroftii Falc. ex Boott

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[51] The present plant list is based on collections of the author made during his field work from 1991 to 1993 in western Sichuan. Greater parts of the collection have been given to the Chengdu Institute of Biology, Chinese Academy of Science. Taxonomic errors as evident in the specimens determined in various herbaria by different taxonomists could not be excluded by authors. This list also includes a few introduced plants and cultivated plants.

Carex muliensis Hand. -Mazz.
Carex nubigena D. Don
Carex praeclara Nelmes
Carex scabrirostris Kükenth
Carex schneideri Nelmes
Kobresia capillifolia (Decne.) C. B. Clarke
Kobresia humilis (C. A. Mey.) Serg.
Kobresia kansuensis Kükenth.
Kobresia macrantha Böcklr
Koresia prattii C. B. Clarke
Kobresia pygmaea C. B. Clarke
Kobresia royleana (Nees) Böcklr
Kobresia setchwanensis Hand. -Mazz.
Kobresia tibetica Maxim.

Gramineae
Agrostis hugoniana Rendle
Agrostis limprichtii Pilger
Aristida triseta Keng
Arundinella chenii Keng
Avena sativa L.
Avena fatua L.
Blysmus sinocompressus Tang et Wang
Brachypodium sylvaticum (Huds.) Beauv.
Bromus inermis Leyss.
Bromus sinensis Keng
Bromus tectorum L.
Deschampsia caespitosa (L.) Beauv.
Deyeuxia scabrescens (Griseb.) Munro
Deyeuxia tibetica Bor
Elymus nutans Griseb.
Elymus sibiricus L.
Elymus breviaristatus Keng
Elymus dahuricus Turcz.
Elymus tangutorum (Nevski) Hand. -Mazz.
Festuca ovina L.
Festuca rubra L.

Festuca sinensis Keng
Helictotrichon schellianum (Hack.) Kitag
Helictotrichon tibeticum (Roshev.) Keng f.
Hordeum vulgare L. var. ***nudum*** Hook. f.
Koeleria cristata (L.) Pers
Koeleria litwinowii Domin
Poa alpigena (Blytt) Lindm
Poa alpina L.
Poa chalarantha Keng
Poa pachyantha Keng
Poa pratensis L.
Poa sinattenuta var. ***vivipara*** (Rendle) Keng
Poa sphondylodes Trin.
Poa tibetica Munro
Ptilagrostis dichotoma Keng
Ptilagrostis mongholica (Turcz.) Griseb.
Roegneria breviglumis Keng
Roegneria brevipes Keng
Roegneria melanthera var. ***tahopaica*** Keng
Roegneria nutans (keng) Keng
Stipa aliena Keng
Stipa capillacea Keng
Stipa purpurea Griseb.
Trisetum spicatum (L.) Richt.
Zea mays L.

Juncaceae
Juncus amplifolius A. Camus

Juncaginaceae
Triglochin maritimum L.

Liliaceae
Fritillaria cirrhosa Don

Dicotyledones

Berberidaceae
Berberis dasystachya Maxim.

Betulaceae
Betula platyphylla Suk.
Betula utilis D. Don

Caprifoliaceae
Lonicera hispida Pall. ex Roem. et Schult.
Lonicera microphylla Roem. et Schult.
Lonicera tangutica Maxim.
Lonicera tibetica Bur. et Franch.

Caryophyllaceae
Arenaria kansuensis Maxim.
Arenaria polytrichoides Edgew.

Compositae
Anaphalis flavescens Hand. -Mazz.
Anaphalis lactea Maxim.
Artemisia sp.
Aster alpinus L.
Aster souliei Franch.
Cacalia palmatisecta (Jeffr.) Hand. -Mazz.
Cacalia davidii (Franch.) Hand. -Mazz.
Heteropappus altaicus (Willd.) Novopokr.
Heteropappus bowoeri (Hemsl.) Griers.
Leontopodium longifolium Ling
Leontopodium nanum (Hook. f. et Thomas.) Hand. -Mazz.
Ligularia virgaurea (Maxim.) Mattf.
Saussurea bodinieri Lévl.
Saussurea globosa Chen
Saussurea stella Maxim.
Saussurea quercifolia W. W. Smith
Senecio kaschkarovii C. Winkl.

Senecio thianshanicus Regel et Schmalh.
Taraxacum lugubre Dahlst.
Taraxacum maurocarpum Dahlst.
Taraxacum mongolicum Hand. -Mazz.
Vladimiria souliei (Franch.) Ling

Crassulaceae
Rhodiola dumulosa (Franch.) Fu
Rhodiola quadrifida (Pall.) Fisch. et Mey.

Cruciferae
Brassisca rapa L.

Elaegnaceae
Hippophae rhamnoides L.

Ericaceae
Rhododendron agglutinatum Balf. f. et Forrest
Rhododendron cephalantnum Franch.
Rhododendron fastigiatum Franch.
Rhododendron flavidum Franch.
Rhododendron intricatum Franch.
Rhododendron anthopogonoides Maxim.
Rhododendron vernicosum Franch.
Rhododendron violaceum Rehd. et Wils.
Rhododendron yunnanensis Franch.

Fagaceae
Quercus aquifolioides Rehd. et Wils
Quercus monimotricha Hand. -Mazz.

Gentianaceae
Gentiana algida Pall.
Gentiana crassicaulis Duthie ex Burkill
Gentiana macrophylla Pall.
Gentiana straminea Maxim.

Juglandaceae
Juglans regia L.

Labiatae
Laminophlomis rotata (Benth.) Kudo

Leguminosae
Astragalus membranaceus (Fisch.) Bunge
Astragalus mahoschanicus Hand. -Mazz.
Caragana erinacea Kom.
Caragana jubata (Pall.) Poir.
Caragana tibetica Kom.
Hedysarum sikkimensis Benth.
Indigofera bungeana Steud.
Medicago sativa L.
Oxytropis kansuensis Bunge
Oxytropis ochrocephala Bunge
Trifolium pratense L.
Vicia unijuga A. Br.
Vicia faba L.

Papaveraceae
Meconopsis horridula Hook. f. et Thomas
Meconopsis integrifolia (Maxim.) Franch.
Meconopsis punicea Maxim.

Polygonaceae
Fagopyrum esculentum Moench
Polygonum viviparum L.
Polygonum sphaerostachyum Meisn.
Rheum officinale Baill.

Primulaceae
Androsace brachystegia Hand. -Mazz.
Androsace mariae Kanitz var. ***tibetica*** (Maxim.) Hand. -Mazz.
Androsace erecta Maxim.
Androsace tapete Maxim.

Primula sikkimensis Hook.
Primula vittata Bur. et Franch.
Prunus pilosiuscula Koehne

Ranunculaceae
Aconitum szechenyianum Gày
Anemone geum Lévl
Anemone rivularis Buch. -Ham
Caltha scaposa Hook. f. et Thomas.
Delphinium trichophorum Franch.
Delphinium tatsienense Franch.
Ranunculus brotherusii Freyn
Thalictrum alpinum L.
Thalictrum finetii Boivin
Trollius ranunculoides Hemsl.

Rosaceae
Cotoneaster microphyllus Wall.
Dasiphora fruticosa (L.) Rydb.
Fragaria orientalis Lozinsk.
Malus pumila Mill.
Potentilla anserina L.
Potentilla bifurca L.
Potentilla leuconota D. Don
Potentilla saunderiana Royle
Rosa omeiensis Rolfe
Sanguisorba filiformis (Hook. f.) Hand. -Mazz.
Sibiraea augustata (Rehd.) Hand. -Mazz.
Spenceria ramalana Trimen
Spiraea alpina Turcz.
Spiraea myrtilloides Rehd.
Sorbus koehneana Schneid.

Rutaceae
Zanthoxylum bungeanum Maxim.

Salicaceae

Salix ernestii Schneid.
Salix myrtillacea Anderss.
Salix rehderiana Scheid.

Saxifragaceae
Ribes glacial Wall.
Ribes meyeri Maxim. var. ***tanguticum*** Jancz.

Scrophulariaceae
Lagotis brachystachys Maxim.
Lancea tibetica Hook. f. et Thomas.
Pedicularis decorissima Diels
Pedicularis longiflora Rudolph var. ***tubiformis*** (klotz.) Tsoong
Pedicularis oederi Vahl var. ***sinensis*** (Maxim.) Hurus.

Solanaceae
Anisodus luridus Link et Otto
Anisodus tanguticus (Maxim.) Pascher
Solanum tuberosum L.

Thymelaeaceae
Stellera chamaejasme L.

Umbelliferae
Notopterygium forbesii H. Boiss.

Valerianaceae
Nardostachys chinensis Batalin

PHOTOS

(all Photos by the Author/1992-1996)

Photo 1 View of the alpine *Kobresia* meadow in *Hongyuan*

High-frigid rangelands in Northwestern Sichuan are the best grazing pastures on the Qinghai-Tibetian Plateau, which have attracted Tibetian nomads to go in for animal husbandry since thousands of years

Photo 2 View of the swamp meadow on the riverbed of *Zhe-qu* valley in *Zamtang*

Swamp meadows are mainly distributed in the depression areas with seasonal water accumulation or bottom of valleys. These areas are always used in spring or early summer

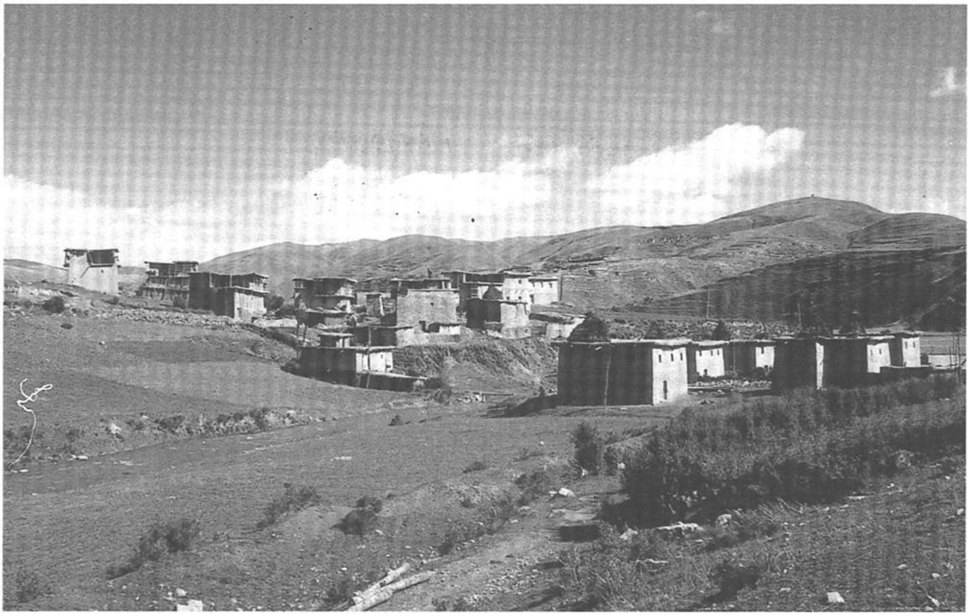

Photo 3 View of permanent settlements, farming fields and winter pastures of semi-nomads in *Zamtang*

Semi-nomads, who have permanent dwellings and take up the largest part of the pastoralists in Western Sichuan, rely for their subsistence not only on their herds but also on cultivation

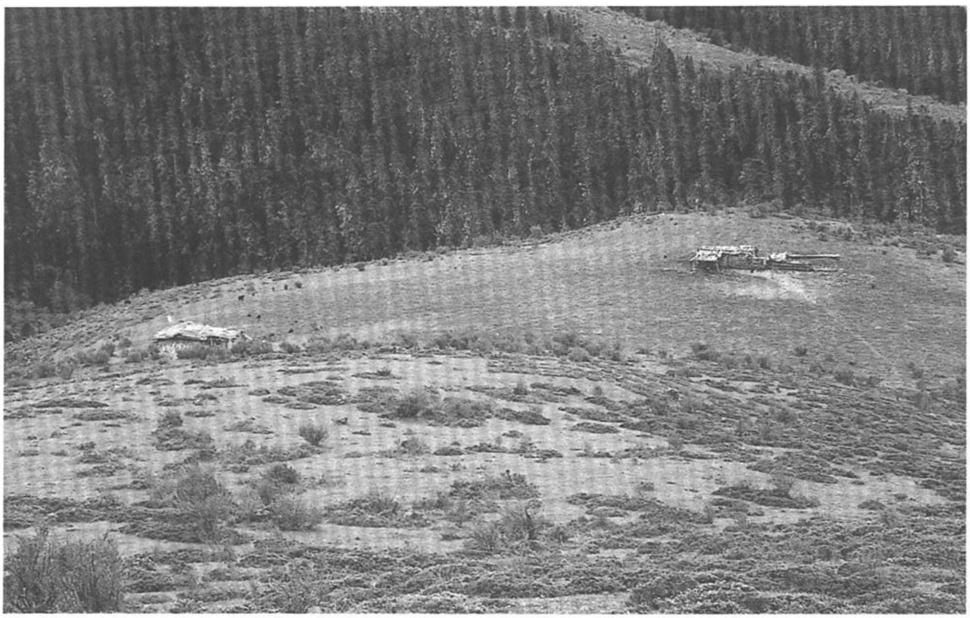

Photo 4 View of a mosaic winter pasture between subalpine forests and bush meadows, and wooden winter houses in a semi-nomadic system

Winter houses have been developed in recent decades both in the nomadic and the semi-nomadic system. They are always located on the sunny slopes, lee side of hills or places with diverse pastures

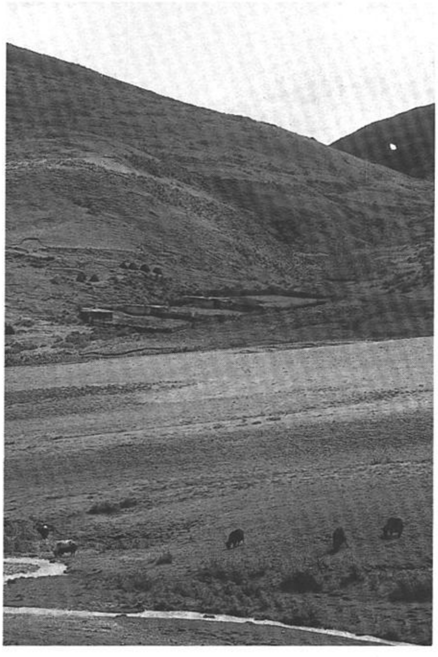

Photo 5 View of a winter pasture, with winter houses and stalls and growing oats in a nomadic system, *Zamtang*

During the last two decades nomads began to plant different forage grasses around their winter houses. The hay is stored in the stalls for supplementary winter feeding

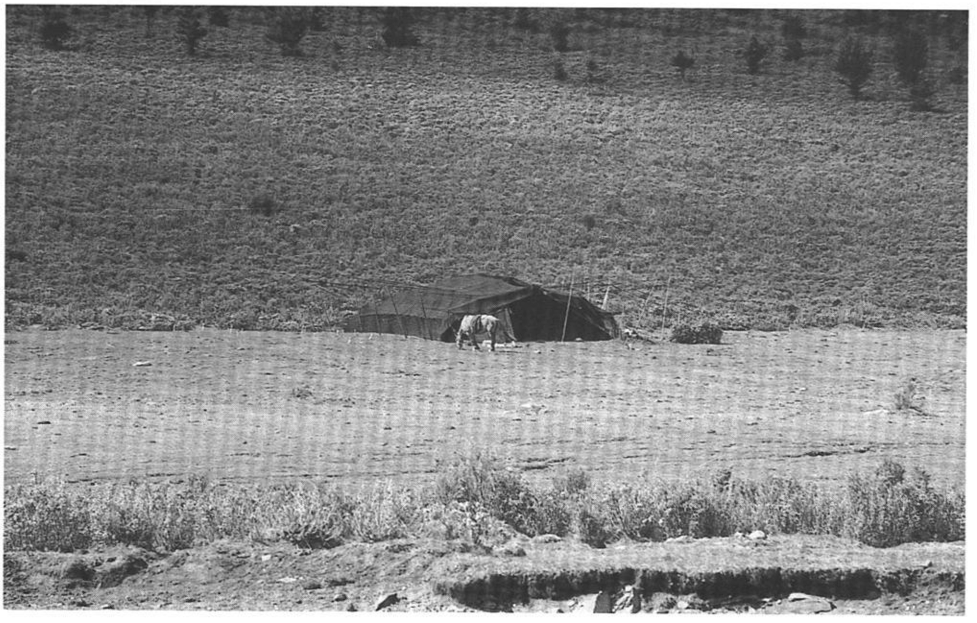

Photo 6 View of a black tent located on the clear-cut site which is being occupied by Rhododendron

Deforestation continually enlarges the winter grazing pastures in Western Sichuan. However, the following succession of shrub always invades these areas at once

Photo 7 View of a traditional winter campsite in *Zamtang*

Landscape interpersed with woodland, bushland and grassland increasing the ecosystem diversity

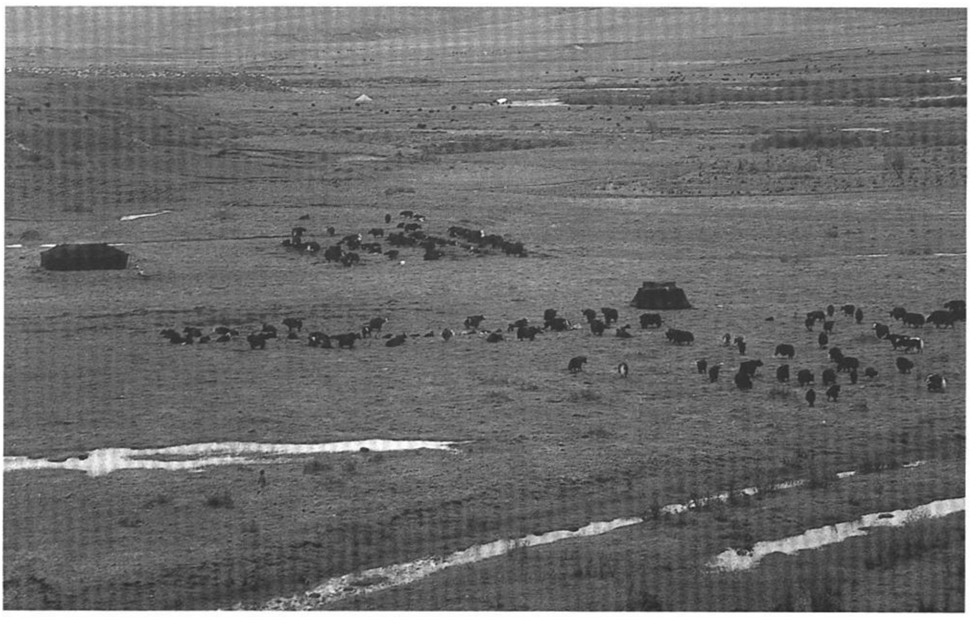

Photo 8 View of a summer pasture, with black tents of nomads and yak husbandry in *Zamtang*

Summer pastures are always located on the plateau surface or alpine area. The smooth slopes, flatvalleys, cool climate and high altitude provide the necessary conditions for the mobility of yak nomadism in summer

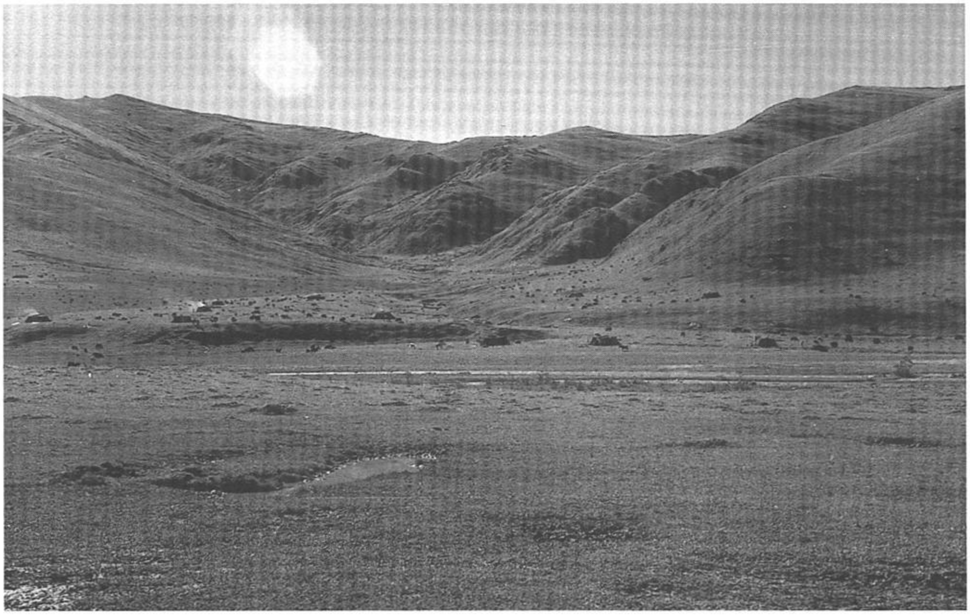

Photo 9 View of a large number of campsites in a transitional spring pasture

The continous increase of livestock density is leading to more grazing pressure on the rangeland ecosystem

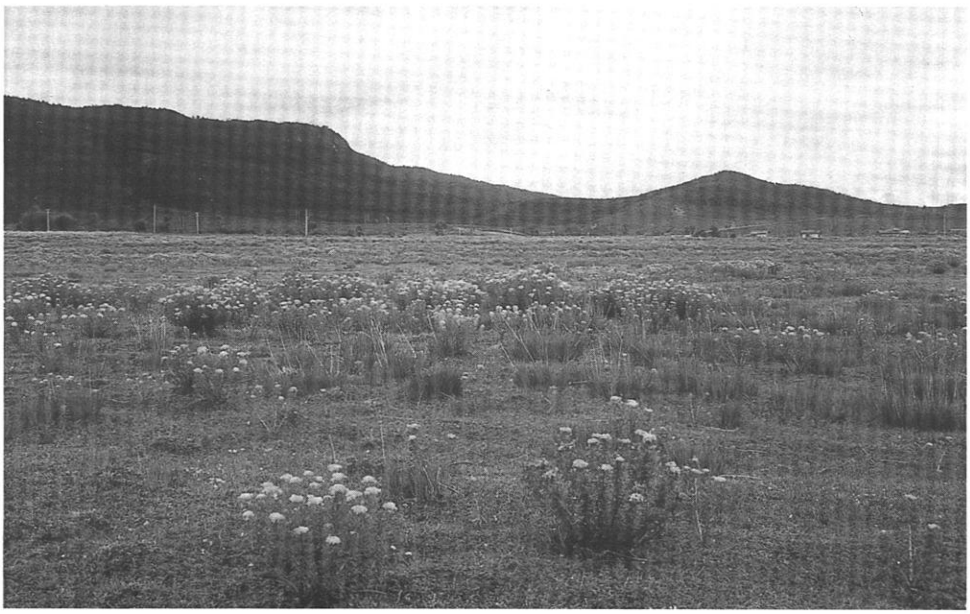

Photo 10 View of a degraded pasture invaded by unpalatable species

Visible changes in the vegetation composition are the first signs of degradation. After a long time selection, concentration of excessive numbers of animals in one area will inevitably result in the disappearance of the more palatable and valuable forage species and their replacement by less nutritious vegetation

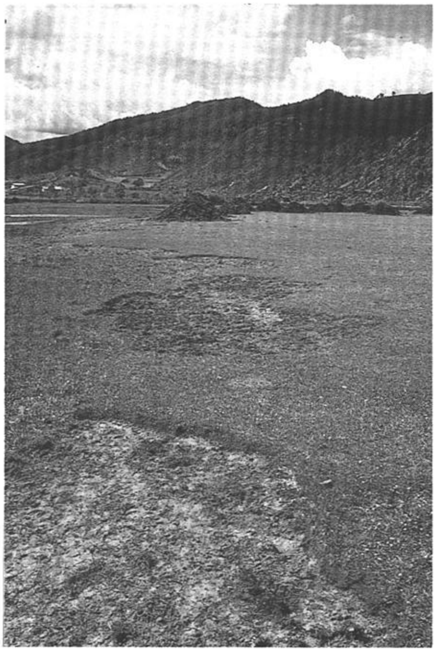

Photo 11 View of a damaged pasture due to the collec - tion of peat

Digging out peat, which is used as fuel or manure, from swamp meadows, is one of the main reasons for the destruction the pasture`s surface

Photo 12 View of the mounds and the loosened soil resulting from the rodents' excavation in *Hongyuan*

Rodents` damages to rangelands are very serious in western Sichuan and greatly affect the pastoral production there

Photo 13 View of the rangeland along the bank of the *Yellow River* in *Zoige*

Desertification is spreading southwards and affecting the rangelands on the southern bank of the Yellow River

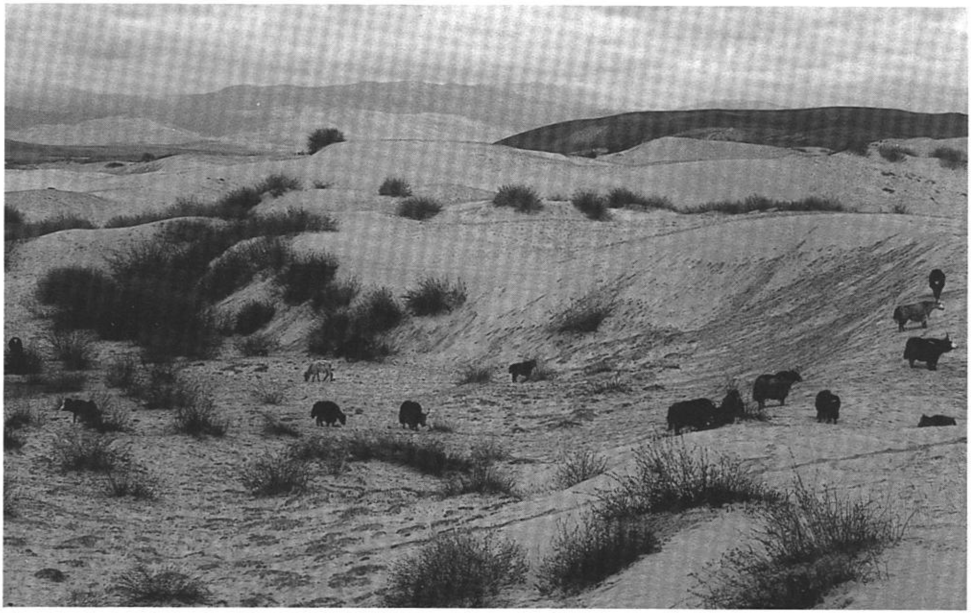

Photo 14 View of sand dunes in the north of *Hongyuan* which occurred in the 1980s

Most of the sand dunes in Northwestern Sichuan are newly formed by overgrazing, agricultural activities, as well as the climatic changes

Photo 15 View of a mixed herd of sheep and yak

Herd diversification is a traditionally risk-reducing strategy, which is practiced as an insurance against major disease outbreaks since the different species are generally not susceptible to the same pathogens and allow for a better utilization of pastures due to the different dietary preferences of the various domestic species

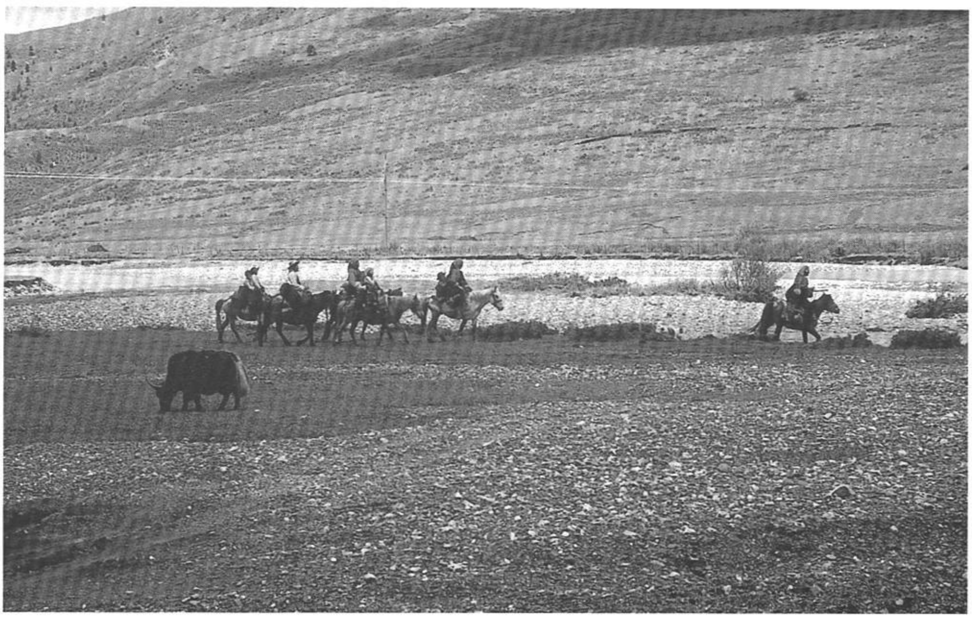

Photo 16 View of migrating nomads

Mobile livestock keeping is an optimum action which adapts people to the physical environment of high altitude areas. Therefore migration is a logical risk-averting strategy adopted by Tibetian nomads on the Qinghai-Tibetian Plateau

Photo 17 Migration of a nomadic family from winter to summer pasture in *Zamtang*

The search for pasture means that nomads have to shift their camps regularly and consequently need mobile, easily transportable or naturally available dwellings and other appropriate types of material goods

Photo 18 View of a Tibetan girl helping her parents to drive herds during the movement from one campsite to another

During the warm season, a yak herd will typically be moved every 10 to 40 days depending on the state of the grass and the size of the herd. One of the procedures is to move the livestock and the people with their tents and belongings all together in one movement, until the new site is reached

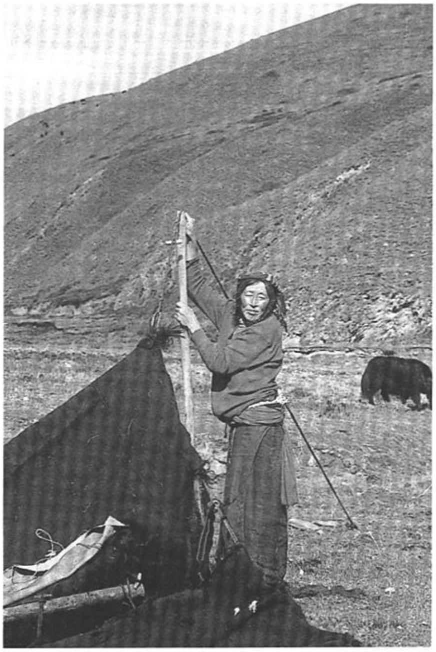

Photo 19 View of a housewife setting up her tent after a migration

The black tents made from yak hair are the typical dwellings for Tibetian nomads

Photo 20 Members of a nomadic family are setting up their tent in the spring pasture

Photo 21 View of an iron-wire fence in *Hongyuan*

The enclosure of winter pastures or degraded pastures in a small scale and only for the purpose of hay meadow construction and rangeland protection will alleviate the shortage of winter forage and improve the range conditions. However, fenced rangelands in a large scale are not only immune against diminishing range condition, but also involve heavy capital investment

Photo 22 View of new permanent settlements for nomads

Sedentarisation of nomads in Western Sichuan has been encouraged since the 1970s. More permanent settlements were built up with the help of the government

Photo 23 View of a milk collecting site in *Hongyuan*

Modern development of pastoralism in Western Sichuan is fundamentally influenced by marketing opportunities. The increasing market outlets provide more chances for private income on the one hand, on the other market oriented production is also affecting the traditional production systems in many aspects

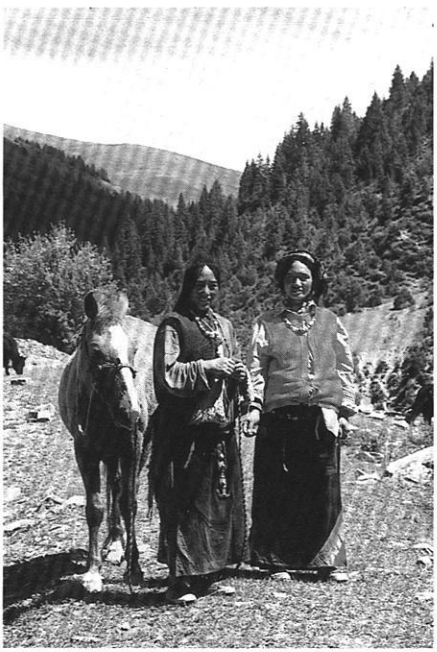

Photo 24 Nomads - the main users of natural resources on the Plateau

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