Nomadic Geography: Pastoral Environments in the Gobi Desert, Mongolia

Troy Sternberg

Hilary Term 2009

St Cross College
School of Geography
Oxford University

BODLEIAN LIBRARY OXFORD
DEPOSITED
THESIS
8/x/09

Thesis submitted in partial fulfilment of the degree of

Doctor of Philosphy

Abstract

Pastoralism on the Mongolian steppe encompasses limited physical resources and evolving anthropogenic influences. Little-studied, the Inner Asian region encounters changing climates, evolving land use practices, and socio-economic transition that impact the natural and human geography. This thesis investigates how bio-physical factors and herder action determine the pastoral environment in the Gobi Desert, Mongolia. Research, focusing on drought, degradation and the extreme winter conditions that define pastoralism in Mongolia, examines pastoralists' perception of and interaction with their environment. This approach highlights steppe ecological and social processes within the global dryland debate.

Fieldwork in Omnogovi and Ovorhangai Province established that drought is endemic in the region. However, drought events were independent of extreme winter conditions and did not exacerbate their impact. Degradation was not found at water points as vegetation cover decreased with distance from water. While remote sensing showed a decline in vegetation cover over time, it did not establish desertification on the steppe.

Changing physical, socio-economic, and political conditions since 1990 continue to impact Mongolian pastoralism. Environmental conditions, particularly water resources and pasture quality, were paramount herder concerns. This research showed that pastoralists are economically motivated, differentiate on multiple dimensions, and value communal land stewardship. On the steppe, traditional mobile livestock practices improve livelihoods and remain an effective management approach. However, the future of pastoralism is uncertain as herders settle, the population ages, and children become educated. Thesis results emphasize the interaction of physical and social environments will define pastoralism's role in the Gobi Deser

Acknowledgements

Deserts are said to lack life yet the Gobi was enchanting; the place, people, and exquisiteness of the steppe inspired the thesis questions. The goal was to make academic inquiry in Mongolia, by nature personal and for the smallest of audiences, relevant to global desert research. In 2001 I innocently walked into the Gobi; now 8 years later I leave with a thesis.

Heartfelt thanks goes to my supervisors. Nick Middleton knew the appeal and possibility of research in Mongolia. His discussion, enthusiasm and timely comments were vital. Nick's credo that geographers should know the world is the truest I have come across. Dave Thomas gave direction, insight, shared impressive knowledge of the desert, and conveyed a greater sense of what geography can offer. Together they encouraged independence and offered guidance throughout as the consummate supervisors.

In Mongolia thanks to my friend, co-researcher, and mentor Dr Batbuyan whose knowledge and passion about pastoralism permeates this project. Sharing his time, office, and laughter made fieldwork and the long winters a pleasure. I hope one day his expertise will be appreciated in Mongolia. Dr. Tsolmon's spirit, conversation, and support at the Remote Sensing Lab at the National University added perspective and depth to the project. Appreciation goes to the Mongolian Institute of Geography that hosted me and shared research, international exchanges, and festivities.

The Slawson Fellowship of the Royal Geographical Society and the interest of Mary and Paul Slawson meant much to me. The U.S. Fulbright Scholarship and the Stapley Trust generously supported the project. Gratitude goes to St Cross College for engagement and funding and to the long history, inspiration, and progressiveness of

Oxford University that provided a home for this research. The School of Geography, the staff, and my fellow D.Phils are fondly appreciated.

Thanks to Vanessa Winchester for her incisive critique, discussion, and English cheer; Heather Viles for broadening my geographical awareness and experience; Dawn Chatty for moving pastoralism beyond a geographical perspective; Mette who knows the steppe as I do; and in Mongolia Algirmaa, Tumor, Urtnasan, Altangerel, Erdenebayer and the Tsog and Munksuld families.

Personal thanks goes to my family and to Arlene, Jenny and Adam whose value of learning and pursuit of knowledge made undertaking a D.Phil seem so natural.

The people, culture, and environment of Mongolia made all possible. Herders shared their lives and knowledge; researchers offered encouragement and wisdom; amiable drivers, translators, officials, and strangers assisted the project. For all the salt tea, the 200 gers I know, mutton – cold or cooked, the kindness, surprise, and smiles of each day in the Gobi I give thanks. Perhaps a written word will lead a herder to water, motivate a worthy policy decision, encourage future research by Mongolian students, and continue the evolution of pastoralism. Ultimately the thesis is given to the vastness of the Gobi Desert, the sense of beauty and freedom of each day, and the people who make it home.

"The science of Geography, which I now propose
to investigate, is, I think, quite as any other
science, a concern of the philosopher"

Strabo *64 B.C. – 19 A.D.*

Table of Contents

Content	Description	Page
Chapter I	**Introduction**	**1**
1.1	Introduction	1
1.1.1	Background	3
1.1.2	Setting	6
1.1.3	Physical	6
1.1.4	Historical and Political	8
1.1.5	Climate	10
1.2	Degradation and Rangeland Dynamics	12
1.2.1	Degradation	12
1.2.2	Mongolian Rangelands	16
1.3	Pastoralist Dimensions	22
1.4	Perspectives on the Mongolian Pastoral Environment	26
1.4.1	Historical	26
1.4.2	Regional	28
1.5	Research Goals	29
1.5.1	Objectives	30
1.5.2	Expected Outcome	30
1.6	Theoretical Framework	31
1.7	Sites	39
1.8	Methods	41
1.8.1	Integrative Research Approach	42
1.8.2	Fieldwork	43
1.8.3	Climate	45
1.8.4	Drought	45
1.8.5	Normalized Difference Vegetation Index (NDVI)	46
1.8.6	Pastoralist Interviews	47
1.8.7	Statistical Analysis	48

1.9	Thesis structure	49
Chapter II	**Environmental challenges in Mongolia's dryland pastoral landscape**	**54**
2.1	Introduction	55
2.2	Methods	58
2.2.1	Area Description	58
2.2.2	Survey	59
2.3	Results	61
2.4	Discussion	65
2.5	Conclusion	70
Chapter III	**Pressurized pastoralism in South Gobi, Mongolia: what is the role of drought?**	**73**
3.1	Introduction	74
3.1.1	Drought in Mongolia	75
3.1.2	Standardized Precipitation Index	77
3.1.3	Study area	79
3.2	Methods	81
3.3	Results	83
3.3.1	Precipitation	86
3.3.2	Temperature	87
3.3.3	Normalized Difference Vegetation Index	88
3.3.4	Human population and livestock	89
3.3.5	Dzud of 1999–2001	90
3.3.6	Dzud and drought; non-drought years	92
3.4	Discussion	93
3.5	Conclusion	96
Chapter IV	**Drought dynamics on the Mongolian steppe, 1970-2006**	**98**
4.1	Introduction	99

4.2	Methods	101
4.2.1	Study area	101
4.2.2	SPI	102
4.2.3	Methods	104
4.3	Results	107
4.3.1	Spatial continuity of droughts	110
4.4	Discussion	111
4.5	Conclusion	115

Chapter V	**Vegetation dynamics and piosphere degradation on the Mongolian steppe**	**117**
5.1	Introduction	118
5.1.1	Mongolian Rangelands	121
5.2	Methods	124
5.2.1	Study area	124
5.2.2	Methods	125
5.3	Results	129
5.4	Discussion	138
5.4.1	Steppe grassland and pastoralism	140
5.5	Conclusion	143

Chapter VI	**Tracking Desertification on the Mongolian steppe through NDVI and field-survey data**	**145**
6.1	Introduction	146
6.1.1	Land degradation on the Mongolian plateau	147
6.2	Study Area	149
6.3	Data	150
6.3.1	In-situ observation	151
6.3.2	Satellite imaging	151
6.4	Results	153
6.5	Discussion	157
6.6	Conclusion	159

Chapter VII **Pastoral mosaic: livelihood, mobility, differentiation, and environmental engagement on the Inner Asian steppe** **161**

7.1 Introduction 162

7.2 Area & Methods 165

7.2.1 Study Area 165

7.2.2 Survey 166

7.3 Results 169

7.3.1 Herders 169

7.3.2 Herder Characteristics 170

7.3.3 Environmental Interaction 172

7.3.4 Mobility 176

7.3.5 Socio-economic factors 179

7.4 Analysis 182

7.4.1 Principal Component Analysis/Linear Regression 182

7.4.2 Differentiation 186

7.4.2.1 Sheep Equivalency Units (SEU) 186

7.4.2.2 Age 187

7.4.2.3 Education 187

7.4.2.4 Province 188

7.5 Discussion 191

7.6 Conclusion 196

Chapter VIII **Discussion** **197**

8.1 Introduction 197

8.2 Degradation 199

8.3 Drought 202

8.4 Significance of Water 204

8.5 Resilience 205

8.6 Steppe Sustainability 207

8.7 Pastoralist-environment dynamics 210

8.8 Research implications 212

Chapter IX Conclusion **217**

9.1 Conclusion 217

9.2 Future Direction 220

References **225**

Appendix A: Thesis article in Mongolian **250**

Мал аж ахуйн хэлбэр, арга ажиллагаа: Малчдын амьжиргаа, нүүдэл шилжилт, ялгаа Төв Азийн тал хээр дахь байгаль орчны талаархи үйл ажиллагаа

Appendix B: Questions in semi-structured herder interviews **280**

Appendix C: Statement of Originality/Co-author statement **282**

List of Figures

Figure 1.1 The Gobi Desert. 4

Figure 1.2 Steppe grassland, Omnogovi Province 5

Figure 1.3 Map of Mongolia with the 2 research areas. 8

Figure 1.4 Pastoral conditions in winter 12

Figure 1.5 Ovorhangai Province wells (*a, b*). 20

Figure 1.6 Ovorhangai Province spring (*a*), well in Omnogovi (*b*). 21

Figure 1.7 Herder milking livestock, Ovorhangai Province 24

Figure 1.8 Omnogovi Province, *ger* home and transport. 24

Figure 1.9 (*a*) Omnogovi Province, inside Tsog family *ger* home (*b*) family with researcher. 25

Figure 1.10 Map of Mongolia with vegetation zones. 40

Figure 2.1 Map of Mongolia with the 3 research areas. 59

Figure 2.2 Number of livestock owned by each herder. 64

Figure 2.3 Herding impact on the Mongolian environment. 67

Figure 2.4 Process of herder interactions affecting rangeland in rural Mongolia. 70

Figure 3.1 Map of Mongolia with precipitation isohyets (mm). 79

Figure 3.2 Standardized Precipitation Index at 3, 6, 12, 24, and 60 months time scale at the end of August, 1970 to 2006. 84

Figure 3.3 Comparison of significant SPI time series 1970 to 2006. 85

Figure 3.4 Long-term decadal precipitation average in South Gobi Province 1970 to 2006. 87

Figure 3.5 Population for Dalanzadgad and Bulgan, 1981 to 2006. 89

Figure 3.6 Livestock population in Dalanzadgad and Bulgan 1980 to 2006. 89

Figure 3.7 12-month SPI records, 1998-2003. 91

Figure 3.8 Average January temperature 1998-2003. 91

Figure 3.9 Average winter precipitation 1998-2003. 92

Figure 3.10 Human and livestock populations in Dalanzadgad and Bulgan, 1991-2006. 92

Figure 4.1 Mongolia with meteorological station locations and surveyed provinces. 102
Figure 4.2 Precipitation distribution in the growing season. 106
Figure 4.3 Precipitation record 1970=2006. 106
Figure 4.4 Annual number of days with precipitation. 106
Figure 4.5 Average January and July and maximum/minimum temperature °C at each station, 1970-2006. 106
Figure 4.6 Standard Precipitation Index at 12 months through August for 5 stations, 1970-2006. 107
Figure 4.7 Spatial drought at ten year intervals, calculated at 12-month scale (A = Arvaheer, B = Bulgan, D = Dalanzadgad, M = Mandalgovi, S = Saixan Ovoo). 110
Figure 4.8 Drought in 2006 at short and long-term time scales, calculated at 12-month scale (A = Arvaheer, B = Bulgan, D = Dalanzadgad, M = Mandalgovi, S = Saixan Ovoo). 111
Figure 4.9 Drought environmental-human processes on the Mongolian steppe. 113
Figure 5.1 Map of Mongolia with vegetation zones. 125
Figure 5.2 (*a*) Field measured vegetation coverage by distance from water point with standard error, and (*b*) species richness in Ovorhangai and Omnogovi by site. Average, 55 sites each, 2006/2007. 130
Figure 5.3 1998-2006 province average annual NDVI (*a*) and average monthly NDVI values (*b*) for Ovorhangai and Omnogovi, with standard deviation. 132
Figure 5.4 NDVI trends from 1998 to 2006 (Ovorhangai $r^2 = 0.19$; Omnogovi $r^2 = 0.23$). 132
Figure 5.5 Average annual precipitation (*a*) 1970-2006 in Ovorhangai ($r^2 = 0.001$) and Omnogovi Provinces ($r^2 = -0.03$); average monthly precipitation (*b*)1970-2006 in Ovorhangai and Omnogovi Provinces with standard error. 133
Figure 5.6 NDVI and precipitation patterns in Ovorhangai (*a*) and Omnogovi (*b*), 1998-2006. 133
Figure 5.7 CCA ordination. *a.* Major species (genus) and sites

distribution at all sites, *b.* main environmental and site characteristics. 136
Figure 5.8 CCA ordination. *a.* Ovorhangai – genus, sites,
b. Omnogovi – genus, sites. 137
Figure 5.9 pH (*a*) and total dissolved solids (*b*) at water points in
Ovorhangai and Omnogovi. 138
Figure 6.1 Map of Ovorhangai Province, Mongolia. 150
Figure 6.2 Relationship of NDVI and vegetation coverage in 2006. 153
Figure 6.3 Average percent vegetation cover with distance from
water point. 153
Figure 6.4 Annual precipitation and NDVI values, 1998-2006. 155
Figure 6.5 Monthly average NDVI values 1998-2006. 155
Figure 6.6 NDVI anomaly from mean value (r^2 =0.20). 155
Figure 6.7 Bi-annual maps of NDVI, Ovorhangai Province, 1998-2006. 156
Figure 7.1 Map of Mongolia with study regions. 166
Figure 7.2 Herder and adult population by percentage of age group. 171
Figure 7.3 Livestock number and Sheep Equivalency Units. 172
Figure 7.4 Herd composition. 172
Figure 7.5 Herder identification of drying water sources. 174
Figure 7.6 Precipitation and NDVI records, 1998-2006. 175
Figure 7.7 Herder income sources. 179
Figure 7.8 Herder expenses. 180

List of Tables

Table 1.1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces. 41

Table 2.1 Pastoral problems identified by herders in rural Mongolia. 62

Table 2.2 Most important water issues by % of citations. 63

Table 2.3 Most important rangeland by % of citations. 63

Table 2.4 Number of interviewees, average herd size, average number of moves per year and main environmental concern (%) by distance to water. 65

Table 3.1 Recent drought and *dzud* events in Mongolia. 80

Table 3.2 Drought events in Dalanzadgad and Bulgan, Mn. using 12-month SPI from 1970 to 2006. Includes droughts reaching moderate (≤-1.0) severe (≤-1.5) and extreme(≤-2.0) intensity.

Table 3.3 Number and percentage of months in drought by 85
severity as measured by SPI. Total number of months = 444. 86

Table 3.4 Annual NDVI value by site, 1998-2006. 88

Table 4.1 Site characteristics. 101

Table 4.2 Drought classification by SPI values and corresponding event probabilities. 104

Table 4.3 Precipitation and Coefficient of Variation records, 1970-2006. 105

Table 4.4 Months in drought 1970-2006, (predicted number of episodes over a 100 year period). 108

Table 4.5 Extreme SPI 12-month drought events. 109

Table 4.6 Significance of SPI values and number of days with precipitation (P = 0.01; 0.05). 111

Table 5.1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces. 125

Table 5.2 Genus and species total and presence by province. 134

Table 5.3. Major plant species by growth, form, livestock palatability, # sites, and province, and relative presence. 135

Table 6.1 Climatology 1998-2006 at Arvaheer meteorological station, Ovorhangai Province with Correlation of Variance (CV). 150

Table 6.2 Change in NDVI from 1998 and from prior year;

mean annual precipitation. 154
Table 7.1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces. 166
Table 7.2 Herder education. 171
Table 7.3 Years herding. 171
Table 7.4 Perceived pasture quality and precipitation. 173
Table 7.5 Distance to water. 174
Table 7.6 Families and number of livestock at water points. 174
Table 7.7 Sand intensity - % respondents. 176
Table 7.8 Significance of number of moves and herding variable. 177
Table 7.9 Number of moves migrating – livestock (9%) and tractors (4%) - were little used. 177
Table 7.10 Distance moved. 179
Table 7.11 Role of government - %. 182
Table 7.12 Principal Component Analysis. 183
Table 7.13 Linear regression for major pastoral factors. 185
Table 7.14 Differntiation between top, middle and bottom 20% of herders by Sheep Equivalency Units and age. 189
Table 7.15 Differntiation between top, middle and bottom 20% of herders by education and province 190

Acronyms

CV: Coefficient of Variation

IFRC: International Federation of the Red Cross

MNE: Ministry of Nature and the Environment

NASA: National Aeronautics and Space Administration

NDVI: Normalized Difference Vegetation Index

PDSI: Palmer Drought Severity Index

SPI: Standard Precipitation Index

UN: United Nations

UNCCD: United Nations Commission to Combat Desertification

UNDP: United Nations Development Programme

UNDPI: United Nations Department of Public Information

UNEP: United Nations Environmental Programme

UNU: United Nations University

WHO: World Health Organization

WMO: World Meteorological Organization

Glossary

Arid – environment with <200mm annual precipitation and high interannual variability.

Degradation - deterioration of the quality of an environment or ecosystem, commonly involving a decrease in biodiversity or capacity to support life.

Desert – environment with limited annual precipitation and a lack of water.

Dryland – environment lacking moisture in average climatic conditions featuring limited and variable precipitation.

Dzud – extreme winter weather event when snow, ice, cold, or freezing wind restricts forage access, often leading to high livestock mortality rates. A result of local conditions, there is not an equivalent English word.

Gobi Desert – located across southern Mongolia and northern China it covers approximately 1.3 million km^2, 1,600 km east to west and 900 km north to south.

Livestock – Mongolian animals include goat, sheep, horses, cattle/yak and camel.

Mongolian Plateau – relatively high (1000-1500m), flat terrain covering much of Mongolia and Inner Mongolia, China.

Nomad – originally a person with no fixed home that migrates to find fresh pasture for its animals. Today semi-nomadic is a more appropriate term in Mongolia as pastoralists often move to traditional pastures and return to a winter camp.

Pastoralism – locally defined as the movement of livestock and herders according to seasonal and ecological conditions.

Semi-arid - environment with 200-500mm annual precipitation and moderately high interannual variability.

Soviet – relating to or under the influence of the former U.S.S.R.

Steppe – vast, comparatively level and usually treeless plains.

Transhumance - seasonal movement of people and livestock over relatively short distances.

Chapter I

Introduction

1.1 Introduction

With the world's "greatest concentration of areas of rapid land-cover changes, and in particular dryland degradation" (Lepers *et al.* 2005, p. 122), Asia is now being impacted by changing climates, increasing aridification, rapid socio-economic and political transition, and evolving land use practices with these affecting both the physical and human geography (Lioubimtseva *et al.* 2005; Yang *et al.* 2005; Geist 2005; Rossabi 2005; Zhang *et al.* 2007). Whereas previous pastoral and degradation/land cover studies and associated models have predominately centred on African environments (Nicholson *et al.* 1998; Sporton and Thomas 2002; Sallu 2008), Asia's geographical conditions, representing differing physical aspects and human influences, compel examination from a regional perspective and revised understanding. Natural processes are shared with other regions yet ecosystem determinants are distinctly tied to local landscapes (Fernandez-Gimenez 2000; Sasaki *et al.* 2008). Research embedded in the Asian environment is critical to assess today's dominant ecological concerns and address the implications of these concerns for the future.

Inner Asia has recently undergone major political and social transition from communism to a market-oriented development model. Within the region, Mongolia is a country where pastoralism, evolved over millennia in a harsh landscape, must now adapt to modern-livelihood challenges. The environment is experiencing a warming climate, increased precipitation volatility, and natural phenomena such as

drought and *dzud* (extreme cold winter weather) (Batima *et al.* 2005); these have been little studied.

Serious climatic events occur with increasing frequency on grasslands identified as highly degraded, with this resulting in an intensification of natural hazards (Fernandez-Gimenez 1999; Bold 2001; UNEP 2002; Yang *et al.* 2004). Traditional, ecologically-based practices continue to evolve as herders concentrate on income generation while government support and development efforts decrease. Pastoral livelihoods, practiced in open-range grasslands, adjust to changing conditions in a harsh landscape. The dryland setting exemplifies how physical and human modifications affect desert and steppe grasslands (Bilskie and Arnold 2002; Louibimtseva *et al.* 2005; Nandintsetseg *et al.* 2007; Normile 2007).

This thesis, by expanding the existing dryland focus from Africa and the Middle East to Inner Asia, aims to broaden knowledge and provide a definition of pastoral environments in the Gobi Desert. Landscape dynamics and herders' ecological interactions and perceptions are examined by restructuring established fieldwork methodologies to fit a region in central and southern Mongolia. The research spans multiple scales, primarily local and national, but also regional as the Mongolian plateau is shared with China; it is intended that it should provide data and results that are applicable across the border.

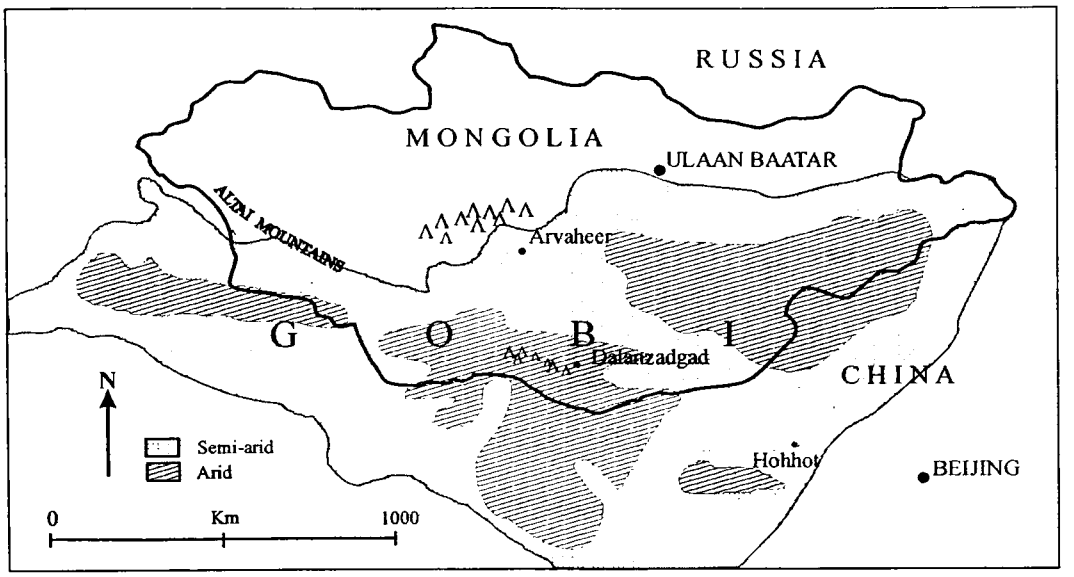
The overall object of the research is to provide an in-depth study of environmental parameters and steppe-ecological processes that inform herder and government management decisions and enables comparison with land use and degradation processes both within the wider region and globally. Dissemination of the research findings will convey little-known steppe environmental dynamics to the international scientific community.

The critical elements of the work focus on drought, *dzud* (extreme winter), degradation, and human interactions within the natural landscape. Research takes place in an ecosystem confronting changing global processes and socio-economic influences. This thesis, by supplying a synthesis of local geography, evolving environmental forces and pastoral motivations, presents a cohesive examination of the Gobi Desert environment.

1.1.1 Background

Drylands cover a third of the world's land mass and are inhabited by a billion people (Veron *et al.* 2006; Washington-Allen *et al.* 2008). In these landscapes pastoralists engaged in mobile livestock-raising are a subset concentrated in Africa and the Middle East (Thomas *et al.* 2000; Evans and Geerken 2004; Herrmann and Hutchinson 2005; Hein 2006); pastoral research has traditionally focused on these regions. Past geopolitical constraints have led to under-representation in the academic literature of pastoral environments in the arid and semi-arid zones of Central and East Asia (Fernandez-Gimenez 1999; Li *et al.* 2006). The regional steppe landscape is characterized by extensive dry plains, great seasonal temperature variability, and extreme cold in an inland continental location. In Asia, where rangelands provide 80% of livestock feed (Sugita *et al.* 2007), local pastoralism lacks the common pastoral conditions of population, agricultural and, until recently, economic pressures. Remote from developed-world paradigms, alternative government interaction models have created a landscape that offers both divergent physicalities and perspectives that differ from conventional pastoral environments. Disengagement from western development approaches provides an original research opportunity to increase dryland understanding regionally and on a larger global scale.

This thesis expands the existing dryland focus on Africa and the Middle East to broaden knowledge and definition of pastoral environments in the Gobi Desert, an area of 1,295,000 km^2 in Inner Asia (Figure 1.1) (Allen and Warren 1993).



after Allen and Warren, 1993.

Figure 1.1 The Gobi Desert.

Nomadic pastoralism, the movement of livestock and herders according to seasonal and ecological conditions (Bazargar 2002), is practiced on the Mongolian steppe with this customary activity continuing to provide a livelihood for 40-50% of the national population (Fernandez-Gimenez 2006; Chuluundorj 2006; Johnson *et al.* 2006). Historically, limited ecological resources and restricted livestock numbers encouraged mobility as a means to use the grassland productively. Today pastoral inputs function within a complex system balancing physical and anthropogenic change against environmental and socio-economic limitations. Sustainable land use, income, modernization, and climate variability are pastoral concerns in an era of social transition. In the steppe landscape pastoral viability is determined by the environment, hence ecological issues must be addressed. Through physical and

social research this thesis examines the bio-physical and human determinants that today shape the environment in the Gobi Desert, Mongolia (Figure 1.2).



Figure 1.2 Steppe rangeland, Omnogovi Province.

Water, land cover, and the human impact on drylands are well studied; these factors can segue into degradation, sustainability, and development. In desert landscapes such issues combine to shape both physical and human pastoral environments. In Mongolia water exemplifies this interaction; its availability determines pasture resources and grazing patterns as its scarcity affects land use and cover and engenders degradation, particularly where livestock intensification has taken place. Centrally, water resources are dependent on climate and human action. The former affects surface sources, underground recharge, and grassland growth; the latter controls water infrastructure (wells), their use patterns, and development. Both the environment and pastoralists react to changing pastoral parameters (*e.g.* livestock, mobility, economic forces) that impact land cover, degradation, and livelihood

practices. On the steppe there are multiple inter-related factors; these require geographical description, environmental definition and an understanding of the composite layers of pastoralism.

1.1.2 Setting

Knowledge of the physical and historical setting is essential for defining the parameters of the pastoral environment. The selected location for this research is the Gobi Desert of Mongolia encompassing desert, desert steppe, and steppe landscapes that represent the majority of the country's terrain (Geographical Atlas of Mongolia 2004). Factors that once ensured seclusion – isolation, distance, limited opportunity - now constrain development. Societal transition from Soviet communism to democratic capitalism since 1990 has reconfigured pastoralism. The customary subsistence approach to livestock-raising has given way to market-oriented demands and intensification around limited water points. Natural hazards, once mitigated by a strong state, are now more likely to become disasters. As pastoral needs and motivations evolve within a modernizing society the key to understanding past and present processes on the steppe is awareness of the physical-human nexus framing the environment. Historically transhumanance has been an effective adaptation to natural limitations yet today's challenges offer perhaps the greatest test to pastoralism's continued existence.

1.1.3 Physical

Mongolia, located in Inner Asia, is bordered by Russia to the north and China to the south (Figure 1.3). Grasslands comprise 80% of the country's 1.56 million km^2, an area that supported 34 million livestock (sheep, goat, horses, camels, cattle/yak) in

2006 (Mongolian Statistical Yearbook 2006). An upland country, 85% of the land is above 1000 m with most grassland between 1000 m to 2500 m. Bio-climatic zones include montane (8%), forest steppe (15%), steppe (34%), desert steppe (23%), and desert (19%) (Geographical Atlas of Mongolia 2004). The continental climate, extreme temperature variation (40°C to -40°C annually, and diurnal ranges of up to 30°C), short growing season, and poor soils limit crop agriculture to <1% of the surface area (Batima and Dagvadorj 2000). Annual precipitation ranges from <50mm in the southern Gobi region to >400 mm in mountain areas; the national average is 224 mm (Batjargal 1997). Two-thirds of Mongolia has no open water sources and is dependent on wells to water livestock and 70% of the country's potential underground water resources are located in the Gobi Desert and steppe regions (Johnson *et al.* 2006). Approximately half the country's 2.5 million people are dependent on pastoralism for their livelihood (Mongolian Statistical Yearbook 2005; Johnson *et al.* 2006). Recent out-migration from rural areas has increased the capital Ulaan Baatar to 1 million inhabitants. The lone city determines the national agenda, leaving herders with minimal input on politics and policy. The low population density (1.7 people per km^2) accentuates the livelihood challenges extant in Mongolia's harsh landscape.



University of Texas, 1996

Figure 1.3 Map of Mongolia showing the 2 research areas.

1.1.4 Historical and Political

Recent luminescence dating applications to sediments suggest a 6,500 year history of grazing on the Inner Asian steppe (Mandzy-Herring 2008); conventional sources trace pastoralism on the Mongolian plateau over more than 4000 years (Fernandez-Gimenez, 1999; Landsberg *et al.* 2003; Sasaki *et al.* 2008). The inhabitants, identified variously as Turkic or Proto-Mongol, were pastoral nomads later supplanted by Mongols. Chinese sources from the 8th century B.C. identify nomadic people whose "power rested in their supremacy as horsemen and warriors, living a nomadic existence based on sheep and goats, with oxen and camels as draft animals" (Moses and Halkovic 1985, p. 17). The loosely-organized tribes that dominated the central steppe were unified in 1206 by Genghis Khan.

Though basic pastoral practices throughout history are recognizable today, the political and economic structure within which pastoralism is now practiced has

evolved markedly over the last century. The current market-oriented, privately-owned livestock system contrasts with the feudal approach of a hundred years ago and seven decades of Soviet communism in the 20th century. During the earlier era, pastoral administration was exercised by secular princes or leaders of Buddhist monasteries through informal regulatory institutions that coordinated seasonal movements and controlled large numbers of livestock maintained by local herders ("serfs") following "unwritten law" (Fernandez-Gimenez 1999; Bold 2001; Suttie 2005). In 1924 Mongolia became the first Soviet satellite nation to adopt a communist system of state-owned rangeland. Collectivization was unsuccessfully attempted between 1929-1932 as Mongolians preferred to let animals perish rather than become state property. Nevertheless, by 1960 re-implementation led to 99% of herders becoming collectivized (Moses and Halkovic 1985; Middleton 1992). From this time a government-directed, centrally-planned economy controlled herding, allocated rangeland, regulated migration and provided livelihood support. This was a period of infrastructure expansion, water development, veterinary services, subsidized transport, emergency fodder and relief. Herders received a salary and had limited livestock (75-150), though in the event of mortality they had to repay the government (Fernandez-Gimenez 2000; Ykhanbai 2004). The era transformed pastoralism from its traditional subsistence basis to a production-oriented system. By maintaining highly mobile, low impact grazing patterns the environmental consequences during collectivization were limited.

Political upheaval in the Soviet Union coupled with a pro-democracy movement in Ulaan Baatar, Mongolia's capital, brought societal transformation in 1990 (Rossabi 2005). Events over a short period saw countrywide transition from state communism to a democratic market economy stressing private ownership and responsibility and a

drastically reduced government role. Elections were held and in 1992 a new constitution was ratified that enshrined human rights, personal freedoms, communal land stewardship, and decollectivized livestock (Bilskie and Arnold, 2002). The last 15 years have seen Mongolia fall into the more universal pastoral norms of maximized livestock production, reduced mobility, increased sedentarization, and concentration on income-producing animals, with herder motivation and options changing from meeting quotas to generating income similar to other pastoral regions in the world (Bedunah and Harris 2002; Sorbo 2003; Lesorogol 2006). Concurrently government levels of support and control have been slashed, land tenure has evolved towards private possession, and poverty is widespread (Sneath 2003). The predictable results are the deterioration of the rural water infrastructure, intensified grazing patterns, increased land degradation, and an end to cooperative herding decision-making and implementation (Batjargal 1997; Janzen and Bazargur 2003).

1.1.5 Climate

Inner Asian pastoralism experiences significant climate variation. The region combines African summers with Siberian winters, Saharan levels of precipitation with alpine environments. *Dzud,* the primary natural hazard caused by extreme winter snow and ice conditions, prevents livestock from foraging and causes high mortality and human displacement (Suttie 2005).

Drought is a major concern throughout drylands, particularly its impact on land degradation (Herrmann and Hutchinson 2006), yet in Mongolia it has received little attention. Fluctuating precipitation, warming temperature (1.8°C increase over 60 years), changes in seasonality, shifting frost-free days, and high climate Coefficients of Variation make a chaotic weather background for pastoralism (Begzsuren *et al.*

2004; Batima *et al.* 2005; Munkhtsetseg *et al.* 2007). As elsewhere, climate defines pastoralism but with factors distinct from most other arid zones. Variable climate patterns control pasture growth, limit agricultural opportunities, and reduce alternatives to herding. The combination of climatic stress and land cover change can cause physical disturbance and social disruption (Williams and Balling 1996).

Climatic benchmarks are important in any ecological system. Several dryland regions have well-established climatic data records and numerous historical analyses of climatic patterns, their impacts, and their implications have been carried out (Hayes 1999; Lloyd and Hughes 2002; Sonmez *et al.* 2005; Mihajlovic 2006). During the communist era meteorological capabilities were developed in Mongolia; data collection continues with the potential for analysis and interpretation that could be instructive for rural livelihoods and provide source material available for informing government action. Detailed knowledge, critical for rangeland planning in other countries, has yet to receive local scientific enquiry. Precipitation anomalies have growing importance for local herders and government pasture management as climate change increasingly affects regional weather patterns and temperature gradients (Wu *et al.* 2007; Nandintsetseg *et al.* 2007).

The Mongolian landscape provides an opportunity to examine links between pastoralism and atypical physical parameters, such as extreme cold Figure (1.4). Whereas drought is common in arid regions, its coupling with severe winter conditions (*dzud)* causes a natural hazard of paramount concern to local pastoralists but unknown outside Inner Asia (Batima *et al.* 2005). The common perception is that the two hazards are related, with drought exacerbating the effects of *dzud* and leading to increased livestock mortality (UNCCD 2002; World Bank 2005; FAO 2006). Investigation of the potential interaction between drought and dzud requires analysis

of meteorological records. Following procedures instituted elsewhere (McKee *et al.* 1993; Hayes *et al.* 1999), in-depth research provides an opportunity to develop a new research component for climate monitoring of potentially serious hazards on the steppe.



Figure 4 Pastoral conditions in winter.

1.2 Degradation and Rangeland Dynamics

1.2.1 Degradation

A primary concern across the world's rangelands is the effect of land cover change, desertification and degradation on grassland productivity and pastoral livelihoods (Veron *et al.* 2006).

The term desertification denotes an "irreversible decrease or destruction of the biological potential of the land" (Mainguet 1991, p. 4); though there are several published definitions the topic remains somewhat controversial. The concept of desertification originated to describe dryland changes in Africa. Reports of the southward expansion of the Sahara desert in the 1970s and the United Nations

Conference on Desertification (UNCOD) in 1977 (Lamprey 1975; Sallu 2008) created international awareness of the issue. Although it is well known that landscapes are impacted by changing climatic and physical factors combined with human action, only recently have the previously remote regions of Inner Asia been included (UNEP 2002; Yang *et al.* 2004; Flores-Flores *et al.* 2008). Research into desertification and degradation on the Mongolian plateau is a significant research topic since it has global implications due to the Pacific-wide effect of associated dust transport and its potential impact on populations (Chen and Tang 2005; Akata *et al.* 2007; Wang *et al.* 2008).

While degradation may represent a loss of land productivity, desertification can signify a system crossing a negative threshold resulting in permanent decline and an inability to return to its original state (Geist 2005; Sasaki *et al.* 2008). Thus, when addressing desertification it is important to assess the extent and nature of the problem, identify relevant physical and social processes, consider mitigating forces, and recognize regional variability (Thomas and Middleton 1994; Thomas 1997).

The United Nations (UNU 2007, p. 1) identifies desertification exacerbated by climate change as the "greatest environmental challenge of our time". However, a major problem limiting clarity on this critical issue is lack of consensus on how degradation is identified and measured. Goudie (1990) highlights several formative processes for desertification. These range from human (Dregne, 1986) or natural causes (Warren and Maizels, 1976) to climatic (Sabadell *et al.* 1982), temporal (Wehmeier, 1980) and spatial agents (Hellden, 1985). Differing definitions reflect the variability and disorder surrounding the science of desertification that continues today (King *et al.* 2007; Behnke 2008; Stringer 2008). Despite varying emphases, the general definition focuses on the "spread of desert surface and reduction of the

potential productivity of affected areas..." (ICIHI 1986, p.4). This basic definition continues to be expanded and modified. Although the term desertification is elusive to define and measure, it has become an important part of the Mongolian national debate (Batjargal 1997; UNCCD 2006; Rudaya *et al.* 2008). While some literature acknowledges data limitations and a shortage of field observations (Wang *et al.* 2005), claims for desertification in the region vary greatly depending on the assessment method and location (Zha and Gao 1997). Sasaki *et al.* (2005) draw their conclusions from one piosphere whereas Normile (2007) suggests that 4 million square kilometres of China are degraded (an area larger than India and Pakistan combined).

Regional assessment methodologies vary widely, including measurement of biomass, soil, erosion, and vegetation cover, lay and expert analysis, remote sensing, climate modelling, and meta-data studies (Xue 1996; Javzandulam *et al.* 2005; Zhao *et al.* 2005; Yang *et al.* 2005; Li *et al.* 2006; Huang and Siegert 2006; Bayarjargal *et al.* 2006; Ma *et al.* 2007). Consequently, the effectiveness of methods used in this vast region (which includes the Gobi Desert), the applicability of results from specific research sites, the limited numbers of surveys, and validity of analyses remains uncertain.

The task in this thesis is to evaluate degradation in parts of the Gobi Desert, Mongolia and, if found, identify whether it is influenced by anthropogenic pressure, natural processes, or a combination of factors (Rudaya *et al.* 2008). Locally multiple causes of degradation are cited, ranging from a warming climate, extreme winter weather, drought, loss of land cover, biomass, and rodent damage, to overgrazing, lack of wells and transport, and mining (Okayasu *et al.* 2007; Asian Development Bank 2004; Baasandorj 2008; Himmelsbach 2008). Yet differing definitions, assessment methods, and interpretation can result in causal ambiguity. Conflicting

results are supplied by two studies in Mu Us District, Inner Mongolia which came to opposite conclusions as to whether desertification was a result of human or physical factors (Yang *et al.* 2005; Wang *et al.* 2008).

The lack of consensus exemplifies the disparate assessment practices for determining and analysing degradation. The challenge is to document ecological processes in order to provide a scientific foundation for claims of degradation. General assertions concerning land conditions are unsupportable without an empirical basis supplying verifiable data. Mongolia's under-researched drylands (Sasaki *et al.* 2008) offer a prime example of how land cover change in arid and semi-arid environments continues to be poorly documented and, consequently, its causes remain inadequately understood (Thomas 1997; Geist 2005). The UNCCD (United Nations Commision to Combat Desertification) (2002) found a lack of information and monitoring of desertification in Mongolia. Rigorous research is needed to improve knowledge of steppe conditions in order to provide a factual basis for debate.

Mongolia's pastoral dynamics, including extreme cold, limited agricultural viability, low population pressure, and high percentage of the population dependent on pastoral livelihoods, create a pastoral system that cannot be subsumed into established international categories (Johnson *et al.* 2006). Thus Mongolia needs to be examined independently to incorporate the diverse elements that shape regional pastoralism. Addressing steppe degradation can determine if land cover change is part of ongoing resilient processes or represents a transition to irreversible ecological states, signifying desertification (Thomas and Middleton 1994; Veron *et al.* 2006).

Extensive research on land degradation, desertification, and human impact on the environment has taken place across the globe. Africa has traditionally been well-studied by western academia for historic, cultural, and political reasons, with much

critical thinking on pastoralism, degradation, sustainability, and land cover change emerging from research (Dougill *et al.* 1999; Thomas *et al.* 2000; Hein 2006; Herrmann and Hutchinson 2005). In contrast, the Mongolian landscape, due to its remote location, and until 1990 a Russian-oriented research paradigm (Fernandez-Gimenez 1999), has received scant documentation. Local knowledge is essential to address degradation and for establishment of linkages between Inner Asia and a broader international context.

Research methods and procedures for investigating land cover change have been established that can be replicated and implemented globally through local fieldwork and remote sensing techniques. These approaches encourage exploration of degradation themes in regions with a shortage of data and can be used to broaden and strengthen the desertification debate (Dougill *et al.* 1999).

1.2.2 Mongolian Rangelands

Unlike some rangelands (*e.g.* Australia or the United States) where there has not been long-term exposure to managed grazing, the Mongolian environment has evolved with domesticated livestock (Fernandez-Gimenez 1999; Landsberg *et al.* 2003). This posits that continual interaction between livestock and vegetation may have contributed to today's landscape where grazing, limited water supply, stable species richness, and variable plant distribution patterns coexist. Sasaki *et al.* (2008) propose that, due to a long history of livestock use, Mongolia's vegetation is relatively resistant to grazing. Few places have had such longstanding human/nature interaction, with this making a distinction between the two either impossible or inappropriate (Dearing 2006). Over this long trajectory the fundamental strategies of pastoralism have been consistent: mobile and adaptive grazing to cope with variable precipitation

and production conditions in a harsh environment (Fernandez-Gimenez 2006). With societal and systemic transformation it becomes imperative to examine current pastoral practices, their impact on the land, and how the human-physical interchange shapes grassland conditions and viability.

The steppe ecosystems in this arid and semi-arid continental climate zone (Shinoda *et al.* 2007) are sensitive to climate change and human disturbance, exemplified by high degradation rates across the Mongolian plateau that comprises Mongolia and Inner Mongolia, China (Yang *et al.* 2005; Jun Li *et al.* 2007; Liu and Osborne 2008). Two divergent governmental systems further influence land cover dynamics in the greater Gobi environment. Differing livestock grazing, human population, agricultural pressures, land tenure systems, management decisions, production inputs, and state support create disparate grassland conditions in Mongolia and China with both facing land degradation risks (Chen and Tang 2005; Kawamura *et al.* 2005). A decline in rangeland functionality and an increase in desertification in China and Central Asia makes understanding vegetation dynamics a prerequisite before addressing regional environmental conditions (Yang *et al.* 2005; Li *et al.* 2006). The United Nations Environment Programme (2002) cites 70% whereas Li *et al.* (2006) identify 75% of Mongolia as affected by desertification with pasture vulnerability rates as high as 90% (Batjargal 1997). Across the border, field surveys and expert assessments identify China as one of the world's most desertified countries (Zha and Gao 1997; Zhao *et al.* 2005; Yang *et al.* 2005). Studies show an increase in desertification from an annual rate of 1,100 km^2 in the 1960s, 2,260 km^2 in the 1990s, to 3,600 km^2 today, with 861,000 km^2 now desertified (Li *et al.* 2006; Normile 2007). However, differing methodologies, approaches to analysis and levels of data accuracy make these claims of high desertification rates in the region difficult to assess.

In arid and semi-arid environments livestock grazing is often considered a major cause of land degradation (Sneath 1998; Nangula and Oba 2004; Zhao *et al.* 2005; Okayasu *et al.* 2007). Additional detrimental impacts in drylands centre on fragility vs. resilience in dryland ecosystems, persistence of "irrational" traditional herding practices and whether human activity (stocking strategies) or natural conditions define grassland productivity (Perkins and Thomas 1993; Reynolds *et al.* 2007). In northern China degradation is driven by livestock grazing, agricultural practices, inappropriate land management decisions, population pressure, mining, and erosional processes (Chen and Tang 2005; Kawamura *et al.* 2005). In Mongolia, low population density, negligible agriculture, a lack of private tenure as well as limited livestock production inputs, capital, and state support create different grassland conditions (Sneath 1998; Johnson *et al.* 2006). Although these conditions remain largely unexamined, livestock grazing is thought to be the main cause of rural land degradation in Mongolia (UNCCD 2002; World Bank 2002; Asian Development Bank 2005).

Land cover change can be investigated through use of piosphere studies to evaluate the role of livestock grazing on range degradation. Studying piospheres – the impact zone around water points - can differentiate the long-term effect of livestock on vegetation from that of other environmental factors at water sources. Such studies have provided a well-established monitoring tool used to determine livestock impact on land cover in Africa, Australia, and elsewhere (Andrew 1988; Nangula and Oba 2004; Todd 2006). Previous piosphere studies in dryland regions show livestock impact to be greatest near water points with influence diminishing with distance from water source (Perkins and Thomas 1993; Fernandez-Gimenez and Allen-Diaz 2000; Adler and Hall 2005). The piosphere effect can create a 'sacrifice zone' immediately

surrounding the water point where grazing and trampling result in bare ground. Water-centered grazing can produce changes in vegetation cover and plant composition that may have potentially severe consequences, with piosphere development forming the first stage in the desertification process (Andrew 1988; Landsberg *et al.* 2003).

Researching piosphere dynamics in Mongolia expands knowledge of degradative processes through confirmation of prior global hypotheses or by documenting original environmental processes as the larger debate of land cover change becomes grounded in local dimensions.

The topicality of degradation in Asia stresses the need for understanding broader regional and global complexities. Not only is Mongolian pastoralism different from that in Africa and the Middle East, it is distinct from Chinese herding practices as open grazing, common land stewardship, a lack of fencing, and low government support contrasts markedly with China's controlled and intensified livestock raising patterns. This is of growing importance as degradative processes on the Mongolian plateau now spread beyond national borders. International land cover change studies suggest that soil particles in southern Mongolia and northern China are the source of Asian dust, with this having a significant influence on the regional and global environment as it spreads to Japan, Korea, and further afield (Murayama *et al.* 2001; Xuan *et al.* 2004; Akata *et al.* 2007; Normile 2007). Evaluating ground-level concerns requires local environmental knowledge, current bio-physical insight, and awareness of relevant dryland ecological and socio-economic systems (Figures 1.5 *a, b*, 1.6 *a, b*).



a



b

Figure 1.5 Ovorhangai Province wells (*a, b*).



a



b

Figure 1.6 Ovorhangai Province spring (*a*), well in Omnogovi (*b*).

Although discussion of desertification rates in Mongolia cannot directly benefit from the application of African experiences, prior research has demonstrated the importance of underlying processes and examination of causal factors when assessing

deteriorating physical conditions and increased human impact on land cover (Hein 2006; Evans and Geerken 2004; Herrmann and Hutchinson 2005). The strength of research efforts over time in Africa is that they have addressed the question of whether the causes and claims of degradation/desertification represent crossing an ecological threshold, or a normal fluctuation in precipitation and grazing response (Nicholson *et al.* 1998; Thomas *et al.* 2000; Fernandez-Gimenez and Swift 2003). Without adequate study the degradation debate in Mongolia has been defined by international organizations such as the World Bank and United Nations rather than academic investigation (UNEP 2002; World Bank 2002).

Though Mongolia covers a vast area, greater than Botswana and Namibia combined, negligible local funding and low global awareness has resulted in limited attention in the Gobi Desert region. While in Africa environmental research drawing together physical and human dimensions has a long history, in Mongolia there is a dearth of similar research. The lack of regional investigation provides a superb setting for a thesis to research environmental processes and identify how indigenous land-use patterns impact land degradation in the Gobi Desert. Until this is empirically tested we cannot make claims for the universality of previous findings from other drylands. Employing established methods provides an opportunity both to test degradation patterns on the steppe and assess commonalities in land cover change trans-regionally.

1.3 Pastoralist Dimensions

Physical parameters that determine the natural environment intersect with anthropogenic factors to shape the pastoral landscape (Thomas and Middleton 1997; Geist 2005; Sallu 2008). The nexus of these forces attracts much attention,

highlighting intensified interest in dryland sustainability and degradation (Pearce 2006). Combined physical and social research can lead to understanding the dynamics and differences between the two realms shaping today's geography. In drylands, where there is often a balance of limited resources in variable ecosystems, the setting provides determinants that human action can either engage with constructively or use detrimentally. This pattern of engagement and research is well established in Africa (Perkins and Thomas 1993; Nangula and Oba 2004; Sallu 2008) and is relevant to the Asian steppe.

Across drylands, pastoral communities have common concerns regarding environmental productivity, evolving landscapes, and livelihood viability (Al-Eisa 1998; Sporton and Thomas 2002; Zhang *et al.* 2007). Mongolian socio-economic issues focus on the efficacy of traditional pastoral patterns, market forces, water availability, mobility, pasture access, modernization, and out-migration. In the Gobi Desert these factors revolve around income sources, particularly goat-cashmere, access to transport for seasonal migration, adequate wells in suitable pasture, and overgrazing/livestock concentration. An additional challenge is maintaining a modified herding lifestyle that incorporates traditional approaches, such as mobility with continued access to seasonal pasture, while accommodating new features including basic technologies (vehicles, solar power, mobile phones), economic forces, and evolving forms of land tenure (Figures 1.7, 1.8, 1.9 *a, b*).



Figure 1.7 Herder milking livestock, Ovorhangai Province



Figure 1.8 Omnogovi Province, *ger* home and transport.



a *b*

Figure 1.9 *(a)* Omnogovi Province, inside Tsog family *ger* home, *(b)* family with researcher.

Sustainability concerns incorporate the dryland dilemmas of climatic variability, temperature, limited resources, and evolving pasture composition with unusual social factors caused by transition from a Soviet to a market-oriented development model, dependence of half the population on pastoral livelihoods, slashed government investment, and recently, competition for water and labour from small-scale mining. An understanding of herder motivations and desires, whether economic, social, or ecological, shows how human actions impact the landscape and affect the resilience of both herding lifestyles and the natural environment. This allows the separation of physical and social factors, such as the effect of drought from the role of grazing practices on pasture productivity or the impact of livestock intensification on land degradation. Once roles are clarified sustainability and degradation and their proximate causes, whether physical or social, can be discussed.

The importance of determining the physical landscape is that it will frame the coming decades of pastoralism on the steppe. The mechanisms that have maintained pastoralism – mobility, seasonal migration, moderate livestock numbers for a subsistence existence, and some regulation of movement and location, are no longer institutionalized. Today's realities place pastoralism as an economic pursuit within a

modernizing society with animals as a source of wealth to provide goods, from food to motorcycles to education.

Income decisions are weighed against expenses so that financial motivations can lead to behaviour that may stress limited pasture resources. Secondary to livelihood concerns are daily pressures in an uncertain environment, particularly declining water sources marked by a 50% reduction in the number of wells (Tanaka *et al.* 2005). These pressures shape the pastoral equation because they determine accessible pasture and thus feasibility of movement. The lack of water sources leads to stock intensification around a reduced number of sources. Inability to develop new water points by the government or herders due to financial or technical constraints then accentuates and perpetuates the scarcity, resulting in increased pressure on the environment. This process resonates through multiple layers as it influences mobility, marginalization, and differentiation within the herding community, factors that are best evaluated in totality rather than isolation to explain the drivers creating the Gobi steppe environment.

1.4 Perspectives on the Mongolian pastoral environment

1.4.1 Historical

Initial western contact and commentary on Mongolia came from the Italian John of Plano Carpini the Frenchman William of Rubruck in the 13th century (Basilov 1989). Writings in the 18th century by Ides (1705) and Bell (1763) provided additional description of the country. Geographical knowledge of the region was expanded in the later 19th century through the explorations of Przhevalsky, Elias (of the Royal Geographical Society) and Gilmour and by Hedin and Verbrugge at the start of the 20th century (Hedin 1925; Miller 1952; Bold 2001). This work was descriptive; over

the last hundred years the physical landscape and pastoral practices have been documented by Russian scholars and western researchers. Early notable observations were made by the naturalist Roy Chapman Andrews on his paleontological expeditions in the 1920s in what is now southern Mongolia. At the same time the Russian geographer Andrei Simukov undertook a systematic examination of Mongolian pastoralism.

With Soviet rule the state favoured Russian researchers in the Mongolian territory. The difficulty with this is that much written in Russian has not been translated (Fernandez-Gimenez 1999), and that at times articles stress a 'Soviet man' angle, such as class formation in nomadic society, for political reasons that do not ensure objectivity. Works by Russian scholars such as Simukov, Vladimirtsov, Shul'zenko, and Murzaev that address pastoralism are often inaccessible to western academics today. Similarly, access to later work by Mongolian researchers of the period including Natsagdorj, Batnasan, and Bazargur is limited. During the communist era some information on the people and ecology of Mongolia derived from original and secondary sources was provided by western researchers including Lattimore and Krader and in the late 1970s by Humphrey (Krader 1955; Fernandez-Gimenez 1999). However, as late as 1987 N. Middleton reported that as the first British Council scholar to Mongolia no travel or fieldwork was permitted outside the capital.

Since Mongolia's transition to a free market democracy in 1990 research in Mongolia has opened to foreign researchers with physical, ecological, and socio-economic processes and their relationship to pastoralism part of the new discourse. In the 1990s work by Humphrey, Sneath, Fernandez-Gimenez, Mearns and others began the process of identifying the Mongolian environment and pastoral livelihood practices. However, because of the country's size and lack of study (Sugita *et al.*

2007) a formative research framework is just beginning to emerge. Physical dimensions are addressed individually and are often site-specific; pastoralism is examined in a piecemeal manner. This approach will continue until a sufficient research base develops that enables a more integrated assessment of the pastoral environment.

Because of this relative isolation pastoral concepts and research parameters have been established in other dryland environments. Non-equilibrium dynamics, Social-Ecological System theory and the desertification debate are examples of discourse that originated globally and are now applied in Mongolia. Methods developed elsewhere, from vegetation plots and soil sampling to socio-economic household surveys, are now undertaken in Mongolia. Greater *in situ* research, increased localized knowledge, and interpretation and dissemination of findings will add a Mongolian dimension to global pastoralism.

1.4.2 Regional

The Inner Asian pastoral region loosely comprises northern and western China, Mongolia, and parts of Central Asia, particularly Kazakhstan and Kyrgyzstan. In the past the area was approached as a distinct whole whereas now it is separated by national boundaries (Miller 1952; Akiner 1998; FAO 2003). The majority of research takes place in China where in the last decade there has been an increasing focus on degradation, ecology, land management, and human and livestock impact (Huang and Siegert 2006; Jun Li et al. 2007; Wang et al. 2008). A growing openness among Chinese researchers now enables discussion of environmental challenges resulting from potentially poor land use practices (farming, intensification, irrigation, fencing), settlement, increasing populations, government policy, socio-economic factors, and

concerns about climate change and ecosystem sustainability (Williams 2002; Chen and Tang 2005; Liu *et al.* 2005; Normile 2008). Findings can potentially inform research and debate in Mongolia.

Largely missing is a discussion of mobile pastoralism; it is seldom practiced in Inner Mongolia and is limited among minority groups (Uighur, Kazakh) in western areas of China. Government schemes, economic development, *de facto* land possession, agriculture, fencing and similar issues limit the relevance of China in a transhumance context (Banks 2001; Shaoliang *et al.* 2007). Zhang *et al.* (2007) note the loss of ecologically sustainable nomadism in northern China and identify the conversion to cropland as destroying the grassland ecosystem. For pastoralism a Chinese perspective is most instructive in delineating the impact human action and state policy can have on the Gobi environment and herding practices.

Former Soviet states in Central Asia, traditional pastoral regions, are currently not well researched. A major factor for this is the 'collapse' of livestock numbers and the breakdown of transhumanance since independence in Kazakhstan and a similar decline in Kyrgyzstan (FAO 2000; Ellis and Lee 2003; Kerven 2003). Additional factors limiting study include a focus on mineral resource development and government restrictions on foreign participation. Thus an area that has a shared pastoral history, including collectivization and similar climatic and physical conditions, is not well engaged in the scientific pastoral debate.

1.5 Research Goals

Mongolian conditions and dimensions are addressed in this study by investigating how natural and human forces impact the landscape using both physical and social

research methods. The research utilizes a bio-physical approach, explores its interaction with human elements and examines the herder-centred perspective. The thesis then draws together these intertwined elements to present a composite of the forces creating today's steppe environment.

Goal to investigate how bio-physical factors and herder action determine the pastoral environment in the Gobi Desert, Mongolia.

1.5.1 Objectives

To achieve this goal the following objectives are addressed:

a. to examine drought, degradation, and *dzud,* environmental conditions that define pastoralism in Mongolia.
b. to investigate of piosphere degradation and vegetation dynamics *in situ.*
c. to analyze of pastoralists' perception and interaction with their environment.
d. to assess of how human actions relating to water, pasture, mobility, and socio-economic factors impact the physical landscape.

1.5.2 Expected Outcome

The significant result of this thesis will be increased academic understanding, some of which is policy-relevant, of the contributory factors defining the Gobi environment. The study initiates research to address drought in Mongolia and drought interactions with *dzud,* a process that is thought to cause the country's worst natural disasters. The work establishes a regional drought history and suggests that similar efforts can

be undertaken by local scientists to better understand climate processes and pasture productivity in Mongolia.

Established techniques from other dryland pastoral regions are used to focus on the land cover change and degradation debate in the steppe environment with the resulting new data and conclusions based on extensive field work. Concurrently, the research measures vegetation dynamics *in situ,* ascertaining species composition and plant density in the region. Centred on piospheres the study assesses how pastoral livestock herding patterns may affect land cover.

Recognizing that the Gobi landscape today represents ongoing physical and human interaction, the thesis explores pastoralists' perceptions of environmental challenges and how herder actions and motivations impact the natural geography. Interview data reflects herder insight and provides a voice for the pastoralist to identify ecological conditions and complexities. This approach elucidates pastoral decision-making and livelihood practices directly impacting the rangeland.

By presenting physical and pastoralist roles a complete understanding of the steppe environment is developed. My thesis presents the opportunity to inform the broader academic community of the unusual and understudied dynamics of the Gobi Desert environment.

1.6 Theoretical Framework: resilience theory and political ecology

This thesis takes the theoretical approach that the physical environment cannot be examined in isolation from herder action and impact (Turner et al. 2007; Brand 2009). This is particularly valid when considering the low resource base of steppe grasslands where subtle fluctuations in bio-physical conditions or herding patterns can impact livelihood and pasture productivity. The intertwined roles of man and nature have

shaped the steppe - failure to recognize this would render any conclusion incomplete (Shinoda *et al.* 2007). For this reason theoretical linkage of the two forces is essential; this is addressed first by examining social-ecological system (SES) theory, then from the perspective of political ecology which recognizes the drivers of ecological states and land cover change. The strength of these analytical strategies is their relevance to the Gobi Desert (Walker and Abel 2002; Chuluundorj 2006; Batima *et al.* 2008) and ability to geographically integrate human and physical factors.

Investigating physical and human environments encourages the use of social-ecological system theory. The strength of an SES foundation is the linkage of bio-physical and social components to underpin research questions through the concepts of vulnerability, adaptation, and resilience (Walker *et al.* 2004; Gallopin 2006). Derived from life sciences and social sciences, as an analytical tool SES can bridge the natural-social divide through cross-discipline application to more fully address environmental dynamics on the steppe (Gallopin *et al.* 2001). The task is selecting the SES component that best encompasses the physical and human spheres in the Gobi Desert.

Vulnerability is composed of a system's exposure and susceptibility to external factors, sensitivity to disturbance, and coping capacity (Adger 2006). Focus has been on human risk and the likelihood of an individual or group being exposed to and adversely impacted by a hazard (Cutter *et al.* 2003). In this way it considers forces that have a limiting or detrimental effect on a system. These forces result from stresses or events beyond normal system variability and can originate internally or externally (Turner *et al.* 2003). While including resource availability, it places society, particularly constraints and response capacity, at the centre of analysis rather than attempting to interpret physical conditions (Kelly and Adger 2000; Smit and Wandel

2006). Vulnerability can be applied to the role of pastoralists in reacting to external hazards and shifting socio-economic forces that may limit their livelihoods, yet it fails to adequately engage with natural factors in the Gobi. In a more physical context vulnerability relates to the impact of new hazards in the human landscape, such as the effect of mining on herders, rather than the physical dimensions such as drought and extreme winter conditions investigated in this thesis. Folke *et al.* (2002) identify vulnerability as the antonym of resilience; thus its applicability to the environment requires a social context.

A second tenet of SES theory is adaptation - how a system responds to disturbances that change the basic structure of the system, possibly to a new state. It is further refined as the capacity to manage change, stressing the role of human action (Walker *et al.* 2004; Gallopin 2006). The concept acknowledges how adaptation is shaped and constrained by social, economic, and political forces, and addresses the notion that risk takes place within the context of human processes and physical limitations (Smit and Wandel 2006). Adaptation becomes the selection of practices that enable a group to survive (O'Brien and Holland 1992) and is also an act of management to influence the state of a system as it adapts simultaneously to changes in its environment away from negative thresholds (Walker *et al.* 2004; Rammel *et al.* 2007).

Gallopin (2006) offers two components of adaptation – the ability to cope with environmental contingencies, exemplified by pastoralist's migration strategies, and the capacity to improve conditions in relation to the environment. The purpose is to mitigate or reduce negative impacts or ameliorate conditions - processes that imply management and decision-making, thus highlighting adaptation as a social phenomenon; similarly, Walker *et al.* (2004) define adaptation as the capacity of

humans to manage resilience, with these definitions limiting applicability to environmental systems (Smit and Wandel 2006).

Resilience theory probes the ability of a system to maintain basic structure and functioning when encountering disturbance and disruption. It allows examination of ecosystem adaptability to changing conditions regardless of cause and asks if a system can return to a stable state (Holling 1973; Walker and Salt 2006). Resilience, in highlighting the systemic ability of an actor or environment to cope with alteration, conceives of a system returning to stability without lasting negative consequences (Pelling 2003; Chuluundorj 2006). This suggests a process that can encompass changing physical dynamics and social patterns and allow for recognition of multiple time-scales within a system. Rather then drawing definitive conclusions, the theory presents conditions and states at a point in time, acknowledging that circumstances are evolving rather than fixed. Originating in ecology, resilience theory has evolved to evaluate environments and encompass social systems through cross-discipline research (Gallopin 2006; Plummer and Armitage 2007).

Though relevant to pastoral livelihoods in this thesis, particularly in Chapter II and VII, both vulnerability and adaptation theory are inadequate to meet the overall research goals. In stressing human action rather than environmental factors they lack broader applicability to the chapters on drought and degradation. Resilience theory best embraces the physical and human environments stressed in this thesis.

When examining variability, resilience can apply to changing environmental conditions as well as human action in a system. This contrasts with vulnerability theory that views a person or community at risk to detrimental external forces and adaptation's concentration on the role of management (Leurs *et al.* 2003; Franklin and Downing 2004). The strength of resilience theory is the recognition that Gobi

pastoral systems, human and physical, are based on flexibility, since both the herder and landscape respond to variable conditions. For example, a normal year in the Gobi such as 2004 (135 mm precipitation) was followed by a dry year in 2005 (51 mm precipitation), eliciting claims of desertification. Yet a similar increase in precipitation can return the land to a more normal state. In such a setting herder responses (differing mobility rates and migration patterns, distance moved, livestock composition) accommodate ecological conditions that shift with climate patterns and increased or decreased pastoral resources. This is an integral part of Gobi pastoralism traditionally implemented to mitigate hazards and adjust to variability. Only when thresholds are crossed preventing a return to stable states, such as after severe degradation, herder settlement, or lack of movement in poor pasture conditions, is desertification an applicable term. Previous research efforts incorporating resilience theory are applicable to the Gobi, such as work by O'Brien *et al.* (2004) on climatic pressure and Chuluundorj's (2006) study on pastoral hazards and livelihood stress in Mongolia.

The strength and challenge of a resilience theoretical approach is its cross-discipline nature in addressing ecological and societal issues. To be effective research must be rigorous yet not constrained by academic boundaries (Robinson 2007; Folke 2007; Brand and Jax 2007). This study incorporates relevant disciplines as a context to evaluate steppe processes. Previously applied to rangelands, resilience models have been used to measure how drought and grazing cause stress and disturbance (Walker and Abel 2002). Research can identify robust landscapes - those that remain in a functional state despite disturbance, and fragile landscapes at risk of shifting to another state. Additionally, reactions to disturbance differ between environments and cannot be generalized as topography, climate, environmental change, land use and

spatial scale affect conditions. Thus functional states in Mongolia will be at variance with findings in Africa or elsewhere, emphasizing the relevance of this thesis in undertaking formative research on resilience in the Gobi environment.

Resilience is measured by a system's ability to manage disturbance; a natural progression leads to evaluation of sustainability (Gunderson and Hollings 2002). Because both are concerned with productive resource use the two can merge into a single conceptual framework (Maler 2008). As the concepts integrate disciplines within the human-nature structure, research findings that suggest resilience can encompass sustainability science to broaden impact and applicability of the study (Clark 2007; Plummer and Armitage 2007). Work in the 1990s identified Mongolian pastoralism as potentially ecologically, economically, and socially sustainable (Fernandez-Gimenez 1999); through this framework the thesis address steppe viability today. Increasingly viewed as a perspective, resilience theory has been conceived as a way of thought, a method to address social process and to represent flexibility in social-ecological systems - values that are relevant to this study (Brand and Jax 2007).

Whereas resilience operates at personal and local levels (the herder and his landscape), political ecology theory enables the development of research questions focused on the causes of environmental change across different spatial and temporal scales. This framework, emphasizing how landscape changes result from interactions between the physical environment and social, political, and economic processes (Olson *et al.* 2004), is essential because it is the interplay of these factors over the last 15 years that creates Mongolia's landscape today. The period covers transition from communism to today's market-oriented democratic system and the resultant reduction in government interaction with herding livelihoods.

Political ecology theory provides a structure to integrate the human-environment relations lying behind current ecological challenges (Turner II 2002; Walker 2005). It identifies resources and social actors; recognizes that the bio-physical environment cannot be understood in isolation from the political and economic contexts within which it operates and explores the role of pastoralists in the landscape in which human actions relate to strategies of use, adaptation to conditions and impact on the terrain. The theory seeks to understand "complex relations between nature and society through...access and control over resources and their implications for environmental health and sustainable livelihoods" (Watts 2000. p. 257). In this exchange of relationships political ecology addresses the research objectives of defining the nature/human interplay that creates the Gobi environment. It also incorporates environmental and social contexts and how the environmental setting, within which power interactions take place, determines conditions (Leatherman and Thomas 2001; O'Brien *et al.* 2004). In Mongolia this inter-relationship can reflect the macro-level, such as how a declining government role, reduced public transport support and emergency fodder, and economic forces interact with natural hazards, livelihood planning, and land degradation patterns. At the micro-scale it represents how herders' immediate decision making, pasture use patterns, and responses to land and water variability interact with area resources such as winter camps, land tenure rights, access to aid programs, and pasture productivity. Herders may pursue short-term well-being at the expense of future ecosystem capability as they struggle to reconcile the challenges of multi-scale processes.

Particularly relevant is the Land Use/Land Cover Change (LUCC) model developed to address land degradation and biodiversity loss in Africa (Lambin *et al.* 1999; de Sherbin 2002, Liverman *et al.* 2005). By linking biophysical and socio-

economic processes the model stresses how the interaction of components impact environmental change (Olson *et al.* 2004); its multi-scalar approach integrates verifiable field-level dynamics with broader national and regional systems. The LUCC, recognizing the need for a stronger empirical foundation, acknowledges the limited understanding of causal factors, particularly societal ones, in current discussion. The lack of research and limited analysis of landscape change in the Mongolian context make this an effective model for this thesis. It provides insight into the type and extent of physical modification and an understanding of societal forces altering the environment (Turner *et al.* 1995).

The thesis emphasises pastoral dimensions that are under-researched yet essential to debate and policy formulation with regard to the countryside. Inter-related components cannot be evaluated in isolation, nor can natural factors like extreme weather, precipitation and drought be ignored when examining environmental change and human action (Turner 1999). Use of the LUCC model together with political ecology theory encompasses the complexity of these interactive effects over different scales, socio-economic hierarchies, and contradictions between social and environmental change through time (Blaikie and Brookfield 1987).

In encouraging recognition and implications of external factors in an environment political ecology stresses the role of political and economic forces in determining ecological outcomes. However, as political ecology embraces and strives for large-scale, even global discourse and structural understanding (Gezon and Paulson 2005), it can downplay bio-physical factors and proximate causes of environmental change (Vayda and Walters 1999). In Mongolia the theory is effective at addressing shifting government and economic roles as they impact the landscape. To be relevant to the steppe, focus on societal complications and processes must encompass the landscape

as a limited resource base and climate factors, both of which are critical in any discussion of degradation or livelihood variability. While providing a research framework, the thesis considers political ecology's social complexities within Mongolia's unusual and challenging environment.

1.7 Sites

This study focuses on pastoral dynamics in Ovorhangai and Omnogovi Provinces in central and southern Mongolia (Figure 1.6). In each province 55 sites were studied in an area (approximately 1° latitude by 2° longitude) where environmental processes allow key ecological and pastoral themes to be surveyed in the desert and steppe grassland.

Omnogovi Province (44° N, 104° E) is dominated by a desert-steppe environment with the Gurvan Saixan Mountains transecting the area. The province was selected because of its lack of surface water (one river, dry at the time of the study, 18 ephemeral lakes, and a few scattered springs) and thus near-complete dependence on man-made water resources (Batima and Dagvadorj 2000). Averaging 121 mm of precipitation a year, it is comparable with the Saharan, Arabian, and Namib regions (Middleton and Thomas 1997; Mongolian Statistical Yearbook 2005). This arid region (Shinoda *et al.* 2005) represents Mongolia's difficult dynamics for human-environment interaction in a zone where mining competes with pastoralism for groundwater and cross-border trade with China influences the rural economy.

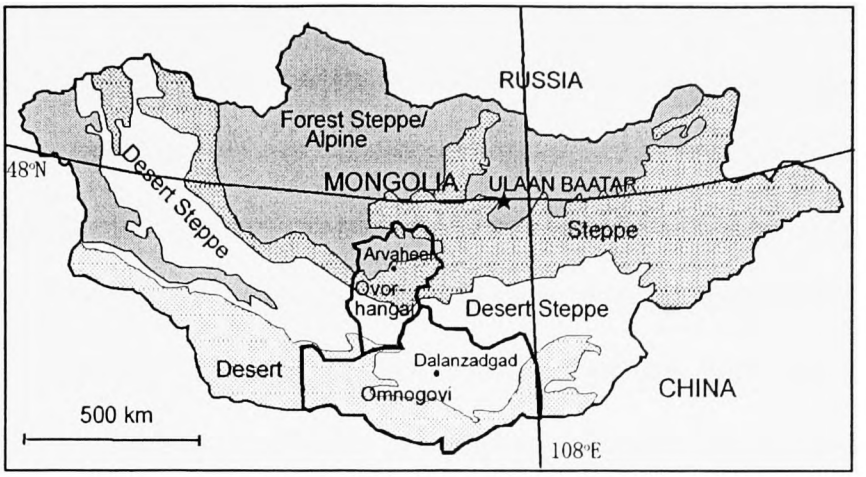


Figure 1.10 Map of Mongolia with vegetation zones and two provinces highlighted.

Ovorhangai Province, though bordering northwestern Omnogovi, represents differing physical characteristics. Framed by the Hangai Mountains to the north, the research area (46° N, 103° E) in central Mongolia encompasses steppe and desert-steppe terrain. Ovorhangai has a mean annual precipitation of 234mm annually and more surface water (243 rivers, 90 lakes), including the Ong, Orhon, and Arguit Rivers, and greater population density than Omnogovi. These traits provide contrasting conditions between the two study sites, increasing study breadth and depth.

The surface morphology of the study region is typically that of a rolling gravel plateau ranging from 1000 to 2000m above sea level (Hilbig 1995). A similarly defined landscape covers over 50% of the country's land surface (Geographical Atlas of Mongolia 2004). Climate in these semi-arid and arid environments is characterized by short hot summers and long cold winters with unimodally distributed rainfall concentrated in summer (Yu *et al.* 1999). In Mongolia, the highly variable precipitation and low soil fertility of the steppe grassland exhibits non-equilibrium characteristics, with edaphic and abiotic factors limiting plant growth (Fernandez-

Gimenez and Allen-Diaz 1999; Begzsuren *et al.* 2004; Retzer and Reudenbach 2005; Munktstsetseg *et al.* 2007). Variability in the timing and amount of rainfall and inter-annual fluctuations strongly influence plant and livestock communities. Ovorhangai's precipitation Coefficient of Variation (CV) is 27% whereas Omnogovi's CV is 34%, with a monthly summer growing season CV of 58% and 72% respectively. Using the common threshold of less than 200 mm annual precipitation and ≥ 30% Coefficient of Variation, Omnogovi fits the non-equilibrium model, whereas Ovorhangai is borderline (Vetter 2005; Begzsuren *et al.* 2004). In Mongolia interannual precipitation variability can lead to considerable fluctuations in vegetation cover (von Wehrden *et al.* 2006). Pastoralism is the dominant livelihood with 85% of the livestock comprised of small stock (sheep and goats) (Table 1.1).

Table 1.1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces.

Province		Ovorhangai	Omnogovi
Sites		55	55
Rangeland		Steppe - Desert Steppe	Desert Steppe
GPS		N 45.7-46.7, E 102.1-104.2	N 43.4-44.5, E 103.2-105.3
Elevation	Average	1678	1533
(metres)	Range	1389 - 2095	1092 - 2067
Mean annual	mm	235	121
precipitation	min-max	119-378	51-235
Mean	January	-14.4°C	-13.9°C
temperature	July	16.3°C	21.9°C
Water point	% well / surface	87 - 13	93 - 7
Herders	% population	57%	49%
Livestock	type	Sheep, Goat, Horse , Cattle	Goat, Sheep, Camel, Horse
Livestock	2002	1,665,000	909,000
numbers	2006	2,623,300	1,155,700

1.8 Methods

This research, incorporating natural and social science techniques, uses an integrated geographic framework to examine how ongoing physical conditions and human interaction impact the Gobi Desert environment. A three-part research approach was

applied and this is expanded on in individual papers. First, work focused on vegetation density and species composition around piospheres in the research regions as part of a spatial ecological study representative of the Gobi environment. Second, a cross-sectional study of 110 households in two Mongolian provinces was carried out. Third, meteorological and remote sensing data were collected for analysis. The approaches were designed to have complimentary distribution patterns so that results would present a cohesive understanding of environmental processes throughout the region. Multiple research techniques and data sources were employed for data collection and evaluation, with each chapter covering in detail the methods used.

1.8.1 Integrative research approach

My thesis investigates the Gobi Desert in substantive chapters that are independent articles united in addressing the central theme. The advantage of this approach is that each chapter topic, written to meet the rigour and concise presentation demanded for an academic publication, is fully developed and able to stand on its own in an academic framework. While the findings could have been presented in the conventional thesis structure, the data and research context is well served through several articles as this encourages dissemination of research to interested parties through published, accepted, and submitted articles. This approach provides access to new research for the academic, government, development, and (when translated) herding communities.

Whereas ecology and social science are often evaluated separately, both are coupled in human and natural systems and can be examined interdisciplinarily to understand pasture dynamics (Liu et al. 2007; Turner et al 2007). The central theme of the thesis - interaction between the physical landscape and pastoralism - unifies the chapters as

articles investigate related topics. The environmental chapters explore the physical landscape that conscribes pastoralism, exemplified by how drought may affect pasture resources, potentially reducing livestock forage and weight gain that in turn can impact herder decision-making and ultimately income and livelihood. The pastoralist chapters identify how herders interact in the bio-physical world and highlights human processes that impact steppe resources. An example is how reduced mobility can lead to livestock intensification at a piosphere, potentially degrading the rangeland. This approach stresses the connection between ecology, economics and society (Plummer and Armitage 2007). Awareness of the physical-human link is essential to understanding the pastoral environment, reflected in the thesis title 'Nomadic Geography' which connects the physical and pastoral worlds that delineate the Gobi Desert, Mongolia.

Such a study requires varied research methods relevant to physical and human geography. Investigating the physical landscape entails quantitative methodology and analysis, including vegetation surveys, drought identification, and remote sensing data. Pastoralist research uses qualitative methods in a grounded theory approach with results analyzed to conceptualize relationships. As a whole the thesis benefits from the two approaches because they enable the key objectives to be studied as an integrated system rather than as separate elements.

1.8.2 Fieldwork - piosphere/vegetation survey

In Mongolia and the Gobi region there has been limited research of land cover change with surveys often being national in scope (Hilbeg 1995; Gunin *et al.* 1999). Several methods exist to assess environmental conditions, such as examination of erosion, vegetation cover, grazing intensity, field interviews, and remote sensing. Research in

Mongolia by Fernandez-Gimenez (2000) stressed that nomadic herders use vegetation cover to evaluate range productivity, suggesting that plant cover, a principal measurement of degradation (Huang and Siegert 2006), was relevant locally. In the country vegetation cover has been studied through biomass/plot sampling (Wesche and Retzer 2005; Van Staalduinen *et al.* 2007), line transects (Stumpp *et al.* 2005), floristic composition/species richness (Sasaki *et al.* 2005), and remote sensing (Erdenetuya 2004). Selecting the line-transect method allows this investigation to draw on and compare findings with similar global dryland research (Perkins and Thomas 1993; Fewster *et al.* 2005).

Previous line-transect investigations in Mongolia has been on a small scale, limiting their wider applicability; Sasaki *et al.* (2007) examined one transect and Stumpp *et al.* (2005) assessed four. In this survey fieldwork was carried out at 110 piospheres to establish vegetation parameters, examine degradation, and provide verification of coverage and potential change (Batterbury *et al.* 2002; Okayasu *et al.* 2007). Vegetation dynamics were investigated over 1 km at each water point using the line-transect method (Thomas *et al.* 2000) with water points located through visual inspection and in consultation with local herders. Investigation was carried out during the April to October plant growth season in 2006-2007.

Plant basal cover was examined in one metre segments, appropriate for sparse vegetation and a more precise measurement than provided by the Daubenmire scale (Jones 2007). At each site a sample of each plant species in the transect was collected to establish species composition and richness at each water point. Plants were dried for later identification (Jamsran and Oyuntsetseg 2000; Jigjidsuren and Johnson 2003) in the Geo-Botany lab of the Mongolian Institute of Geography. At each piosphere, field information (latitude and longitude, elevation, temperature) and water

data (depth, temperature, pH, total dissolved solids, electroconductivity) (HM Digital Inc, Culver City, Ca.) were recorded for analysis with the vegetation data. Analysis was done with SPSS 14 (SPSS Inc. Chicago, Il.) and CANOCO (Ithaca, N.Y.).

1.8.3 Climate Data

Meteorological data for 1970-2006 were obtained from the Mongolian Institute of Meteorology and Hydrology. Daily precipitation and temperature records were analysed with standard statistical methods to provide relevant climate information. Data were critical to evaluate drought and *dzud* conditions and were used to corroborate herder perceptions.

1.8.4 Drought - Standardized Precipitation Index

Several indices have been developed to assess drought including the Standardized Precipitation Index, the Palmer Drought Severity Index, the Drought Area Index (similar to the Bhalme-Mooley Index), and the Rainfall Anomaly Index (Byun and Wilhite 1999). Prior research has evaluated index effectiveness and found the Standardized Precipitation Index (SPI) to be a robust drought measurement tool (Guttman 1999; Keyantash and Dracup 2002, Ntale and Gan 2003). Advantages of the SPI are its statistical consistency, ability to describe short and long-term drought episodes, and effectiveness in areas where limited data availability can restrict drought quantification (Smakhtin and Hughes 2007; Cancelliere *et al.* 2007). Not previously used in Mongolia, the SPI has been widely applied in East Asia and throughout dryland regions (Wu *et al.* 2001; Seiler *et al.* 2002; Min *et al.* 2003; Bhuiyan *et al.* 2006; Serrano and Cuadrat-Prats 2006; Hallack-Alegria and Watkins 2007; Morid *et al.* 2007; Mpelasoka *et al.* 2008).

SPI was selected to assess anomalous and extreme precipitation and drought events in the Gobi Desert (McKee *et al.* 1993; Hayes et al 1999; Sonmez *et al.* 2005; Wu *et al.* 2007). The SPI gives a numeric value to precipitation that allows monitoring of meteorological drought at different time scales and enables comparison across regions and varied climatic zones. Used to calculate drought initiation, magnitude, duration, and frequency while providing spatial and temporal flexibility, the SPI reflects the probability of precipitation at selected timescales measured by the number of standard deviations the observed value is from the long-term mean. Since precipitation is not normally distributed, data must be transformed so precipitation values follow a normal distribution. This allows the SPI to monitor the probability of wet or dry periods at multiple time steps and shows that it is possible to simultaneously experience drought at one time scale yet wet conditions at another (Rouault and Richard 2003).

Employing SPI software from the U.S. National Drought Mitigation Center (2006), precipitation data were examined for drought occurrence at multiple timescales to identify spatial and temporal drought dynamics at meteorological stations in Mongolia. Over multiple monthly time scales (3, 6, 12, 24, 60 months) the SPI was calculated through the end of August to monitor drought during the critical summer plant growth season because of Mongolia's short (90-130 frost-free days) vegetation growth and intensive grazing season (Begzsuren *et al.* 2004; FAO 2006).

1.8.5 Normalized Difference Vegetation Index (NDVI)

Remotely sensed Normalized Differential Vegetation Index (NDVI) values were used to measure land-cover change over time. Research has established that NDVI,

sensitive to vegetation density and photosynthetic capacity, is highly correlated with biophysical parameters such as vegetation coverage and biomass (Kerr and Ostrovsky 2003; Yu *et al.* 2004). Multi-temporal SPOT-4 satellite imagery generated thirty-day images from 1 April through 30 October, 1998-2006 time series. The months were selected to encompass the potential growing season and peak precipitation period. Similar to other regional studies, a 1 kilometre spatial resolution was used to generate pixel values on a scale equivalent to the line transects (Khuldumur and Erdenetuya, 2002; Huang and Siegert, 2005; Okayasu *et al.* 2007). Data were used to derive NDVI monthly and annual coverage values throughout the time period. While NDVI has limitations (Richard and Poccard, 1998), it is used here to provide an estimate of vegetation density and land-cover change over time relating to drought events and herder perceptions of vegetation and precipitation. By using several years' data it gives an historical perspective to vegetation coverage and change in the region.

1.8.6 Pastoralist Interviews

Field surveys were conducted with herders to establish their perspective on environmental challenges and to determine herder interaction with the physical environment. Herders from different districts were selected by physical location rather than social criteria. The survey assessed herder practices through field-site interviews and participant observation to ascertain how livelihood and the environment interactions have evolved (Lee and Zhang 2005). Topics addressed included herder characteristics, water resources, pasture use, and mobility. In this setting semi-structured interviews were found to be a more effective assessment tool than questionnaires or structured surveys (Robson 2002). Pastoralists were asked a set of standardized questions that were not conditional on prior answers. This allowed

respondents to express personal ideas and behaviour (Pratt *et al.* 2004; Jiang 2004), though not all respondents answered all questions. This approach developed an understanding of herding livelihoods, economic impacts and land use for comparison with claims of degradation in published reports (Mearns 2004; Middleton and Thomas 1997; MNE 2002; Asian Development Bank 2004). Interviews were conducted through a translator in the pastoralist's habitation after cultural formalities had been observed; handwritten notes were taken at the time of the interview. Analysis synthesized responses with results reflecting herder responses and data estimates. Wherever possible, herder reports were verified by personal observation of water sources, pasture, and livestock numbers.

1.8.7 Statistical Analysis

Throughout this thesis data were analyzed using SPSS 14.0 (Chicago, Il) to determine statistical significance. Dominant factors were then re-examined to evaluate their impact on variance within categories. Linear regression was applied to identify key determinants for multiple variables. Principal Component Analysis (PCA) was used as a data reduction technique to reduce the volume of data to a more manageable size while retaining as much original information as possible (Field 2005). PCA improves classification through identifying structure in relationships while accounting for most of the variance in the observed variables. The derived Eigenvalues explain the percentage of data variance accounted for by the major data components.

1.9 Thesis Structure

The thesis consists of an introductory chapter, six academic articles that have been published or submitted to relevant peer-reviewed journals, a discussion chapter, and a conclusion. A brief description of the journal articles follows below:

Chapter II. Environmental challenges in Mongolia's dryland pastoral landscape.

Changing environmental, economic, and political conditions since 1990 have impacted Mongolian pastoralism. Privatization of livestock, reduced government support, and immediate livelihood needs have affected traditional herding practices and human-environment dynamics. This study examines herder perceptions of major challenges facing pastoralism today. Mongolian herders identified ongoing ecological processes as dominating daily life and actions. Environmental conditions, particularly water resources and pasture quality, were paramount concerns. Transformation to a market economy coupled with limited state assistance over the last 15 years has decreased rural water supplies, reduced mobility, and increased overgrazing, leading to land degradation. Herders specified water availability, variable precipitation, insect invasion, adequate pasture, and extreme winters as the primary pastoral challenges.

Chapter III. Pressurized pastoralism in South Gobi, Mongolia: what is the role of drought?

The desert-steppe region of southern Mongolia is susceptible to drought and extreme winter weather (*dzud*) that in combination form Mongolia's worst natural hazard. Low precipitation and high climatic variability in this dryland environment

1.9 Thesis Structure

The thesis consists of an introductory chapter, six academic articles that have been published or submitted to relevant peer-reviewed journals, a discussion chapter, and a conclusion. A brief description of the journal articles follows below:

Chapter II. Environmental challenges in Mongolia's dryland pastoral landscape.

Changing environmental, economic, and political conditions since 1990 have impacted Mongolian pastoralism. Privatization of livestock, reduced government support, and immediate livelihood needs have affected traditional herding practices and human-environment dynamics. This study examines herder perceptions of major challenges facing pastoralism today. Mongolian herders identified ongoing ecological processes as dominating daily life and actions. Environmental conditions, particularly water resources and pasture quality, were paramount concerns. Transformation to a market economy coupled with limited state assistance over the last 15 years has decreased rural water supplies, reduced mobility, and increased overgrazing, leading to land degradation. Herders specified water availability, variable precipitation, insect invasion, adequate pasture, and extreme winters as the primary pastoral challenges.

Chapter III. Pressurized pastoralism in South Gobi, Mongolia: what is the role of drought?

The desert-steppe region of southern Mongolia is susceptible to drought and extreme winter weather (*dzud*) that in combination form Mongolia's worst natural hazard. Low precipitation and high climatic variability in this dryland environment

impact the landscape and affect pastoralism, the dominant rural lifestyle. Using the Standard Precipitation Index (SPI) this paper identifies drought occurrence in South Gobi Province, Mongolia. It then examines the relationship of drought with climate factors, interaction with vegetation (derived through Normalized Differential Vegetation Index (NDVI) data), local human and livestock populations, and the *dzuds* of 1999-2001. Results indicate that drought is recurrent in the region, reaching extreme intensity most recently in 2005-2006. In contrast to the prevailing concept of drought impacting *dzuds,* the study did not find a connection between the two in South Gobi Province. Climate variables show warming temperatures (>1°C over 37 years), fluctuating precipitation patterns, and a decline in vegetation cover. The principal long-term correlation of drought is with human population rather than natural factors, *dzud*, or livestock numbers.

Chapter IV. Drought dynamics on the Mongolian steppe, 1970-2006.

In this study long-term precipitation records from 1970-2006 are analyzed with the Standard Precipitation Index (SPI) to identify drought events at 3, 6, 12, and 24-month timescales at 5 meteorological stations in three steppe and desert steppe provinces. Awareness of drought conditions is important in the countryside because a majority of the rural population derive livelihood from weather and pasture-dependent pastoralism. Results indicate the steppe was in drought 15% of the time, with occurrence, intensity and duration being site-specific characteristics. Drought patterns suggest ongoing climate variability today with the most extreme event recorded at the end of the study. The lack of mitigating factors, such as government intervention, can cause drought to be a major natural hazard that impacts physical, economic, and social systems.

Chapter V. Vegetation dynamics and piosphere degradation on the Mongolian steppe.

The Mongolian plateau in East Asia is part of a new hotspot of land cover change. Recent human activity and natural forces have degraded grasslands in northern China with southern Mongolia similarly vulnerable. Examination of vegetation patterns at piospheres - the zone of ecological impact around livestock watering points - identified pasture conditions and degradation trends. Through fieldwork and remote sensing this paper examines plant density and species richness at water points to establish land cover patterns in two Mongolian provinces where overgrazing is widely cited as a major cause of degradation. In contrast to established piosphere patterns, vegetation was greater near water points and decreased with distance. This suggests that livestock are not concentrated at water points in Mongolia and that piosphere dynamics are more influenced by precipitation and edaphic factors. The lack of degradation at piospheres implies that pastoralism, with mobile livestock management, is a suitable adaptive strategy to the low forage capacity of steppe grasslands.

Chapter VI. Tracking desertification on the Mongolian steppe through NDVI and field- survey data.

Changing environmental and socio-economic conditions make land degradation a major concern in Inner Asia. This study examines 33 grassland water points using vegetation field studies and remote sensing techniques to track desertification on the Mongolian plateau. Findings established a significant correlation between same-year

field observation (line transects) and Normalized Difference Vegetation Index (NDVI) data, enabling an historical land cover perspective to be developed from 1998-2006. Results show variable land cover patterns in Mongolia with a 16% decrease in plant density over the time period. Decline in cover indicates degradation; however continued annual fluctuation suggests desertification – irreversible land cover change – has not occurred. Further, *in situ* data documenting greater cover near water points implies livestock overgrazing is not causing degradation at water sources. In combination the two research methods strengthen findings and provide an effective way to track desertification in dryland regions.

Chapter VII. Pastoral mosaic: livelihood, mobility, differentiation, and environmental engagement on the Inner Asian steppe.

Throughout its long history on the Inner Asian steppe pastoralism's adaptive livelihood strategies have ensured its viability. Today changing environments, economics, and herder motivations challenge traditional pastoralism in Mongolia. To understand current processes in the countryside knowledge of herder livelihoods and behaviour is imperative. Data from extensive on-site interviews (n=112) identifies herder vocational approaches and interaction with the physical landscape. Results stress the importance of both number and distance of moves on herder welfare. Rather than the homogeneous model of the collective era, herders now act independently, employ varied work strategies, are motivated by economic factors, and do not see herding as a career choice for their children. At the same time traditional foundations – communal land stewardship, independent decision-making, and mobility - remain valued. Pastoral differentiation occurs along several dimensions, including age,

education, number and type of livestock, and location. Herding risks are both physical (lack of water sources, variable pasture quality, low precipitation) and socio-economic (expenses, evolving perceptions and motivations, a lack of government support). Recognition of pastoralism's environmental challenges and role in a modernizing society is essential for current and future policy, management, and development efforts to be effective.

Chapter II

Environmental challenges in Mongolia's dryland pastoral landscape

Troy Sternberg

Published in *Journal of Arid Environments*. 2008. 72:1294-1304.

Abstract

Changing environmental, economic, and political conditions since 1990 have impacted Mongolian pastoralism. Privatization of livestock, reduced government support, and immediate livelihood needs have affected traditional herding practices and human-environment dynamics. This study examined herder perceptions of major challenges facing pastoralism today. Mongolian herders identified ongoing ecological processes as dominating daily life and actions. Results established that environmental conditions, particularly water resources and pasture quality, were paramount concerns. Transformation to a market economy coupled with limited state assistance over the last 15 years has decreased rural water supplies, reduced mobility, and increased overgrazing, leading to land degradation. Herders specified water availability, variable precipitation, insect invasion, adequate pasture, and extreme winters as the primary pastoral challenges.

Key words Mongolia, water, pastoralism, grazing land, mobility

---

2.1 Introduction

Water, grazing land, and mobility are central to most pastoral livelihoods in arid landscapes. Today the subject of dryland pastoralism includes concerns about land degradation, desertification, and human impact on the environment. Much of the debate concentrates on Africa, where extensive research has taken place across dryland regions of the Sahel, East and southern Africa (Hiernaux 1996; Eriksen 2001; Sporton and Thomas, 2002). Investigations in the Middle East (Al-Eisa 1998; Gardner 2005) and more recently on degraded arid lands in China (Liu *et al.* 2005*a*; Li *et al.* 2005) continue efforts to understand dryland processes. Under-researched, however, are the cold drylands of Inner Asia (Li *et al.* 2005; Sugita *et al.* 2007). In an effort to make arid lands dialogue more inclusive and relevant to diverse regions, this exploratory paper considers rangeland issues in a Mongolian context.

Mongolia represents an evolving pastoral landscape facing the challenges of adapting a traditional nomadic lifestyle to modern realities. With 50% of the population dependent on livestock production for its livelihood (Johnson *et al.* 2006) developing enduring herding practices is a national concern. Historically, pastoralism was organized by nobles and monastic representatives in a feudal system that provided regulation of herding practices and allowed for adaptation to environmental conditions (Mearns 1993). This gave way to seven decades of Soviet communism and collectivization. The communist era shifted livestock and land possession to a powerful central government that gave financial and logistical support and salaried herders (Fernandez-Gimenez 2000). Removed from economic and social pressures, collectivization provided water infrastructure, transport that ensured mobility, veterinary care, emergency fodder, and controlled livestock numbers and movement (Fernandez-Gimenez 1999). This era transformed pastoralism from its traditional

subsistence basis to a production-oriented system. By maintaining highly mobile, low impact grazing patterns the environmental consequences during collectivization were limited. Since 1990, Mongolia has shifted to private ownership in a democratic market economy (Bilskie and Arnold 2002). Dramatic change over the last 15 years has seen Mongolia fall into the more universal pastoral norms of maximizing livestock production, reduced mobility, increased sedentarization, and concentration on income-producing animals as herder motivation and options changed from meeting quotas to generating income as in other pastoral regions of the world (Bedunah and Harris 2002; Sorbo 2003: Lesorogol 2006). Concurrently government levels of support and control have been slashed, land tenure has evolved towards private possession, and poverty is widespread (Sneath 2003). The predictable results are the deterioration of the rural water infrastructure, intensified grazing patterns, increased land degradation, and an end to cooperative herding decision-making and implementation (Batjargal 1997; Janzen and Bazargur 2003).

In Mongolia's low precipitation, often highly variable conditions (Batima and Dagvadorj 2000, Begzuren *et al.* 2004, Retzer and Reudenbach 2005) mobility and opportunistic grazing patterns make efficient use of the ecological system and allow adaptation to Mongolia's periodic extreme winter and drought conditions (Sneath 2003). Mongolian rangeland has customarily been open and communal with varying degrees of control exercised by local authorities in the pre-Soviet era, the state during communism, and now by a weak government (Fernandez-Gimenez 2000). These authorities traditionally defined seasonal grazing areas and coordinated migration and herd composition. The dismantling of collectivization and tight control of herding patterns has challenged the traditional pastoralist land use paradigm. A shift to private

livestock ownership, changes in land tenure, a lack of government regulation, and new economic pressures now alter land use. This is seen in the desire to secure control of winter camps, to establish water access, such as private hand wells, reduced migration, and increased settlement. As the structural realities behind herding evolve state attempts to address land possession, contracts, and privatization in the Land Laws of 1994 and 2002 have been inconclusive (Janzen and Barzagur 2003).

Herders' ability to migrate with seasonal or ecological conditions has decreased over the last 15 years. Mobility is essential for sustainable rangeland use by dryland herders (Fratkin and Mearns 2003; Ykhanbai *et al.* 2004), yet several contributory factors now reduce movement. Transport costs and access, no longer provided by the government, become a limiting factor, particularly for poor herders. Decreased water points restrict movement to known sources, often (over)used by others. Between 1990 and 2000 the number of engineered wells fell 80% as functioning hand wells dropped from approximately 35,000 to 20,000 (Tanaka *et al.* 2005). Water becomes the keystone ingredient, motivating both migration when practical or increasing sedentarization near existing water points among herders with reduced mobility. Settlement for economic (access to markets, jobs) and social (health and education) reasons further inhibits movement. Fewer moves result in increased grazing pressure and lead to speculation of long-term pasture damage.

Concern about grassland degradation was highlighted in the government's first National Action Plan to Combat Desertification in 1996, yet by 2002 there had not been research on desertification in the country (UNCCD 2002). The UNEP (2002) claimed 70% of Mongolia as degraded and using remote sensing. Javzandulam *et al.* (2005) identified 31% of the land as severely degraded with pastoralism being cited as ecologically detrimental at the national level (UNCCD 2006). This suggests that

changes to the ecological system are occurring though whether the result of variable rainfall (Stumpp *et al.* 2005), human action (Lee and Zhang 2005), or a combination is not clear. What is evident is that Mongolia now shares similar environmental concerns as other arid lands.

The effects of governance and land tenure change on pastoralists' welfare and environmental degradation have been explored in numerous studies from other regions (Thebaud 1995; Dougill *et al.* 1999; Christensen *et al.* 2003). In Mongolia, however, information on transitions in pastoralism prior to 1990 was published mainly in Russian, and since 1990 has received limited documentation. This paper aims to contribute to the broader literature on social and ecological issues in pastoralist areas by documenting Mongolian herder perceptions of current environmental conditions and challenges. It was expected that herders would find both ecological issues (water availability, pasture resources) and social changes (economics, reduced government role) to be major concerns.

2.2 Methods

2.2.1 Area Description

Mongolia is located in Inner Asia, bordered by Russia to the north and China to the south. Grasslands comprise 80% of the country's 1.56 million km^2 area that is home 30 million livestock (camels, cattle, yaks, horses, sheep, and goat). Bio-climatic zones include montane (8%), forest steppe (15%), steppe (34%), desert steppe (23%), and desert (19%) (Geographical Atlas of Mongolia 2004). An upland country, 85% of the land is above 1000m with most grassland between 1000m to 2500m. Annual precipitation ranges from <50mm in the southern Gobi region to >400 mm in mountain areas with a national average of 224 mm (Batjargal 1997). The continental

climate, extreme temperature variation (40°C to -50°C annually, diurnal ranges of up to 30°C), short growing season and poor soils limit crop agriculture to <1% of the surface area (Batima and Dagvadorj 2000). Out of a population of 2.5 million, approximately half are dependent on pastoralism for their livelihood (Mongolian Statistical Yearbook 2005). Three research areas were selected (Figure 2.1) for geographical breadth to represent a range of potential water and land use scenarios across Mongolia.



Figure 2.1 Map of Mongolia with the 3 research areas.

2.2.2 Survey

From March to August 2005 I conducted surveys of herders in the three study areas. The western region was represented by Hovd province, located in a low precipitation (127mm/yr) steppe and desert-steppe zone with some surface water availability. The north-central forest and grassland steppe of Selenge province and the bordering region is comparatively water-abundant with an annual precipitation average of 289 mm and several surface water sources. Dundgovi and Omnogovi provinces occupy the south-central desert-steppe and desert areas with low precipitation levels (156mm and 127mm per year respectively) and minimal surface water (Mongolian Statistical Yearbook 2005; Geographical Atlas of Mongolia 2004).

From the province capital I followed dirt tracks towards a selected district town, and along the way gers (tent homes) were visually located for field interviews. This led to a stepping-stone process where abodes were spotted and visited along a general trajectory towards the town. Once reached, an alternate route was taken to return to the province capital. In this way herders from different districts were selected by proximity to the travel route, irrespective of social or economic attributes such as family size or wealth. The surveys conducted were designed to examine pastoralist perceptions of impacts and challenges in the herding environment, with particular focus on their daily interactions with water and land. The survey assessed herder knowledge and opinions through field-site interviews and participant observation to ascertain how and in what ways the environment may have altered and how the pastoral nature interaction has evolved (Lee and Zhang 2005). This can provide a perspective on claims of degradation and desertification stressed in published reports and limited relevant articles (Middleton and Thomas 1997; MNE 2002; Asian Development Bank 2004).

Assessments (n=53, not all answered all questions) were made to determine herder concepts of water and land issues in their respective area. Topics addressed included water resources, pasture issues, mobility and land use, environmental challenges, changes to pastoral systems, and herder insights. Pastoralists were asked standardized questions that were not conditional on prior answers. Interviews were conducted through a translator in the pastoralist's habitation after cultural formalities were observed with handwritten notes taken at the time of the interview. Analysis synthesized statements with results reflecting herder responses and estimates. When possible herder reports were verified by personal observation of water sources, pasture quality, and number of livestock.

Answering a set of semi-structured questions regarding water and grazing practices allowed respondents to express personal ideas and behavior. From this common themes emerged relevant to daily pastoral life in the Mongolian countryside. A drawback to this form was that herders spoke about basic themes in different manners, often not responding directly to uniform questions, limiting the scope of comparison. Further study with increased interview numbers in each region would strengthen survey validity and range.

2.3 Results

Surveyed pastoralists expressed clear positions on factors affecting their livelihoods. When asked issues affecting their lives the top eight problems identified were nature/environment related (Table 2.1). Water problems were access and supply, precipitation, and drought. Pasture issues included vegetation quality and availability, insect competition for grass, and extreme winter conditions limiting forage. Weather indicated variability as well as hot and cold temperatures; dust interfered with herding operations. Potential anthropogenic impacts were rarely mentioned. Government policies and actions, efforts to develop water supplies, increased numbers of livestock, mobility patterns, competition for resources, and mining illustrate points where humans interact with the environment. Connections between human agency and ecological conditions were infrequently stressed.

Table 2.1 Pastoral problems identified by herders in rural Mongolia.

Pastoral Problems	
Problem	*Times Cited*
Water Supply	25
Precipitation	24
Insects	21
Pasture	19
Extreme winter	14
Weather	10
Dust	6
Drought	3

Note: Total is greater than respondents (n = 53) as several listed more than one issue

Water Issues: *"Can't have many animals without water"* Water issues were the most frequently cited problems, and included both livestock needs and precipitation impacts on pasture conditions (Table 2.2). Responses regarding lack of water, broken wells, and drying of surface water sources identify absence as a problem; salinity addresses suitable quality. Low well level relates to changes in existing sources while mining can impact access to water and quality. More than half of the respondents felt there was insufficient water availability. Forty of the 53 respondents (75%) obtained water from wells, and even those who had river or spring access at the time depended on wells at other seasonal campsites. The particular concerns expressed regarding wells were as follows: engineered wells are broken, the government should fix or replace them; more hand wells are needed in grazing areas and in unused pasture to expand rangeland; it is not possible for herders to build deep wells, hand wells are costly and difficult to construct, thus government financial and technical assistance is needed; water levels are decreasing; water is saline. One western site exemplified several issues – the herder used a broken engineered well, the hole was too small for a standard bucket, the water was considered polluted and unsuitable for humans, and because of the low water level it took six hours to water 276 animals by hand. In a

country with limited surface water supplies (Asian Development Bank 2004) pastoralists identified the disappearance of streams and springs as a problem. Herders in the southern region, where mining is undertaken with little environmental oversight (Farrington 2005), thought severely decreased water flow in the Ong River was due to mining activity diverting water sources.

Table 2.2 Most important water issues by % of citations.

Water Issue *Problem*	%
Lack of Water	33
Broken Well	21
Saline	16
Low Level	12
River/Spring Dry	10
Mining	8

Table 2.3 Most important rangeland by % of citations.

Rangeland Issue *Problem*	%
Rainfall	26
Insects	23
Pasture Quality	20
Extreme Winter	15
Increase in Livestock/Herders	10
Dust	6

Rangeland Issues: *"I want more animals but the pasture is not good"* – Herders cited the condition of the physical landscape and natural elements in several different forms. Range concerns were discussed generally as pasture quality and specifically as a lack of rainfall for vegetation growth. After precipitation the greatest perceived threat to grazing land was from insects, translated as locusts, eating available grasses, followed by pasture quality (Table 2.3). The winter *dzud,* a condition of extreme cold and ice-crusted snow that prevent animals from grazing, was considered a much greater threat than droughts. Secondary factors included the pressure of increased

livestock numbers and families moving into a herder's traditional pasture, dust storms resulting from a lack of plant cover, and periods of drought and prolonged heat.

Livestock numbers varied greatly, ranging from less than 100 to more than 800 animals per household (Figure 2.3). Herders with moderate (200-399) and high (≥400) animals numbers averaged 5.8 moves and cited water as their main concern whereas those with fewer animals (<200) moved 4 times and cited precipitation as their main concern. Livestock were typically categorized by size with sheep and goats identified as small stock and large stock including horses, camels, and cows/yaks. Similar to a previous study (Stumpp *et al.* 2005), small stock represented approximately 85% of herd composition, horses 10%, and camels, cows, and yaks comprised 5%. Bedunah and Schmidt (2004) suggest 100 animals are a viable herd size and Janzen and Bazargur (2003) identify those with 200 – 300 livestock as mid-level herders. Results imply study participants were reasonably successful in Mongolian pastoral terms.

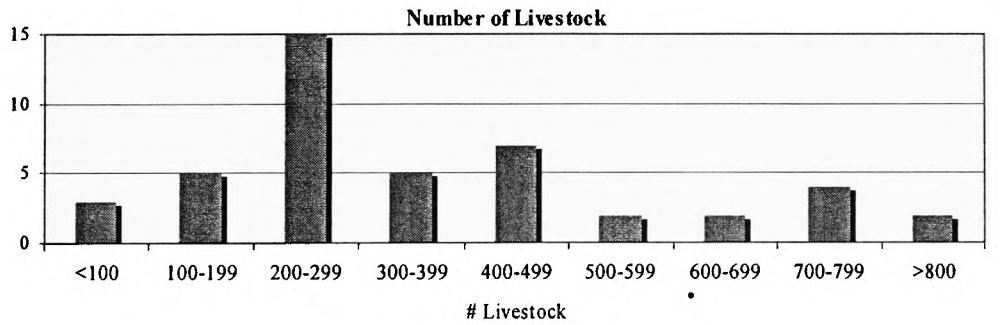


Figure 2.2 Number of livestock owned by each herder.

The annual number of moves varied from 0 to 20, with 30% moving twice or less, over half migrating 3-6 times, 15% moving 8 - 10 times. Herders moving twice or less had half as many livestock as those moving 3 to 6 times and 30% less than

herders who migrated 8 or more times though there was not a significant correlation between moves and number of livestock. Claimed annual migration distances ranged from 100m to 100+ kilometres with long distances perhaps conflated with the common theme of how far one would go in search of water, rather than actual distance of a recent move. Twenty-two percent made annual moves of $\leq$ 5 km, 31% moved 7-15 km, with 47% moving >20 km. While herders with more livestock moved more frequently, they tended to move shorter distances.

Stated distance from herder's dwellings to a water point ranged from 100 m to 8 kilometres. Those using surface water, located predominantly in the north, were a mean of 1.8 km from a water source whereas well users distance from water averaged 1.3 km. Herders within a kilometre of a water source averaged 20% more livestock than those farther away. Those located 1 to 3 km from water moved 1.2 times more per year than those nearest and furthest from water points. Herder environmental concerns were similar regardless of distances from water points (Table 2.4).

Table 2.4 Number of interviewees, average herd size, average number of moves per year and main environmental concern (%) by distance to water

		Distance to Water (km)		
		0-1	1-3	3+
Number of	Interviewees	20	15	12
	Livestock	346	242	304
	Moves	4.6	5.8	4.4
Main Environmental Concern (% cited)	Water	21	20	23
	Pasture	15	16	15
	Precipitation	21	18	15
	Locust	21	18	12

2.4 Discussion

Water (indicated by responses of water, precipitation, and drought) and pasture quality (noted by responses of pasture, locusts, and extreme winter) were pastoralist's main concerns. Economics were considered a derivative of water and range issues: if

these were adequate income would follow. Other agents, such as the government, were seen as peripheral to environmental concerns and of little relevance to livelihood issues except as they impinge on the ability to herd, such as limiting migration or imposing taxes. Concerns such as poor pasture quality, high livestock concentration, and a lack of water were defined as herding problems but become environmental issues. Water and pasture elements were broken down individually; combined they define the pastoralist's physical space. Actions and behavior, often motivated by livelihood issues, also impacted the pastoralist's interaction with nature.

Primary rangeland issues – rainfall and locusts – reflect the inter-annual variability of pasture factors. Locust infestation at the time of the survey was severe (Onoodor/UBP 2004) but is cyclical and was not identified in a previous ecological study (Fernandez-Gimenez 2000) or subsequently noted. Herders believed rainfall had decreased in their area though provincial records showed fluctuating precipitation patterns from 2001-2004 (Mongolian Statistical Yearbook 2005). The most recent *dzud* in 1999-2001 (Nandintsetseg *et al.* 2007), exacerbated by drought, killed approximately 10 million animals, a third of the national herd, leaving 5% of herders with no animals (Ykhanbai *et al.* 2004). Differing intensity and pasture levels, rainfall patterns, localized conditions, and herder/government response affect *dzud* distribution in the country, reflecting how the interplay of several factors defines the pastoral environment. Relevant to pasture quality was a shift in herd composition from sheep to goats as the dominant animal over the last four years (Mongolian Statistical Yearbook 2006). Herders considered goats good economically for the cashmere produced though prior study suggests goats have a detrimental impact on grasslands (Tumurjav 2003). Drought was seldom cited as a major factor, perhaps due to perceived mobility and grazing strategies adapted to low precipitation.

Pastoral challenges were largely expressed in environmental and natural terms. Less evident in this survey were how the changing human - nature interaction impacts the environment. In the last century pastoralism shifted from a pre-Soviet subsistence orientation, through a centrally planned collectivize system that made an effort to mitigate natural effects, to a capitalist approach in which herders define and determine their interaction with the environment. Market economics now plays a key role – driving livestock numbers, type of animal raised, and affecting the number and distances of moves. What is identified as poor pasture quality may in fact be an outgrowth of a lack of movement, often cited as a key feature in maintaining a viable, low-input pastoral structure (Sayre and Fernandez-Gimenez 2003). Declining mobility intensifies grazing pressure and has a detrimental effect on rangeland that, when paired with reduced water sources, serves to create a positive feedback loop as human action exacerbates natural forces in affecting the environment (Figure 2.3).

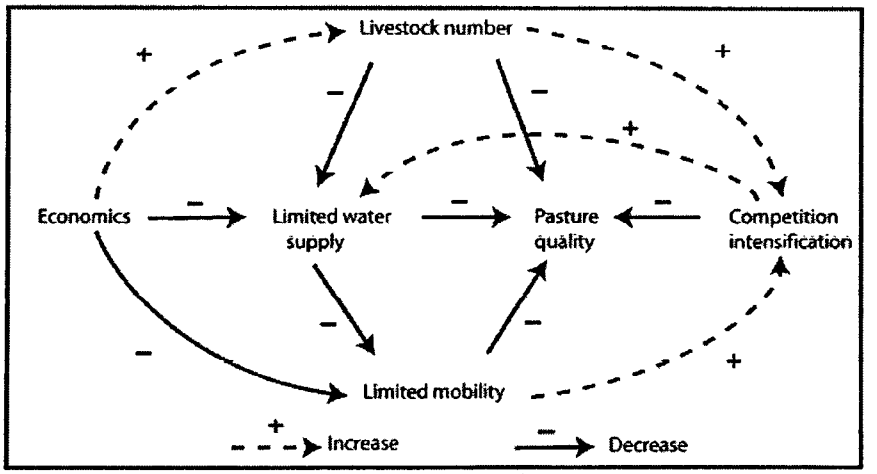


Figure 2.3 Herding impact on the Mongolian environment

Pastoralists' perceptions did not reflect how externalities such as herder decisions, government policy, or social factors impacted the environment. If ecological concerns are to be addressed, an awareness of these relations and the de facto

responsibility of different participants is needed (Walker *et al.* 2004; Reynolds *et al.* 2007). Attitudes towards water resources portray this interconnectedness as respondents focused on a desire for more wells, particularly in places with adequate pasture, and the rehabilitation of broken wells. This continues to be viewed as the role of the government, a holdover of Soviet patterns (Ykhanbai *et al.* 2004), despite years of evidence showing that the state has limited ability to build or fix wells. Thus beyond natural factors the improvement of water supply depends on herder action repairing wells, investing in new wells, or motivating the state to re-engage in water development. Water access can differentiate herders with the inclination and means to improve water points or move to less-used sources from poorer families with reduced pastoral options. Yet possessing a well, like a campsite, is a disincentive to migrate. Today limited water supply concentrates livestock around functioning water points (Bedunah and Schmidt 2004), increasing competition exemplified by one site in western Mongolia where herders reported several thousand livestock watering at one well. A situation is created where present needs for water and the behavior it entails may decrease future rangeland utility, thus impacting long term pastoral viability (Lambin 2005).

Local dynamics are also part of global processes. The Intergovernmental Panel on Climate Change (IPCC) identifies a decrease in summer precipitation and rising temperatures that are projected to reduce net primary productivity in the Mongolian steppe by >10% (Cruz *et al.* 2007). Mongolia, with its dry climate, low soil fertility, and sparse vegetation is susceptible to land degradation and desertification processes (Yang *et al.* 2004) documented in neighboring China (Sneath 2003; Lee and Zhang 2005) and other arid lands more commonly studied. As one herder summarized, "with little good land, too many herders leads to pasture degradation." These terms are

used by international development agencies and government officials yet definition is elusive. When viewed as irreversible and negative change desertification entails crossing thresholds, the identification of which depends on how terms are defined and by whom (Batterbury *et al.* 2002). Natural processes and biophysical vulnerability work in tandem with human personal and socio-economic motivators to impact the environment, a process that can be influenced by government policy. Overgrazing and questionable land use patterns in rural Mongolia reflect intertwined human and environmental roles. To identify degradation necessitates differentiating natural fluctuations from anthropogenic factors over a sufficient timeframe in the country's variable dryland setting (Lambin 2005).

A clear understanding of degradation processes and terminology is important in pastoral issues because future Mongolian government initiatives and laws may reshape the herder paradigm. Foremost will be increasingly complex tenure issues as traditional and more formal rights of possession evolve. User contracts now exist to winter and spring camps while pasture remains under public stewardship. Land privatization is discussed by members of the government with encouragement from the Asian Development Bank and international consultants (Sneath 2003), a possibility that remains an anathema to herders (Sayre and Fernandez-Gimenez 2003). In this survey only one herder considered privatization a feasible alternative, explaining that new approaches might be tried to address poor current conditions. The conventional global argument continues in Mongolia where privatization is presented as a remedy for poor land use and as a way to promote pastoral investment. An alternative approach would address local practices that lead to inappropriate land use and evaluate if the causes (economic) or the remedy (privatization) is likely to be effective in light of Mongolia's history and environment. Parallels can be drawn

from research in other arid lands that individualized property rights had little impact on land productivity or investment in improvements in Africa and China (Lane and Moorehead 1994; Sporton and Thomas 2002; Williams 2002). Lund (2000) states there is not a link between privatizing property and investment. Thebaud (1995) points out that privatization may be contrary to the essential nature of pastoralism – the ability to deal with variegated environmental conditions through mobility – that can be equally applicable to what Mongolia encounters today. The IPCC states that traditional pastoral systems would provide greater resilience and better strategies to cope with climate change in the region (Cruz *et al.* 2007). Also relevant are the drivers of the degradation-desertification debate – politics, economics, development aid and projects, and individual, business, government and international agendas that can use the topic towards their own ends. What looks clearly physical – land and water – are also social issues because their roles are influenced by human forces (Figure 2.4).

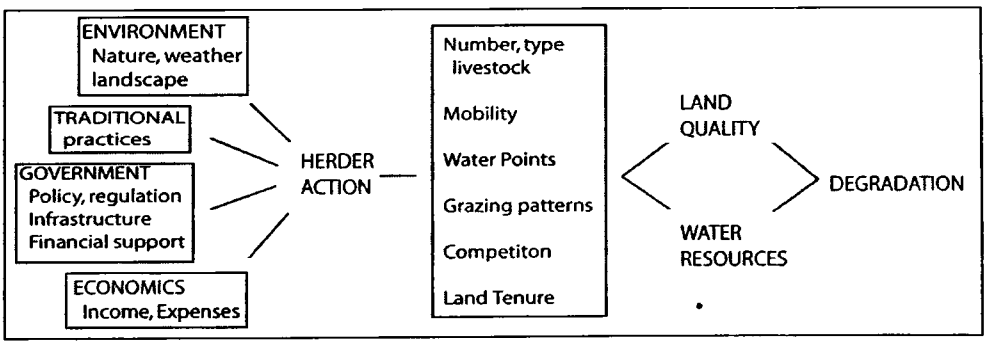


Figure 2.4. Process of herder interactions affecting rangeland in rural Mongolia.

2.5 Conclusion

Mongolia, isolated from western, non-Soviet systems until 1990 (Swift and Mearns 1993), has emerged into a world that challenges its longstanding approaches to pastoralism as the state retreats from active participation and market economics

becomes a driving force. From a broad perspective environmental changes are affected by mobility, water supply, variable rangeland quality, land tenure, livestock preferences, and herder motivations. At the local level pastoralists remain in need of water and adequate grazing land for livestock, and the skills to cope with natural variables - precipitation, *dzuds,* drought, and heat; naturally occurring events – insect invasions, wind, dust storms, saline water; and human agency – movement patterns, intensified grazing, constructed water sources, motorized transport, emergency fodder, mining, and financial decisions. The sustainability of pastoralism remains uncertain with new government regulations, climate change, economic forces, and natural conditions impacting herding.

Embedded in a natural system, this survey highlights the challenges herders face, many beyond their control. Encountering predominant contemporary forces relatively later than other pastoral groups, Mongolia can sift through several perspectives when considering potential future development decisions and directions. Pastoralism has continued through previous transformations; the task will be to evolve a modern hybrid pastoral system where neither pre-Soviet nor communist era approaches are feasible. This can best be done by incorporating the concerns and needs of the large percentage of society that continues to engage in mobile livestock production for their livelihood into the broader societal debate. It will be the herder who is able to adjust to current realities while maintaining the essential adaptive features, such as mobility, that will meet today's physical and economic complexities and lead herding into its evolving future form.

Larger scale issues like degradation are alluded to by the nature of the problems faced. Today's physical conditions, herder behavior, natural cyclical events, and socio-economic needs and choices form land use patterns. Rather than accepting

determinations at face value further scientific research addressing the degradation/desertification debate can establish a basis for environmental claims in this little-studied region. Future efforts can untangle currents trends and perceptions from pre-existing physical conditions in Mongolia's arid countryside. Without a factual basis, ecological terms can be co-opted to serve the arguments and desires of groups with the power to shape the rural landscape. Local conditions need to be evaluated and environmental challenges addressed for the continued sustainability Mongolian pastoralism.

Chapter III

Pressurized pastoralism in South Gobi, Mongolia: what is the role of drought?

Troy Sternberg, David Thomas, Nick Middleton

Accepted by: Transactions of the Institute of British Geographers, April 2009.

Abstract

The desert-steppe region of southern Mongolia is susceptible to drought and extreme winter weather (*dzud*) that in combination form Mongolia's worst natural hazard. Low precipitation and high climatic variability in this dryland environment impact the landscape and affect pastoralism, the dominant rural lifestyle. Using the Standard Precipitation Index (SPI) this paper identifies drought occurrence in South Gobi Province, Mongolia. It then examines the relationship of drought with climate factors, interaction with vegetation, (derived from NDVI data), and local human and livestock populations, and the *dzuds* of 1999-2001. Results showed that drought is recurrent in the region, reaching extreme intensity most recently in 2005-2006. In contrast to the prevailing concept of drought impacting *dzuds,* the study did not find a connection between drought and *dzud* in South Gobi Province. Though repeated events, these natural hazards occur independently in the region. Climatic variables show increasing temperatures (>1°C), fluctuating precipitation patterns, and a decline in vegetation cover. The principal long-term correlation of drought is with human population rather than natural factors, *dzud,* or livestock numbers.

Key words Drought, *dzud*, Mongolia, Standardized Precipitation Index (SPI), natural hazard, pastoralism

---

3.1 Introduction

Drought is an elusive natural disaster – onset, duration, intensity, and conclusion are hard to identify – yet it affects more people than any other type of hazard (Kenyatash and Dracup, 2002; Shinoda *et al.* 2005). Often detrimental environmentally, socially, and economically, drought remains a poorly understood weather phenomenon (Wu *et al.* 2001). Appearing as below-average precipitation over an extended period of time but defined in detail in multifarious ways, it can develop into a severe climatic event affecting water-related processes and vulnerable communities (WMO 1986; Sonmez *et al.* 2005). Drought is trans-regional, occurring in both low and high rainfall areas in any season (Lloyd-Hughes and Saunders 2002).

Drought, generally regarded as significant negative variation from mean precipitation, is identified in three main forms. Hydrological drought entails a shortage in volume of water supply, including streamflow, surface storage, and/or groundwater levels. Agricultural drought describes a lack of water for plant growth. Meteorological drought results from a precipitation deficiency and is the most appropriate for evaluating drought in dryland environments (Keyantash and Dracup, 2002). Arid regions with limited water resources remain sensitive to precipitation fluctuation and shortages. Concurrently, additional features such as temperature extremes, high wind, and low relative humidity can amplify a drought's intensity (Sonmez *et al.* 2005). In drylands, water deficit and climate factors can combine to exacerbate drought effects on local ecological conditions and populations. Physical impacts and socio-economic costs in affected areas have led to several studies of

drought vulnerability in arid zones in recent years (Nicholson *et al.* 1998; Nasri *et al.* 2006; Wu *et al.* 2007).

Monitoring spatial extent and temporal progression of specific drought events is difficult: to address this problem scientists have consequently designed several drought indices. Since its introduction in 1965 the Palmer Drought Severity Index (PDSI) has been widely used to evaluate drought. More recently the Standardized Precipitation Index (SPI) has found broad application and acceptance for drought monitoring and research (Cancelliere *et al.* 2007). McKee *et al.* (1993) developed the SPI to track precipitation deficiencies and anomalies that create drought conditions in the western United States. As an index the SPI provides a clear quantitative assessment of drought characteristics and is adept at evaluating drought at multiple timescales. This index identifies the cumulative probability of precipitation for desired months over specified time periods at a given meteorological station (Rouault and Richard 2003). Currently applied in 60 countries (Wu *et al.* 2005), the SPI has been used for drought assessment in several arid and semi-arid regions, including East Africa (Ntale and Gan 2003), the Sonoran desert of Mexico (Hallack-Alegria and Watkins 2007), Northwest China (Wu *et al.* 2001), India's Thar Desert (Bhuiyan *et al.* 2003), and Australia (Prasad and Khan, 2002). This paper takes drought indicated by SPI and expands its implications to understand how drought episodes at different timescales interact with climate variables and natural hazards to affect Mongolia's regional environment and pastoral community.

3.1.1 Drought in Mongolia

A prominent feature of Inner Asian desert and steppe landscapes, drought is a common natural hazard in Mongolia (World Bank 2002; FAO 2006; Johnson *et al.* 2006). The

country's traditional nomadic pastoralism has evolved into mobile livestock-raising that enables herders to cope with recurrent hazards in a region where livestock production can be critically affected by climate variability and extreme events. This arid environment combines limited precipitation (concentrated in summer), a great annual temperature range, and sparse vegetation, factors that can result in an unusual natural phenomenon known as *dzud*. A *dzud* occurs when extreme winter cold, snow, and ice limit forage potential, threatening livestock survival. Drought, which reduces summer grazing potential and thus livestock weight gain, can magnify a *dzud's* intensity and impact (Shinoda *et al.* 2005; Asian Development Bank 2005). Limited reports of *dzuds* suggest they occur from once in three to once in seven years (World Bank 2002; Begzsuren *et al.* 2004). A combination drought-*dzud* ("perfect storm") event happens periodically. The most recent was in 1999–2001 when livestock mortality reached 8 to 10 million animals, approximately 30% of the national herd, in the worst natural disaster in Mongolia's recorded history (UNDPI 2000; Batima *et al.* 2005). This *dzud* affected South Gobi Province and 70% of the country and led to international relief efforts from the UN, International Red Cross, European Commission, and the World Bank (UN 2000; UN 2001). Despite the importance of drought-*dzud* episodes in rural Mongolia perceived linkages between the two natural hazards are inferred rather than based on research findings. This paper addresses the lack of drought-*dzud* analysis by examining their interaction and potential correlation in South Gobi Province.

Using the SPI to determine drought occurrence in South Gobi Province, Mongolia we examine the implications of drought and climate stress on local ecological and pastoral communities, including its potential interaction with *dzuds*. Temperature, precipitation, and vegetation were correlated with human and livestock populations to highlight the role of drought in the pastoral context. Identification of drought implications within the

physical and social environment could inform governance, management, and development at local and national levels and better comprehension can improve response and mitigation of drought processes in southern Mongolia. Particular attention is given to the 1999-2001 *dzud* to evaluate the contributory role of drought and climate stress to this extreme weather event and its impact on the local pastoral community.

3.1.2 Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is used to assess anomalous and extreme precipitation. It monitors meteorological drought at different time scales and enables comparison across regions and varied climatic zones. The SPI, used to calculate drought initiation, magnitude, duration, and frequency while providing spatial and temporal flexibility, reflects the probability of precipitation at selected timescales measured by the number of standard deviations the observed value is from the long-term mean. SPI for a specific time period at any location requires a monthly precipitation database for a continuous period of at least 30 years. As precipitation is typically not normally distributed data is transformed using equal probability to a normal distribution (McKee *et al.* 1993; Hayes *et al.* 1999). The cumulative distribution is then transformed to a mean of zero, with the SPI value being the difference of precipitation from the historic mean for the selected period divided by the standard deviation from the mean (Sonmez *et al.* 2005).

The precipitation for a specified time generates an SPI value where the magnitude of divergence from zero represents the probability of occurrence (Hayes *et al.* 1999). Positive values signify wet conditions while negative values indicate drought. A drought event occurs when the SPI is continuously negative and reaches a value of $\leq$ -

1.0 and ends when the SPI attains a positive value. Details of the SPI algorithm are found in work by Ntale and Gan (2005), Lloyd-Hughes and Saunders (2002), and Wu *et al.* (2005).

The SPI is effective because of its simplicity, the sole requirement being a long-term precipitation history. This makes it particularly suitable for developing countries such as Mongolia where limited data availability can be a challenge to drought quantification. Though straightforward, the SPI is robust, having been favorably evaluated relative to other drought indices, including the Palmer Drought Severity Index (Guttman 1999; Keyantash and Dracup 2002). The advantages of the SPI are its statistical consistency, ability to describe short and long-term drought, and the potential for carrying out drought risk analysis (Cancelliere *et al.* 2007). The U.S. National Drought Mitigation Center adopted the SPI after Hayes *et al.* (1999) demonstrated how it can be used to detect the onset, spatial extent, and temporal progression of droughts. Worldwide use of the SPI (Wu *et al.* 2007), including Europe (Lloyd-Hughes and Saunders 2002), South Africa (Roualt and Richard 2003), and East Asia - Korea (Min *et al.* 2003) and China (Bordi *et al.* 2004) - shows its broad acceptance for real-time drought monitoring and retrospective analysis.

However, because the SPI is normally distributed it identifies drought events that reflect local aberrations. Thus it cannot distinguish regions that are more "drought prone" than others. Additionally, as Wu *et al.* (2007) demonstrated, in arid locations and dry seasons short time scales may have skewed precipitation distribution when relatively small precipitation anomalies cause large SPI values. Therefore duration of drought is a critical feature in arid climates.

3.1.3 Study area

South Gobi Province, Mongolia lies in the country's southern desert steppe region bordering China, 560 km southwest of the capital city Ulaan Baatar and approximately 1000 km northwest of Beijing (Figure 3.1). This territory of 165,000 km^2 is inhabited by semi-nomadic pastoralists raising sheep, goats, horses, cattle, and camels in the arid environment. Over the last century their traditional livelihood has evolved in distinct phases, from a feudal approach through 70 years of Soviet rule to become, since 1990, a market-oriented democracy (Fernandez-Gimenez 1999). As systems have changed herding inputs, demands, and challenges have modified. Since the end of the collective system the once-dominant government role, which provided wells, emergency fodder, and transport, has given way to private livestock ownership and individual responsibility. Without the previous external support and mitigation the impact of natural disasters has increased in the region (Begzsuren *et al.* 2004). Dalanzadgad and Bulgan are located north of the Gurvan Saixan Mountain range on rolling gravel plains at an elevation of 1000 to 1500 metres.



Figure 3.1 Map of Mongolia with precipitation isohyets (mm).

Two natural hazards dominate in the South Gobi – drought and extreme winter *dzuds*. The former inhibits vegetation growth, reduces livestock summer weight gain, and results in livestock concentrating around water points with this damaging

vegetation; the latter restricts the ability of animals to forage and threatens livestock survival (Suttie 2005) (Table 3.1). Insects, disease, wind and dust storms, and harsh temperatures – both in degree and range - are further potentially disrupting events. Based on an aridity index (P/PET) and 121 mm average annual precipitation at the two sites over the length of the study, the region is arid and sensitive to precipitation fluctuations and timing (Middleton and Thomas, 1992; Shinoda *et al.* 2007). The inter-relationship of drought and *dzud* hazard episodes is examined in this paper.

Table 3.1 Recent drought and *dzud* events in Mongolia.

Natural Disasters	
Year	Type of Disaster
1944-45	*Dzud* + drought
1954-55	*Dzud*
1956-57	*Dzud*
1967-68	*Dzud* + drought
1976-77	*Dzud*
1986-87	*Dzud*
1993-94	*Dzud*
1996-97	*Dzud*
1999-00	*Dzud* + drought
2000-01	*Dzud* + drought

from Reading et al. 2006

Livestock raising is the dominant livelihood in South Gobi Province with goat cashmere, meat, dairy products and wool the main income sources. Animals represent sustenance, wealth, and material for herders' tent homes and lifestyles. Livestock, and thus herders, are dependent on summer vegetation growth for adequate animal fat gain to survive through winter. In addition to natural factors anthropogenic influences such as water resources (wells), grazing patterns, emergency fodder, external support, and "market economics" can impact this livelihood and ecosystem.

Articles and reports, stressing drought frequency (World Bank 2002; Johnson *et al.* 2006) and the severity of extreme winter weather, state that summer droughts in

1999-2001 caused *dzuds* (Batima *et al.* 2005; Asian Development Bank 2005; Nandintsetseg *et al.* 2007). These authors recognize how water and forage resources affect livestock conditions and herder well-being and then infer a causal role for summer droughts in *dzud* events. As this multi-year event imprints itself on the nation's consciousness I take the opportunity draw together the above-mentioned factors to assess the causes, impacts, and relationships that now define the 1999-2001 disaster.

3.2 Methods

The use of the SPI is particularly appropriate in Mongolia because of the limited amount of data required compared with soil moisture, evapotranspiration, and recharge-rate data needed to calculate the PDSI. The SPI highlights meteorological drought in this region with little surface water and minimal agricultural production. Daily precipitation records dating from 1970 were obtained from the National Institute of Meteorology and Hydrology for two sites – Dalanzadgad (N 43.57°, E 104.43°), the province capital, and Bulgan district, 100 kilometres northwest (N 44.01°, E 103.53°). Further statistical information was provided by the provincial government. Six factors that interact with natural hazards in the region were examined. These were drought as measured by the SPI, precipitation, temperature, Normalized Difference Vegetation Index (NDVI), and human and livestock population. Data were analyzed with SPSS 14.0 (SPSS Inc., Chicago, Il.) to establish if drought plays a role in the natural and social environment in the South Gobi. Pearson correlation coefficients were used to determine the significance (2-tailed) of relationships between variables.

Using the SPI software program from the U.S. National Drought Mitigation Center drought was examined at 3, 6, 12, 24 and 60 month time scales. This study focuses on drought events only when they are at moderate, severe, and extreme levels. Given the short (90-130 frost-free days) vegetation growth phase and intensive grazing season (FAO 2006), annual SPI values were measured from September through the end of August to best monitor summer drought at several temporal phases. This period coincides with high seasonal precipitation, with ≥60% falling during June, July, and August and ≥80% between May and September (Hilbig 1995).

As the SPI is based on precipitation records, local conditions need to be understood to clarify the role of precipitation in a region dependent on livestock-raising. Using daily climate data we looked at precipitation amount, frequency, inter-annual variation, decadal change, and any correlation to *dzuds* over the long-term record. Using the coefficient of variation (CV) for the mean annual precipitation at both sites (121mm) the variation was calculated as CV=(S/X) ×100%, with X being the mean annual precipitation and S standard deviation.

Temperature becomes an important factor in the region as cold weather relates to *dzud* events in winter and high temperatures increase evapotranspiration in summer, affecting both summer vegetation growth and potential winter hazards. South Gobi Province, with a continental climate, experiences dramatic annual temperature ranges of >65°C. Temperature was evaluated for long-term change and potential relationship to drought or *dzud* events.

Normalized Difference Vegetation Index (NDVI) data were derived using Spot-4 1 kilometre resolution satellite data available from 1998 to 2006. Thirty-day digital number values were calculated at twenty sites in each district for April through October, matching the maximum potential vegetation growth period. Results were

averaged to provide a yearly NDVI value. While NDVI has limitations (Richard and Poccard, 1998), it is used here to provide an estimate of vegetation density and land cover relating to drought events.

Local human (1981-2006) and livestock (1980-2006) population data from annual spring censuses were obtained from the province government. Data for the site districts were compared with environmental conditions to assess how drought and climate stress affect pastoralists and livestock. This was done through examining district human and livestock records to identify population fluctuations to natural variables and tracking population trends between herders and animals.

3.3 Results

Time series - 3, 6, 12, 24 and 60-month SPI

To derive a climatology of drought events at different time scales the SPI was applied to a time series over the 37 year historic record in South Gobi Province, Mongolia. Figure 3.2 shows SPI values at the end of August at Dalanzadgad and Bulgan. At shorter time periods a pattern emerges: the 1970's were mixed - dry to wetter, the 1980's drier, the 1990's moderate and the 2000's drier with drought more pronounced on longer time scales. Between the sites there was greater variance in the shorter term. At the end of 2006 Dalanzadgad was drought stricken at all time scales whereas Bulgan had mildly wet conditions. The most significant drought period was the 1980's with both sites having negative SPI values for multiple years, reflected at major time scales in Figure 3.3.

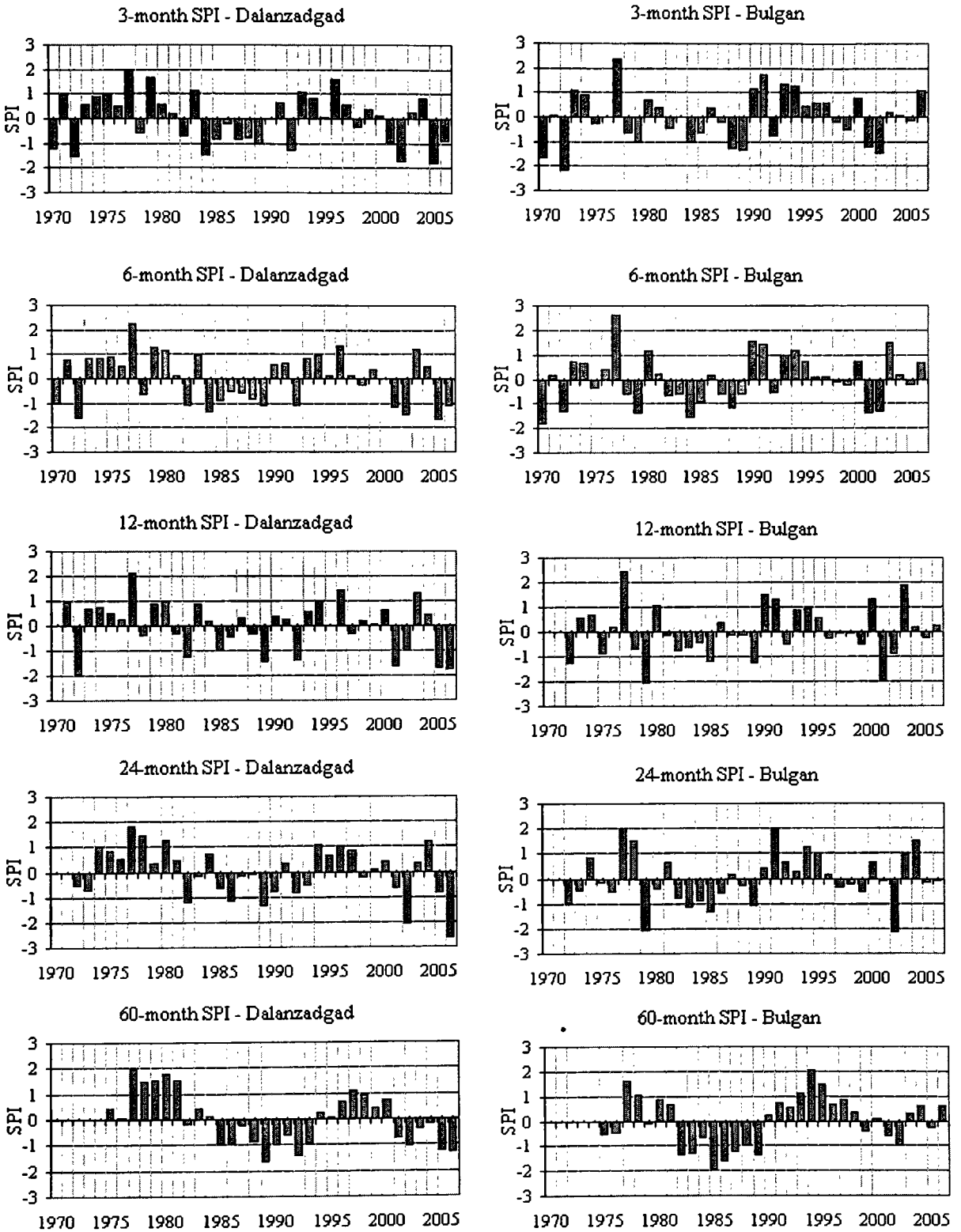


Figure 3.2 Standardized Precipitation Index at 3, 6, 12, 24, and 60 months time scale (top to bottom) at the end of August, 1970 to 2006.

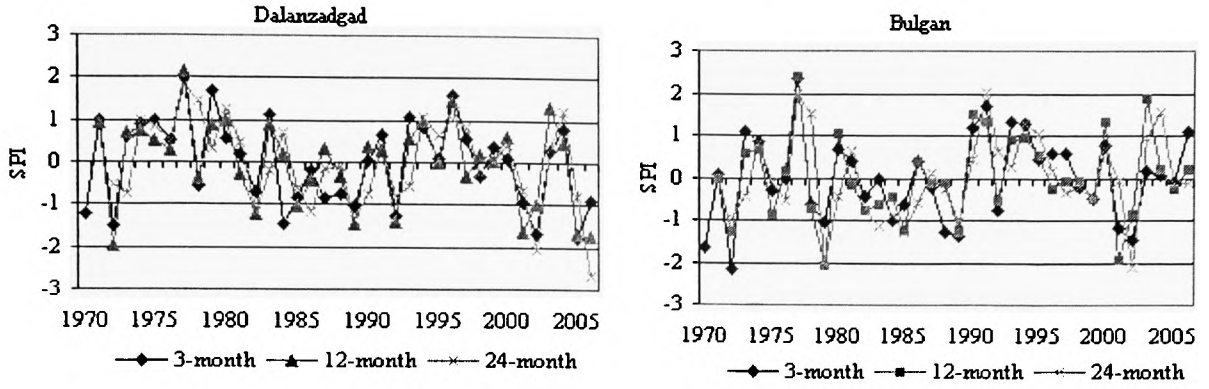


Figure 3.3 Comparison of significant SPI time series 1970 to 2006.

There are multiple drought episodes throughout the historic record, identified by peak drought intensity (Table 3.2). The two sites experienced a similar number of events differing in timing, intensity and duration. Seven droughts were simultaneous, one concurrent for 27 months, with 2 of the same intensity. In the 2000's Dalanzadgad had severe and extreme droughts whereas Bulgan experienced only short moderate droughts. Conversely in the 1970's Bulgan had three long extreme drought episodes when Dalanzadgad had shorter moderate and severe droughts, reflecting inter-site difference.

Table 3.2 Drought events in Dalanzadgad and Bulgan, Mn. using 12-month SPI from 1970 to 2006. Includes droughts reaching moderate (≤-1.0) severe (≤-1.5) and extreme(≤-2.0) intensity.

Dalanzadgad							**Bulgan**						
Onset (year/month)		End (year/month)		Duration (months)	Intensity (peak)	*Event Index*	Onset (year,/month)		Completion (year,/month)		Duration (months)	Intensity (peak)
1971	4	1971	5	1	Moderate	*1*	1970	12	1970	12	6	Extreme
1972	8	1972	4	9	Severe	*2*	1972	8	1973	5	10	Extreme
1973	6	1973	7	2	Severe	*3*	1978	10	1980	3	18	Extreme
1978	10	1979	5	8	Severe	*4*	1982	7	1982	7	1	Moderate
1982	8	1983	2	7	Moderate	*5*	1982	11	1982	11	1	Moderate
1984	10	1985	8	11	Severe	*6*	1983	5	1983	6	2	Moderate
1988	7	1988	8	1	Moderate	*7*	1984	9	1985	8	12	Extreme
1989	1	1989	3	3	Moderate	*8*	1988	10	1989	9	12	Severe
1989	5	1989	6	2	Moderate	*9*	1993	5	1993	5	1	Moderate
1989	8	1990	2	7	Moderate	*10*	2001	8	2001	9	2	Severe
1992	8	1993	6	11	Severe	*11*	2002	6	2002	6	1	Moderate
1995	7	1995	8	1	Moderate	*12*	2002	10	2002	10	1	Moderate
2001	8	2001	9	2	Severe	*13*	2005	6	2005	6	1	Moderate
2002	8	2003	4	9	Severe	*14*	2006	5	2006	6	2	Moderate
2005	7	2006	9	15	Extreme	*15*						

To clarify drought frequency and intensity Table 3.3 portrays the two sites having different overall rates of drought. Dalanzadgad had higher than expected rates at 6, 12, and 60 months and elevated severe drought percentages at 3, 24, and 60 months. Bulgan exhibited lower than expected moderate drought frequency yet consistently high rates of severe drought. Although both sites had limited extreme drought periods, overall Dalanzadgad experienced more extended episodes with 20% of the long-term period representing a 12-month drought. The six previously identified *dzud* years did not correlate with 12-month drought in South Gobi Province (Table I). This may reflect differing local conditions and the variability of *dzud* impact across Mongolia's large territory.

Table 3.3 Number and percentage of months in drought by severity as measured by SPI. Total number of months = 444.

	Months in Drought						% Time in Drought by level					Cumulative
Dalanzadgad	3	6	12	24	60	**# Months**	3	6	12	24	60	Probability %
Moderate	32	53	62	34	50		7.2	11.9	14.0	7.7	11.3	9.2
Severe	23	17	19	23	29		5.2	3.8	4.3	5.2	6.5	4.4
Extreme	10	7	8	12	0		2.3	1.6	1.8	2.7	0	2.3
Total	65	77	89	69	79	Total %	14.6	17.3	20.0	15.5	17.8	15.9
Bulgan	3	6	12	24	60	**# Months**	3	6	12	24	60	
Moderate	32	37	41	38	37		7.2	8.3	9.2	8.6	8.3	9.2
Severe	23	25	21	29	31		5.2	5.6	4.7	6.5	7.0	4.4
Extreme	10	7	8	5	0		2.3	1.6	1.8	1.1	0	2.3
Total	65	69	70	72	68	Total %	14.6	15.5	15.8	16.2	15.3	15.9

3.3.1 Precipitation

Long-term (1970-2006) mean annual precipitation in South Gobi Province averaged 121 mm at both sites and ranged from 51.6 to 235.7 mm in Dalanzadgad and 57.1 to 216.5 in Bulgan. The inter-annual Coefficient of Variation (CV), equaling 33% and 32% respectively, crosses the 30% threshold that defines non-equilibrial ecosystem dynamics, a state that limits stable plant and animal ecosystem interactions (Ellis and

Galvin 1994). When calculated for June, July, and August the CV jumps to 42% and 52%.

Examination of the decadal variability for long-term trends and management implications (Rouault and Richard 2003) shows a 17% precipitation decline at Dalanzadgad between the first (1970-1979) and last (1997-2006) ten-year period (Figure 3.4). In the key summer growing season precipitation fell by 30%, with a 45% fall in June, reducing moisture availability for incipient grass growth. In contrast Bulgan saw a 10% increase in precipitation over the same time period with a 6% decline in summer. June rainfall decreased 30% but was moderated by a large increase in May and a lesser gain in August. Annual days with precipitation (43.8) and average amount per event (2.75 mm) were the same at both sites though distribution differed. Precipitation correlated with population in Bulgan (P=0.05). Winter precipitation was minimal throughout the period.

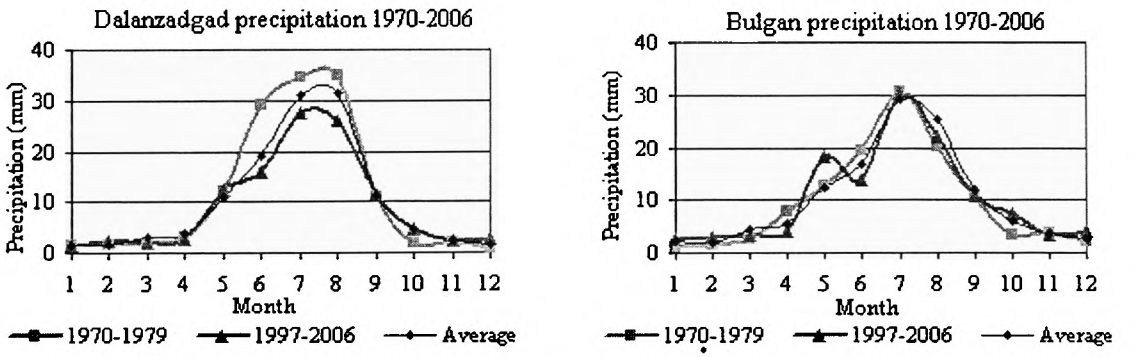


Figure 3.4. Long-term decadal precipitation average in South Gobi Province 1970 to 2006.

3.3.2 Temperature

Interdecadal comparison shows increasing average temperature at both locations. Dalanzadgad rose 1.5°C overall with a 1.8°C summer and a 1.1°C winter temperature gain (R^2 = 0.47). Similarly Bulgan increased 1.05°C overall with summer 1.7°C

higher (R^2 =0.25). In this region changing temperature patterns may impact vegetation growth and winter weather extremes. Historic average January temperature had a significant negative correlation with SPI in Bulgan (3, 6, 12 month P=0.01; 24, 60 month P=0.05); in Dalanzadgad this was significant at 24 and 60 months (P=0.05) whereas at 3, 6, and 12 months mean July temperature was negatively correlated with SPI (P=0.05). At both sites July temperature showed a significant relation (P=0.05) with livestock numbers.

3.3.3 Normalized Difference Vegetation Index

NDVI is used as a measure of vegetation cover to assess if drought and climate stress affect growth patterns and forage resources over time. South Gobi Province manifests limited precipitation in consistently low SPOT-4 derived annual values (-1 to 1.0 scale) that provide an historical perspective of land cover (Table 3.4). Recent NDVI values fluctuated by 35% at the sites with lowest values in 2002, 2005, and 2006. Inter-annual values varied from 28% greater to 30% less than average values whereas monthly values diverged from 25% above to 31% below average, with highest values in April and October and lowest values in July and August. Both areas have similar trends though Bulgan shows slightly lower vegetation levels. NDVI correlated with SPI at 3, 24, (P=0.05) and 60 (P=0.01) months in Dalanzadgad and with livestock numbers (P=0.05) yet shows no such significance in Bulgan.

Table 3.4 Annual NDVI value by site, 1998-2006.

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bulgan	0.11	0.12	0.13	0.09	0.07	0.12	0.10	0.07	0.07
Dalanzadgad	0.12	0.14	0.14	0.11	0.08	0.11	0.11	0.09	0.08

3.3.4 Human population and livestock

Population trends in the two districts were similar from 1981 through 2006. Gradual 20 year population growth was followed by a 50% drop in 2001 and an equal rebound in 2003 (Figure 3.5). This reflects pastoral migration motivated by perceived poor ecological conditions, concern for potential *dzud* impact, and a lack of mitigating factors, such as emergency fodder, in harsh circumstances. Population was significantly correlated (P=0.01) with SPI at all time periods in Bulgan as well as 3 and 6 months in Dalanzadgad and (P=0.05) at 12 and 24 months. The strong tracking of population with SPI identifies herder-adaptive strategies to drought conditions that impact their livelihood.

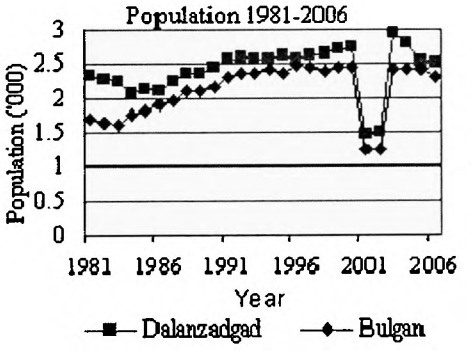


Figure 3.5 Population for Dalanzadgad and Bulgan, 1981 to 2006.

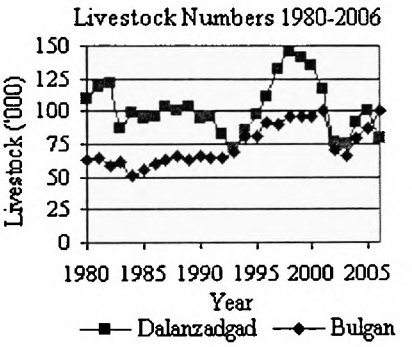


Figure 3.6 Livestock population in Dalanzadgad and Bulgan 1980 to 2006.

Following a period of political and socio-economic transition in the early 1990's there was an increase in livestock numbers (Figure 3.6). Dalanzadgad, which saw a 200% increase in livestock from 1993 to 1998, experienced a 14% drop in 2001 followed by a further 35% fall in 2002. Bulgan livestock figures increased 71% over the same period and maintained numbers until a 30% decline in 2002. These decreases represent mortality as well as pastoralist out-migration to regions with greater forage potential. Environmental factors improved in 2003 as precipitation

increased 123% in Dalanzadgad and 97% in Bulgan and NDVI values rose 20% and 29% respectively. The livestock population increased in 2004, indicating the rapid reproduction amongst of the dominant sheep and goats and animal in-migration (Bezsguren *et al.* 2004). However, changes in livestock numbers were not always matched by the demographic patterns. In Dalanzadgad notable livestock declines occurred in 1982-1983 (28%) and 1991-1992 (15%) that were not related to human population shifts or identified *dzuds*.

Livestock numbers reflect drought at the 60 month interval (P=0.01) in Dalanzadgad whereas in Bulgan there emerges a link between livestock and temperature (P=0.01). Population and livestock numbers in the same year showed little relationship though population with one-year delay in livestock figures was significantly related throughout the study in both Dalanzadgad (P=0.05) and Bulgan (P=0.01). The one-year delayed association between the two factors may reflect census timing in the country as previously noted by Shinoda *et al.* (2005).

3.3.5 Dzud of 1999–2001

Further investigation of the 1999-2001 drought-*dzud*, Mongolia's worst natural disaster in recorded history, focused on climate data for 1998 through 2003. SPI values for Dalanzadgad and Bulgan, South Gobi Province show in 1999 and 2000 neither site experienced drought at any timescale. The 1999 12-month SPI values were mild, changing in 2000 to wet conditions (Figure 3.7). In July and August 2001 both sites became drought stricken at 12 months in July and August. Dalanzadgad reached drought status at all time scales in 2002 whereas Bulgan at 3, 6, and 24 months was in drought. From August 2002 through April 2003 the two sites

experienced a 24-month drought, reaching extreme intensity in August. In May 2003 both sites shifted to wet conditions.

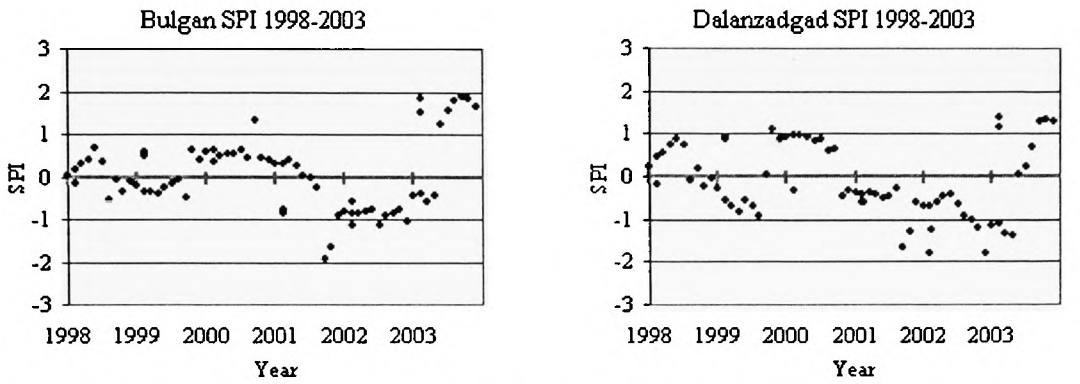


Figure 3.7 12-month SPI records, 1998-2003.

During 1999–2002 mean January temperature was generally warmer at both sites than the long-term averages; 2000-01 was ~ 3°C colder (Figure 3.8) although 2002 was 4.8°C and 3.8°C warmer than historic norms at the two sites. Winter precipitation (December, January, February) in 1999-2001 was normal or slightly less at both sites (Figure 3.9). Notable was high precipitation in December 2001 with this preceding livestock losses in 2002 coinciding with above average temperatures.

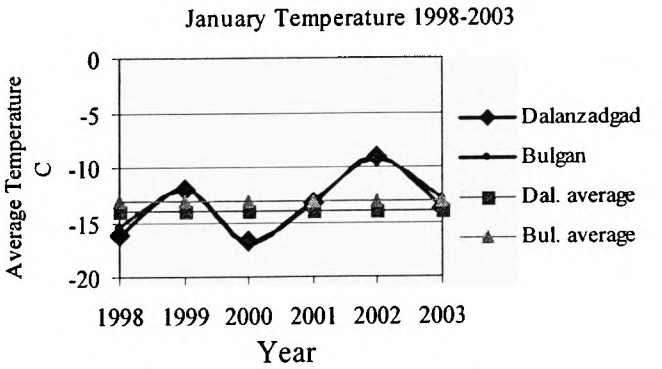


Figure 3.8 Average January temperature 1998-2003.

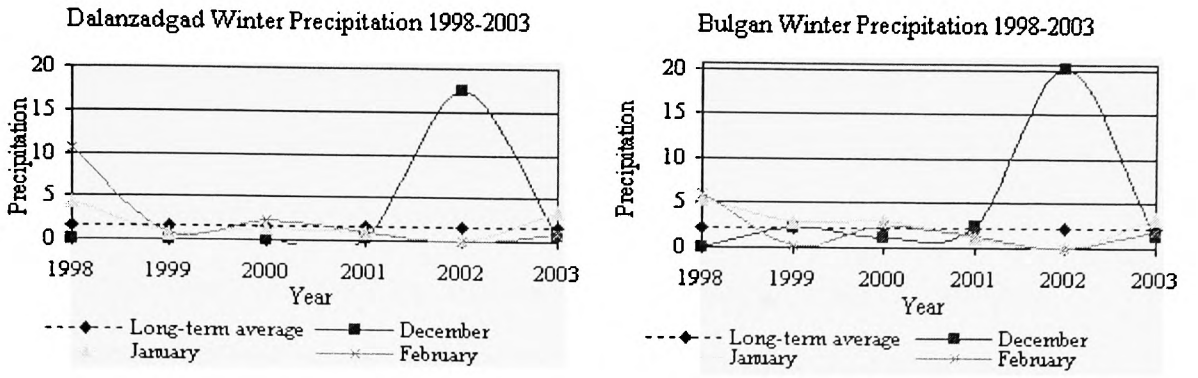


Figure 3.9 Average winter precipitation 1998-2003.

In 2001 the human population fell by 50% in both districts, with livestock numbers dropping the following year (Figure 3.10). Both groups remained below normal for two years, then, as the precipitation and vegetation cover increased, both populations rebounded, pastoralists in 2003, livestock in 2004.

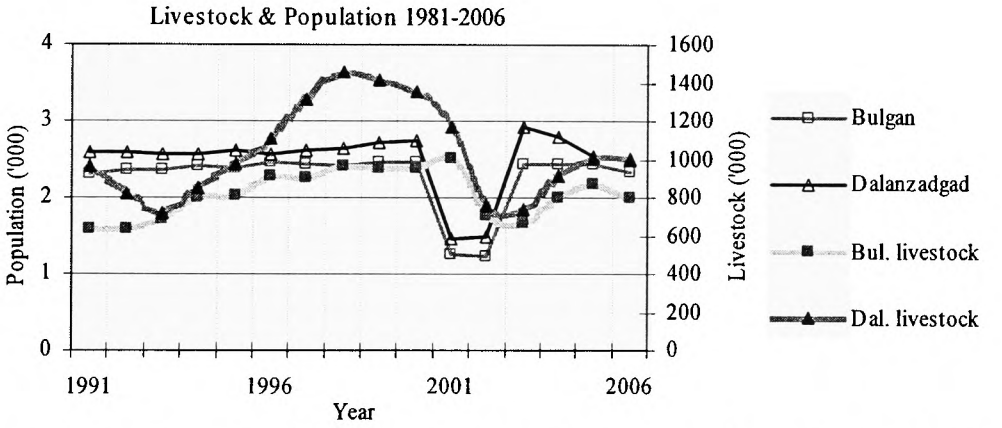


Figure 3.10 Human and livestock populations in Dalanzadgad and Bulgan, 1991-2006.

3.3.6 Dzud and drought; non-drought years

Examining other historic *dzuds* (1987-88, 1994-94, 1997-98) at both sites found that drought was not present during these *dzud* events. 5 of the 6 *dzud* periods (3 Bulgan, 3 Dalanzadgad) experienced above average rainfall as *dzud* years recorded higher average precipitation than drought years at both sites. The year after the *dzud* saw

precipitation declines in all cases, increased livestock numbers 5 of 6 years, increased population in four years with a slight decrease (2%) two years. An analysis of *dzuds* found there were not significant correlations between *dzud* years and livestock, precipitation, or January average temperature.

Using time series analysis the relation of non-drought years to livestock, precipitation, NDVI, and January and July temperature since 1981 was investigated at the 12-month time scale (through August). Results showed that livestock numbers and July temperature were significantly related ($P = 0.01$) at both sites and that NDVI was correlated to livestock in Dalanzadgad ($P = 0.05$) whereas other factors in were not correlated. Non-drought years showed less correlation with environmental factors than drought years.

3.4 Discussion

The SPI identifies recurrent, site-specific meteorological droughts across five time-scales in South Gobi Province, Mongolia. 93% of 12-month droughts occurred during the May to September peak precipitation and vegetation growth seasons. Drought is widespread, occurring on average every third year, with the duration of moderate, severe, or extreme states varying from 1 to 18 months. The strongest long-term correlation of drought is with human populations rather than climatic or ecological variables, reflecting how pastoralists, through mobility, adapt to drought stress. Yet livestock numbers displayed independence, implying association with economic motivators rather than environmental factors. Results show that drought events are not strongly associated with climate variables like mean annual temperature, decadal precipitation changes, and identified *dzuds*. Between-site SPI

values are unassociated, explaining divergent findings such as a link between vegetation and drought in Dalanzadgad yet none in Bulgan.

In this study *dzuds* were not preceded or concurrent with 12-month droughts. Years with extreme drought – 1970, 1972, and 1978 in Bulgan and 2005-06 in Dalanzadgad were not followed by identified *dzud* conditions and in South Gobi Province the *dzuds* of 1999–2000 and 2000–2001 were not correlated with drought. Before and during these events much of the time wet conditions prevailed at the sites, notably in 1998 and 2000. Prior *dzud*s (1987, 1994, 1997) were not associated with drought.. The conventional understanding of *dzud* and drought is that drought precedes or intensifies a *dzud.* This study suggests that drought and *dzud* are de-coupled in South Gobi Province; thus the prevailing concept needs more thorough examination, particulary when *dzud* is defined by stock losses rather than meteorological data alone (Suttie 2005).

International relief efforts were directed to the province 2000-2001 (UN 2001; IFRC 2001) though a natural disaster was not identifiable. This suggests that understanding the impact of winter hazards, extreme or otherwise, involves acknowledging anthropogenic as well as environmental causes. Myriad herder-related issues influence livelihoods in this pastoral environment with these including high livestock numbers, resource competition, herder preparedness, lack of fodder or adequate shelter, emergency relief, and land degradation (Suttie 2005). Addressing these challenges requires planning, organization, and governmental or private support. Human agency and natural factors need to be separated when considering hazard mitigation at the same time as pastoralist motivations and broader development and sustainability themes. Reacting to perceived random environmental events, such as with international *dzud* aid, reflects a short-term approach to disaster alleviation.

The findings of this study question the oft-cited detrimental effect of drought in Mongolia (Adiyasuren 1998; UNCCD 2002; World Bank 2002; FAO 2006). Drought is a commonplace event and only one of several environmental challenges affecting this arid region. Its frequency and intensity here showed only a moderate link with natural factors with little impact on livestock numbers. Pastoralists have adapted and evolved mechanisms to reduce drought impact on their livelihoods.

The long-term record in this survey shows South Gobi Province experienced *dzud* conditions in 2002. Out-migration of half the population in 2001 was followed by livestock decreases of ≥30% in 2002. July and August drought in 2001 may have impacted the *dzud*, yet a more extended drought in 2002 saw human and livestock populations stabilize. As precipitation and vegetation conditions improved pastoralists returned in 2003 with a corresponding >20% rise in livestock in 2004. During this time the greatest climatic variant was a multi-fold increase in winter 2001-02 precipitation providing sufficient moisture as snow or ice to create *dzud* conditions. In combination with higher than average temperature this may have impacted environmental events, perhaps as warmer temperatures created differing circumstances (such as more freeze-thaw cycles) that contributed to a *dzud* (Batima *et al.* 2005).

The most notable climate factor is a warming temperature trend as mean decadal temperature (1970-1979 and 1996-2005) rose by 1.5°C in Dalanzadgad and 1.05°C in Bulgan. Summer increases of 1.8°C and 1.7°C respectively over the same two periods had implications for moisture availability, growth patterns, future ecological productivity, and related livelihood issues. Precipitation varied throughout, with decreases in June and declining precipitation, particularly in summer, in Dalanzadgad. Yet drought episodes did not logically mirror changing precipitation patterns –

overall decadal increases in Bulgan saw more drought events whereas although there was a fall in Dalanzadgad's precipitation there were fewer droughts.

3.5 Conclusion

The SPI was shown to provide an effective tool for monitoring meteorological drought in Mongolia with this suggesting it could be implemented in other regions of the country. Improved understanding of drought dynamics – initiation, intensity, and duration in this arid region could identify drought risks and the degree of pastoralist vulnerability to precipitation deficiency over multiple time intervals. The ability of the index to track dry conditions and identify drought onset could be useful for mitigating drought impact and increasing preparedness to deal with natural hazards for the 40% of the nation dependent on pastoral livelihoods (Mongolian Statistical Yearbook 2005). Its site-specificity makes it applicable across Mongolia's varied ecological zones while the SPI's simplicity allows it to be computed in local meteorological and government offices. SPI can be a productive pastoral management tool for concerned public and private agencies.

Although perceived to have a direct influence on the occurrence and intensity of *dzuds*, we find that drought and localized extreme weather events in Mongolia are unassociated. Despite government and international organizations continuing to group the two together we propose that it would be more productive for development design and aid relief efforts to recognize that these hazards can be unconnected. Such acknowledgement would decouple pastoralists' traditional ability to accommodate drought through migration and their need for better preparedness or external support to deal with *dzuds* that threaten livestock survival. Establishment of adequate risk

management strategies would further improve herders' ability to cope with drought and *dzuds*.

We hypothesized that the SPI could define drought and clarify its relationship with climatic variables, vegetation, and human and livestock populations in South Gobi Province. Results show droughts are commonly site-specific events and suggest that they are relatively independent of other natural factors and are not an indicator or magnifier of extreme winter conditions in the region. Pastoral movements clearly recognize and are motivated by these factors. Usage of the SPI can inform preparation and policy for pastoral livelihoods. Although drought is often cited as a cause of negative environmental conditions in Mongolia we found no strong correlation between drought and other natural factors in South Gobi Province. We propose that the SPI could be used for informing policy preparation for pastoral livelihoods.

Chapter IV

Drought dynamics on the Mongolian steppe, 1970-2006

Troy Sternberg, Nicholas Middleton, David Thomas

Submitted to: International Journal of Climatology, June 2008.

Abstract

Drought is an ongoing feature in Mongolia's steppe environment yet drought occurrence and intensity is seldom identified. In this study long-term precipitation records from 1970-2006 were analyzed with the Standard Precipitation Index (SPI) to identify drought events at 3, 6, 12, and 24-month timescales at 5 meteorological stations in three steppe provinces. Awareness of drought conditions is important in the countryside because a majority of the rural population derive livelihood from weather and grassland-dependent pastoralism. Results found the steppe was in drought 15% of the time, with occurrence, intensity and duration being site-specific characteristics. Distribution was not spatially consistent or uniform over time. Drought patterns suggest greater climate variability today than in the past with the most extreme event ongoing at the end of the study. A lack of mitigating factors, such as emergency fodder or transport, causes drought to become a natural hazard that impacts the physical environment and economic and social systems.

Key words drought, Mongolia, Standard Precipitation Index, steppe

---

4.1 Introduction

Drought, regarded as a significant negative variation from mean precipitation, is a recurrent feature on the Mongolian plateau and has had a "drastic impact" on the region in recent years (Davi *et al.* 2006). Global warming is thought to contribute to more frequent and persistent droughts in the region, reflected in increased dry periods in China since the 1970's and widespread droughts in recent decades in Mongolia (Bordi *et al.* 2004; Li *et al.* 2007; Shinoda 2007). Drought may accelerate pasture desertification and threaten local livelihoods in Mongolia (Bayarjargal 2006; World Bank 2004), where due to climate change the grasslands are considered to be on the verge of "ecological collapse" (Bohannon 2008).

Awareness of drought patterns is of particular concern in Mongolia where nomadic pastoralism is the dominant rural livelihood and supports half of the population (Johnson *et al.* 2006). In this dryland region pastoralists are climate-dependent with precipitation variability and drought occurrence key factors driving livestock dynamics and human subsistence (Barfield 1993; Li *et al.* 2007). Livestock are raised outdoors in severe weather conditions exposed to natural hazards including: extreme winters where snow and ice limit forage, drought, sand storms, high winds, heatwaves, locust infestation, and land cover change, factors that affect pasture resources and may be a result of recent climate trends (Batima 2005). Nandintsetseg *et al.* (2007) identified marked warming in the country with a 1.8°C temperature increase over the last 40 years. Rising temperatures and variable precipitation patterns and intensity are likely to increase climate unpredictability and extremes. Such uncertainties make drought an integral, though little understood or documented, natural hazard on the steppe, particularly as it impacts livestock and human

populations and exacerbates extreme winter conditions (UNDPI 2000; World Bank 2002; Asian Development Bank 2005; FAO 2006; Johnson *et al.* 2006; Shinoda 2007).

To investigate drought in Mongolia a consistent framework is essential to study the phenomenon. Effective moisture levels are impacted by precipitation and potential evapo-transpiration (PET). In drylands, especially in the developing world, data on PET are sparse. Investigating drought through precipitation data is therefore justified, both by practical considerations and because it is the primary factor influencing meteorological drought in such regions (Sonmez *et al.* 2005). The great cost and detrimental natural and socio-economic impact of drought has lead to the creation of several indices to assess events and their intensity (Wilhite et al 2001; Boken et al 2005). For Inner Asia drought classification using available precipitation data is practical as well as robust, with such indices often outperforming more complex hydrological indices (Guttman 1999; Keyantash and Dracup 2002; Lloyd-Hughes and Evans 2002). Of these the Standard Precipitation Index (SPI) has received much attention since its introduction by McKee *et al.* (1993). Recommended as a simple and objective measurement of meteorological drought (US National Drought Mitigation Center 2006), it has been applied effectively to dryland settings in countries on six continents, including Argentina, Australia, China, India, Iran, Kenya, Mexico, South Africa, Spain, Turkey, and the United States (Seiler *et al.* 2002; Mpelasoka *et al.* 2007; Wu *et al.* 2001; Bhuiyan *et al.* 2006; Morid *et al.* 2007; Ntale and Gan 2003, Hallack-Alegria and Watkins 2007; Rouault and Richard 2005; Vicente-Serrano and Cuadrat-Prats 2006; Sonmez *et al.* 2005; Hayes *et al.* 1999).

Determining regional and local processes is key to understanding the factors that make drought a major natural hazard in Mongolia. Event identification and awareness of nature-human interactions can increase drought knowledge and inform decision-making at both the household and government level. Though indices based on precipitation are available, drought assessment is lacking in Mongolia. The goal of this study is to analyze meteorological drought in Mongolia, identifying drought onset, frequency, intensity, duration, and dynamics at different timescales in a representative region of the steppe grasslands.

4.2 Methods

4.2.1 Study area

Five meteorological stations reflecting the steppe to desert-steppe zone encompassing >50% of the country were selected in south-central Mongolia. This region, situated between the Hangai Mountains to the north and the Gobi Desert to the south, consists of Dundgovi, Ovorhangai, and Omnogovi Provinces, covering 300,000 km^2 (Table 4.1; Figure 4.1). The terrain is comprised of rolling gravel plains at an elevation of 1000 to 2000 metres a.s.l. (Hilbig 1995). The area has a harsh continental climate with distinct seasons and large daily and annual temperature fluctuation. In Omnogovi 49%, Ovorhangai 57%, and Dundgovi 63% of the population is engaged in weather-dependent pastoral livelihoods (Statistical Yearbook 2006).

Table 4.1 Site characteristics.

	Elevation	Latitude	Longitude	Zone
Arvaheer	1813	46.25	102.76	Steppe
Bulgan	1400	44.11	103.55	Desert steppe
Dalanzadgad	1465	43.58	104.44	Desert steppe
Mandalgovi	1396	45.75	106.26	Desert steppe
Saixan Ovoo	1317	45.45	103.90	Steppe - Desert steppe

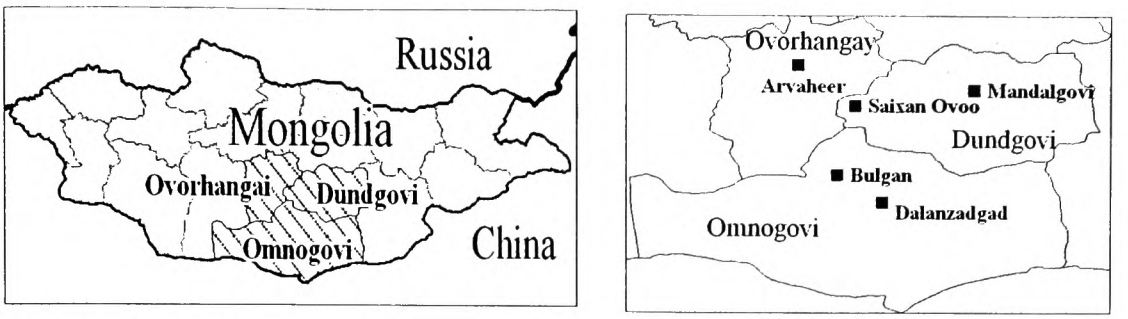


Figure 4.1 Mongolia with meteorological station locations and surveyed provinces.

4.2.2 SPI

The Standard Precipitation Index (SPI) was developed to identify and monitor droughts at multiple timescales with minimum data requirements – long term (≥ 30 years) monthly precipitation records (McKee *et al.* 1993). It assesses anomalous and extreme precipitation by giving a numeric value to the precipitation, enabling tracking and comparison of meteorological drought across areas with different climates. The SPI is based on the probability of precipitation distribution at a given meteorological station for a selected time period, and reflects the number of standard deviations that an observed value deviates from the long-term mean. To calculate the index precipitation values are transformed to follow a normal distribution. Calculation involves fitting a gamma probability distribution to monthly time periods of interest. The resulting function provides the cumulative probability for precipitation at a specific station for a given month and period of interest. In this way drought initiation, intensity, frequency, and duration can be computed. (Ntale and Gan 2003; Rouault and Richard 2003; Mihajlovic 2006).

The SPI's direct approach has proved robust in comparison with other drought indices including the Palmer Drought Severity Index, the Bhalme-Mooley, and the Rainfall Anomaly Index (Guttman 1999; Keyantash and Dracup 2002). Cancelliere

et al. (2007) identified advantages of the SPI over other indices that included statistical consistency, ability to describe short and long-term drought, and the ability to carry out drought risk analysis. Being normally distributed, the index reflects local aberrations rather than distinguishing drought-prone regions. In arid zones and in dry seasons relatively small rainfall anomalies may skew SPI values, thus in drylands duration of drought is the most critical feature (Wu *et al.* 2007). The straightforward requirements of the SPI make it well suited to rural Mongolia where limited long-term data availability (soil moisture, evapotranspiration, recharge rates) inhibits drought quantification (Klein Tank *et al.* 2006). Currently used in 60 countries (Wu *et al.* 2005), the SPI has been applied in East Asia to China (Wu *et al.* 2001; Bordi *et al.* 2004) and Korea (Min *et al.* 2003) but not in Mongolia.

SPI values vary between 3 to -3 with the magnitude of divergence from zero representing the probability of drought occurrence (McKee *et al.* 1993). Positive values indicate wet conditions and negative values signify dry periods (Hayes *et al.* 1999). The SPI has been calibrated in previous studies to map onto the beginning and duration of a drought event. Drought onset starts when the SPI reaches $\leq$ -1 and continues while values remain at or below this threshold (Table 4.2). In some studies drought onset begins at SPI = -0.7, or even -0.5, and termination occurs at a positive "wet" value (>0) (Reyes-Gomez and Nunez Lopez 2006; Labedski 2007; Smakhtin and Hughes 2004). In this survey's dryland setting we use SPI crossing the -1 level for drought initiation and cessation: thus only months where SPI is $\leq$ -1 are considered to be in drought (Wu *et al.* 2007).

Table 4.2 Drought classification by SPI values and corresponding event probabilities.

SPI value	Category	Probability %
2.00 or more	Extremely wet	2.3
1.50 to 1.99	Severely wet	4.4
1.00 to 1.49	Moderately wet	9.2
0 to .99	Mildly wet	34.1
0 to -0.99	Mild drought	34.1
-1.00 to -1.49	Moderate drought	9.2
-1.50 to -1.99	Severe drought	4.4
-2.00 or less	Extreme drought	2.3

The probability that an SPI value of ≤ -2.0 (extreme drought) will occur over a 100 year time period is 2.3; severe drought 4.3, mild drought 9.2 times with cumulative drought probability at 15.9 %. Droughts per 100 years for different timescales at each location and drought intensity class (Labedzki 2007) were calculated :

$$N_{i,100} = \frac{N_i}{i \cdot n} \cdot 100 \qquad (1)$$

where $N_{i,100}$ = the number of droughts for a timescale i in 100 years;

N_i = the number of months with droughts for a timescale i in the n-year set;

i = timescale (=3, 6, 12, 24 months);

n = the number of years in the data set (= 37)

4.2.3 Methods

Precipitation data for 1970-2006 were obtained from the Mongolian Institute of Meteorology and Hydrology. Employing SPI software from the U.S. National Drought Mitigation Center (2006), precipitation data were examined for drought occurrence at four timescales - 3, 6, 12, and 24 months – to identify spatial and temporal drought dynamics at 5 meteorological stations in Mongolia. Because of Mongolia's short (90-130 frost-free days) vegetation growth and intensive grazing season, the SPI was calculated through the end of August to monitor drought during the critical summer plant growth season (Begzsuren *et al.* 2004; FAO 2006). This matches the peak precipitation period as ≥80% of precipitation falls between May and

September (Figure 4.2) (Hilbig 1995). In this ecosystem rainfall and Coefficient of Variation (CV) are telling statistics as they confirm substantial precipitation variability over the study period, particularly in the key summer months (Table 4.3; Figure 4.3). Such high precipitation variability implies a non-equilibrium environment as noted by prior study (Begzsuren *et al.* 2004; Retzer and Reudenbach 2005; Munktsetseg 2007). Drought and the annual number of days with precipitation (Figure 4.4) were compared to explore the strength of the relationship. Temperature is important as the combination of drought and extreme winter *dzud* creates a condition where due to heavy snow or ice cover livestock are unable to forage and thus starve to death (UN 2000; Shinoda 2005; Asian Development Bank 2005). Additionally, Mongolia's great winter-summer temperature range, to >80°C in the survey period, can create severe summer heat episodes and high evapotranspiration rates that impact pasture quality (Figure 4.5). SPSS 14.0 (Chicago, Il) was used for statistical comparison.

Table 4.3 Precipitation and Coefficient of Variation records, 1970-2006.

	Precipitation		Coefficient of Variation	
	Mean	Min - Max	Annual	Summer
Arvaheer	231	119 - 378	27.3	60.1
Bulgan	122	57 - 261	35.0	87.8
Dalanzadgad	122	51 - 235	33.5	71.8
Mandalgovi	147	72 - 243	31.6	60.8
Saixan Ovoo	115	59 - 268	39.5	76.2

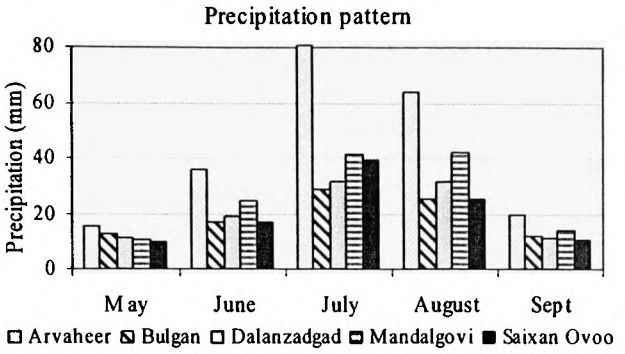


Figure 4.2 Precipitation distribution in the growing season.

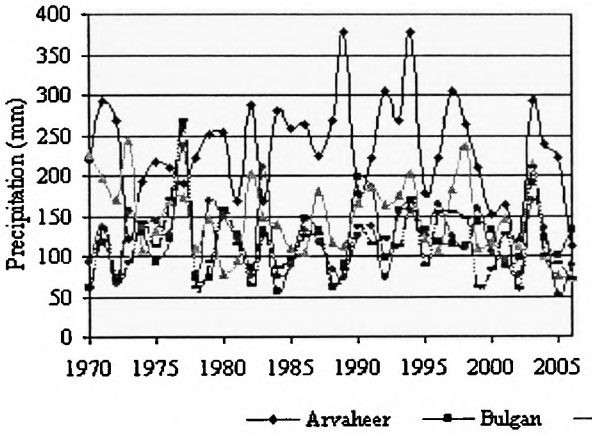


Figure 4.3 Precipitation record 1970-2006.

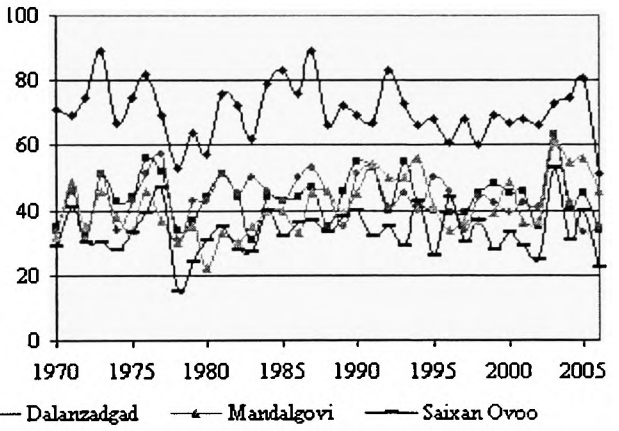


Figure 4.4 Annual number of days with precipitation.

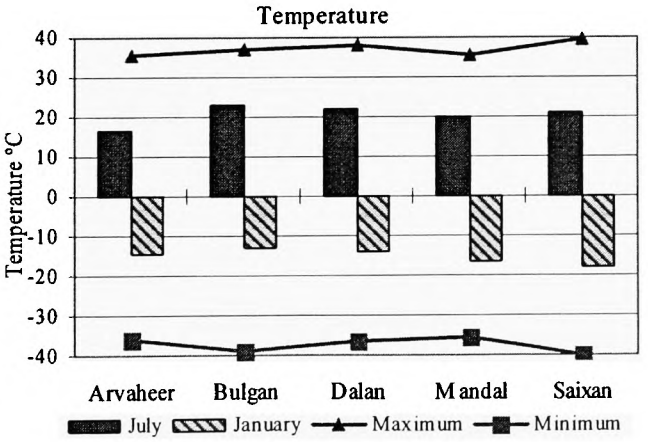


Figure 4.5 Average January and July and maximum/minimum temperature °C at each station, 1970-2006.

4.3 Results

Wet and dry conditions across the region were established using the SPI. Results show cyclical fluctuations with broadly wetter conditions in the 1970s and 1990s, a notably drier period in the 1980's, and alternating wet-dry episodes in the 2000's with 2006 a particularly dry year (Figure 4.6). Drought event rates varied within and between sites and at different timescales. In general drought measured to the end of August was less prevalent than cumulative probability would predict, with drought highest at the 12-month scale. Site drought records fluctuated with Arvaheer and Bulgan below estimated probability at each measurement and Dalanzadgad in drought 25%

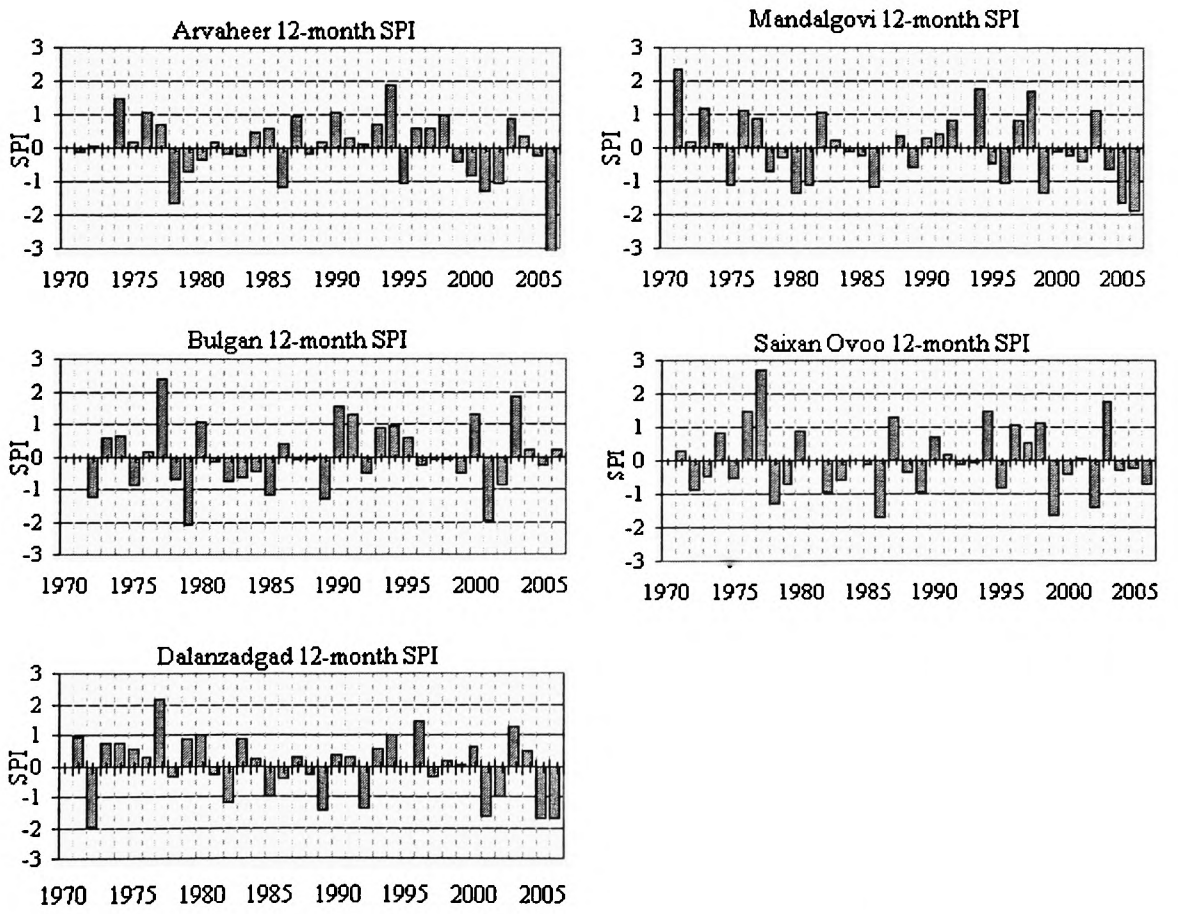


Figure 4.6 Standard Precipitation Index at 12 months through August for 5 stations, 1970-2006.

more of the time than Arvaheer. Moderate and extreme drought rates were slightly below average whereas severe levels were somewhat elevated. Months in drought at each location and timescale and the predicted number of droughts (Formula 1) for a 100 year period is shown in Table 4.4.

Table 4.4 Months in drought 1970-2006, (predicted number of episodes over a 100 year period).

Arvaheer	3	6	12	24
Moderate	32 (7.2)	36 (8.1)	37 (8.3)	16 (3.6)
Severe	18 (4.0)	9 (2.0)	11 (2.5)	26 (5.9)
Extreme	9 (2.0)	11 (2.5)	13 (2.9)	18 (4.1)
Total	59 (13.3)	56 (12.6)	61 (13.7)	60 (13.5)
Bulgan				
Moderate	32 (7.2)	38 (8.6)	40 (9.0)	28 (6.3)
Severe	23 (5.1)	25 (5.6)	22 (4.9)	29 (6.5)
Extreme	10 (2.2)	6 (1.4)	8 (1.8)	5 (1.1)
Total	65 (14.6)	69 (15.5)	70 (15.7)	62 (13.9)
Dalanzadgad				
Moderate	31 (7.0)	53 (11.9)	62 (13.9)	34 (7.7)
Severe	19 (4.3)	17 (3.8)	19 (4.3)	23 (5.1)
Extreme	10 (2.2)	7 (1.6)	8 (1.8)	12 (2.7)
Total	60 (13.5)	77 (17.3)	89 (20.1)	69 (15.5)
Mandalgovi				
Moderate	37 (8.3)	36 (8.1)	34 (7.6)	44 (9.9)
Severe	25 (5.6)	24 (5.4)	19 (4.2)	18 (4.1)
Extreme	4 (0.9)	6 (1.4)	10 (2.2)	14 (3.1)
Total	66 (14.8)	66 (14.9)	63 (14.1)	76 (17.1)
Saixan Ovoo				
Moderate	46 (10.3)	40 (9.0)	41 (9.2)	32 (7.2)
Severe	23 (5.1)	12 (2.7)	16 (3.6)	29 (6.5)
Extreme	3 (0.6)	12 (2.7)	0 (0)	1 (0.2)
Total	72 (16.2)	64 (14.4)	57 (12.8)	62 (13.9)

Ten extreme SPI-12 month drought events occurred from 1970-2006 with 2005-2006 the driest period on record (Table 4.5). The most serious in magnitude, -3.66 (Arvaheer) and longest duration, 18+ months (Mandalgovi), were ongoing at the end of the study period. All sites experienced extreme droughts with Bulgan most vulnerable. There were no extreme events in the 1990's; only twice did extreme

droughts take place simultaneously at multiple sites (1978, 2005-2006). Examination of drought at other timescales found that the longest droughts occurred at SPI-24 months. An intense Mandalgovi episode (-2.47) lasted 35 months from August 2000 through June 2003. This was followed by an 18 month (Mandalgovi 1-1981 to 6-1982) and a 14 month drought (Dalazadgad) that was ongoing at the end of the survey. Drought at 3 and 6 month time scales did not exceed 6 months in duration.

Table 4.5 Extreme SPI 12-month drought events.

Station	Intensity peak	Onset year/month		End year/month		Duration months
Arvaheer	-3.66	2006	6	ongoing	~	7+
Bulgan	-2.77	1978	10	1980	3	18
Dalanzadgad	-2.54	2005	7	2006	9	15
Mandalgovi	-2.51	1980	7	1980	12	7
Bulgan	-2.42	1984	9	1985	8	12
Mandalgovi	-2.41	2005	6	ongoing	~	18+
Arvaheer	-2.41	2002	8	2003	6	11
Bulgan	-2.28	1972	8	1973	5	10
Arvaheer	-2.22	1978	7	1979	6	12
Bulgan	-2.08	1970	12	1971	5	6

At moderate and severe levels drought was extant at multiple sites and different timescales. Saixan Ovoo SPI values were significantly related with all sites at all timescales (P=0.05) whereas Mandalgovi, at 50%, was least related to other sites (P=0.05). Patterns emerged between sites with Mandalgovi appearing to follow latitude-influenced relationships with Arvaheer and Saixan Ovoo whereas Dalanzadgad had longitudinally-based similarities with Bulgan, Saixan Ovoo, and Arvaheer. Bulgan's relationships were proximal with Dalanzadgad and Saixan Ovoo, the two nearest sites. Arvaheer's distribution was consistent with all but Bulgan. Numbers of inter-site correlations were the same at 3, 6, and 12 months and slightly increased at SPI 24-month.

4.3.1 Spatial continuity of droughts

The magnitude of drought events fluctuated between stations. Mapping shows spatial drought coverage at decadal intervals (Figure 4.7) and at different timescales in 2006 (Figure 4.8). Distribution is not spatially consistent nor are there uniform patterns over time. Within the same year drought identification and coverage are timescale-dependent. In 2006 Arvaheer was in extreme drought at all time periods whereas Mandalgovi and Dalanzadgad moved into extreme drought when examined over a longer duration. At the same time Bulgan and Saixan Ovoo fluctuated between mildly wet and dry episodes, only reaching moderate drought conditions.

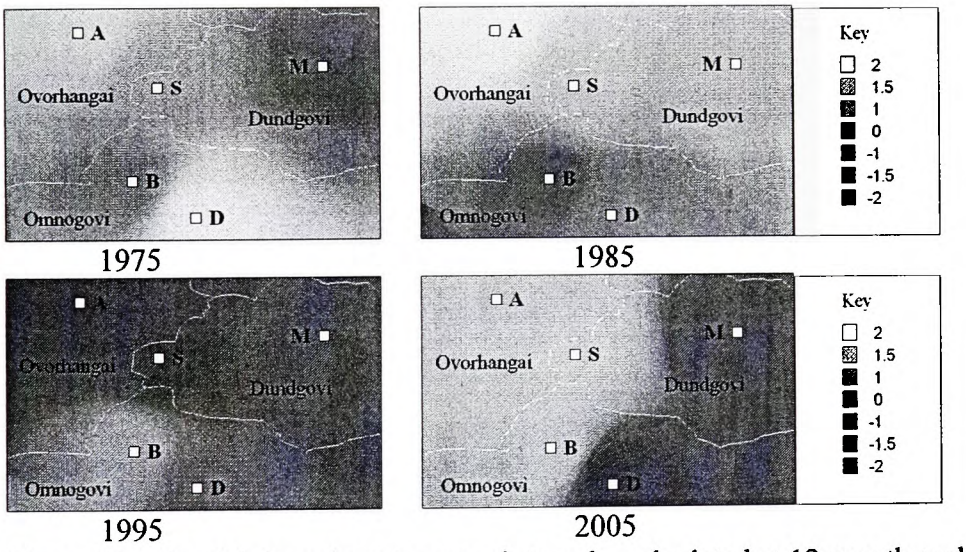


Figure 4.7 Spatial drought at ten year intervals, calculated at 12-month scale (A = Arvaheer, B = Bulgan, D = Dalanzadgad, M = Mandalgovi, S = Saixan Ovoo).

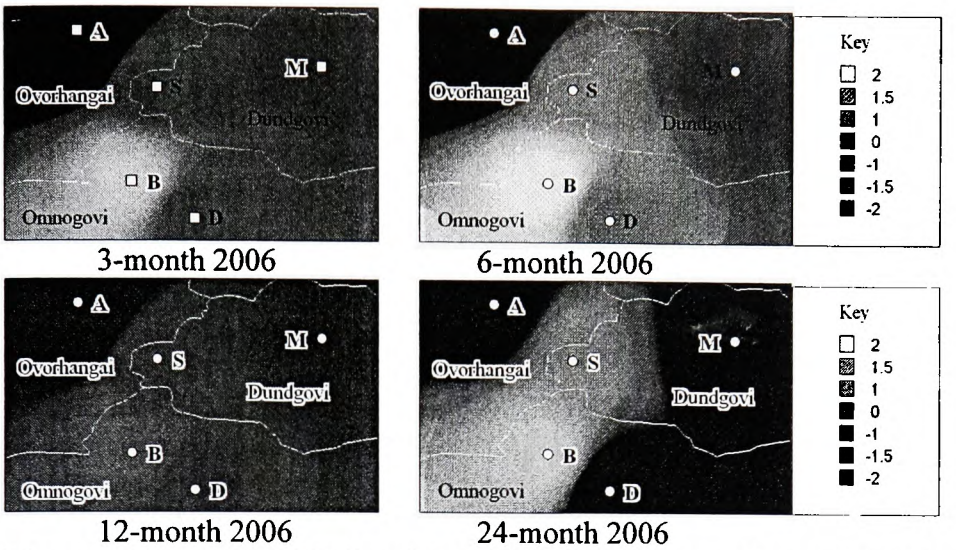


Figure 4.8 Drought in 2006 at short and long-term time scales, calculated at 12-month scale (A = Arvaheer, B = Bulgan, D = Dalanzadgad, M = Mandalgovi, S = Saixan Ovoo).

Comparing the number of days of precipitation per year with SPI values through August found that at 3, 6, and 12 months there was a significant relationship between the number of days with rainfall and drought rating at most sites (Table 4.6). This correlation was not prevalent at 24 months. An evaluation of the relationship between number of days with precipitation and amount of precipitation per year found no association in Arvaheer and Mandalgovi but a significant relationship in Dalanzadgad (P = 0.01), Bulgan, and Saixan Ovoo (both P = 0.05).

Table 4.6 Significance of SPI values and number of days with precipitation (P = 0.01, 0.05).

Month	3	6	12	24
Arvaheer	0.05	0.01	0.05	~
Bulgan	0.01	0.01	0.01	0.05
Dalanzadgad	0.05	0.01	0.01	~
Mandalgovi	~	0.05	0.05	~
Saixan Ovoo	0.01	0.01	0.01	~

4.4 Discussion

Drought is a regular and iterative feature in the Mongolian steppe and desert-steppe landscape. This study identifies drought variability historically, at different

timescales and intensities, and between sites within the region. The most salient factors are the variability of drought events over time, their site-specificity, and duration at SPI $\leq$ -1. The implications are several for human populations: unpredictability in pasture resources for pastoral livelihoods, the danger of drought exacerbating extreme winter *dzud* conditions, the limitations of the climate regime on potential agricultural production in the steppe zone, the marginality of the desert-steppe areas experiencing drought, and the ongoing threat to livelihoods dependent on the natural environment for sustenance and survival. Local processes that make drought a major natural hazard in Mongolia are shown in Figure 4.9. Knowledge of regional drought conditions is essential information for herder decision-making and readily obtainable through use of the SPI. This study establishes a drought record for south-central Mongolia; similar assessments can be undertaken throughout the country. Beyond documenting historical patterns, such an index can serve as a predictive tool for both the immediate future, through identifying precipitation shortfalls at selected timescales, and generating drought probability perspectives for the long-term (Cancelliere *et al.* 2007).

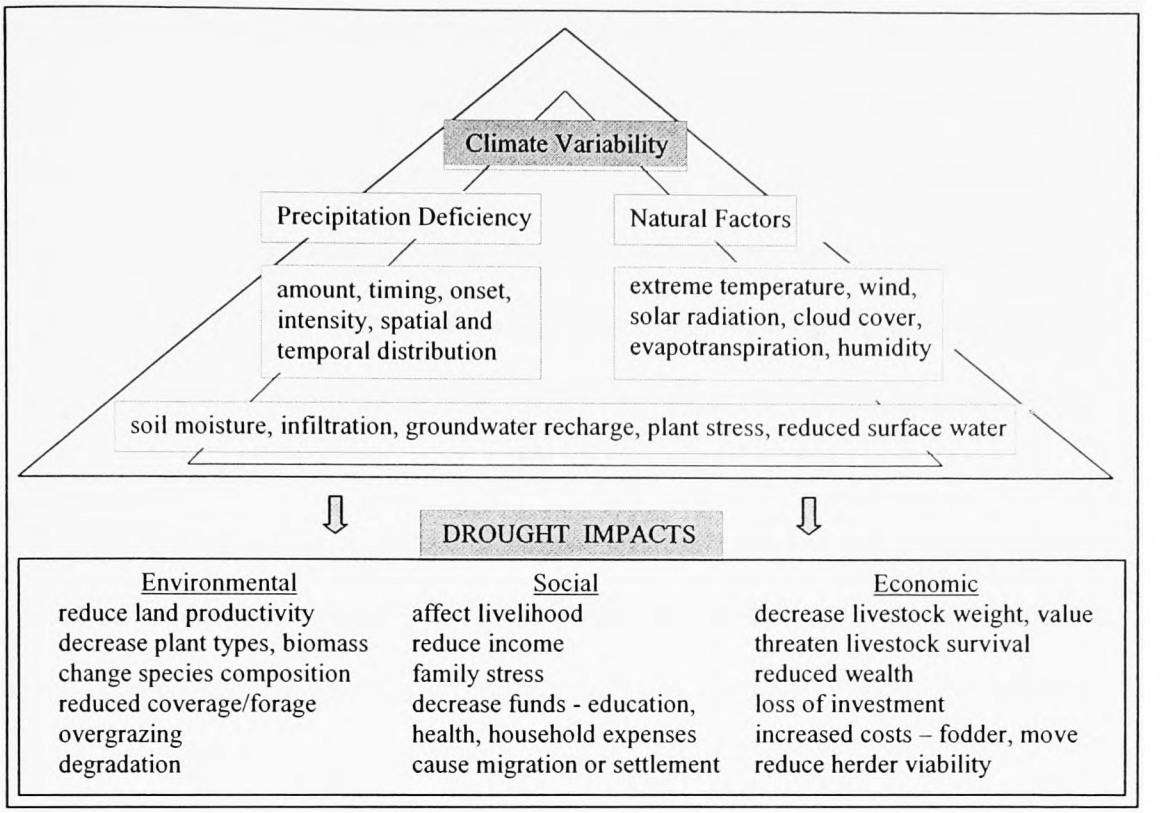


Figure 4.9 Drought environmental-human processes on the Mongolian steppe.

Examining between-site data showed SPI values were associated over the long-term, particularly between Saixan Ovoo, perhaps due to its central location, and all other stations, and at the SPI 24-month timescale. However, drought episodes were site-specific with the -1.0 threshold individually determined. Though the meteorological stations assessed cover a broad region, geographical variation was muted. This may be due to stable steppe-zone weather patterns across the area, its inland continental location, and a lack of local physical features, such as orography or bodies of water, to influence climate. While different sites may be in concurrent dry conditions, the intensity and duration reflected local anomalies.

The longest drought at all timescales was a 35 month event at SPI 24-month at Mandalgovi from August 2000 to June 2003. Across the stations the SPI 24-month

scale detected drought conditions that were not evident at shorter time periods. At 3 and 6 months drought events were of more limited duration than at longer time periods. Monitoring drought at different scales is essential for identification of present trends and also enables events to be placed within a longer perspective. To examine drought only at a short-term scale would miss broader implications and not clarify if a lack of precipitation was an isolated event or part of an ongoing dry episode.

Results highlighted the topicality of current drought research as the most extreme (Arvaheer) and second longest (Mandalgovi) SPI 12-month droughts were in progress at the survey's end. In addition, an enduring SPI 24-month drought was taking place at Dalanzadgad (14+ months, SPI -2.65), and a lesser drought (4 months, SPI -1.37) at Saixan Ovoo. These suggest greater climate variability today than in prior periods of the 1970-2006 record with droughts exacerbated in duration and intensity at 12 and 24-month timeframes. Further expanded research could indentify national patterns and strengthen interpretation of how climate change may now impact the Mongolian environment.

In the study two causal factors stand out – great inter-annual precipitation variability, more than a factor of 3 at each site, and high rainfall Coefficient of Variation, especially in the key summer plant growth season (Bohannon 2008). This reflects unpredictability dominating not only annual precipitation totals but also monthly patterns. The serrated nature of the rainfall graph line shows the dependence and susceptibility of the region to a volatile climate regime. The number of days of precipitation per year, regardless of volume, proved to be related to drought at the 3, 6, and 12-month scale. Yearly days with precipitation as well as total amount of rainfall can both provide an indicator of present and near-future drought status at an

individual meteorological station. Diligent tracking of rainfall impact through an index such as the SPI can be an effective, low cost management tool to provide current information that can improve pastoralists' assessment and decision-making concerning migration patterns, potential need for fodder, herd numbers and composition, and livestock offtake. If encouraged by the government drought understanding could improve policy and planning as well as hazard preparedness and mitigation and relief efforts.

4.5 Conclusion

Drought, though normal on the Mongolian steppe, becomes disruptive as impact spreads beyond physical systems and into economic and social realms (Sonmez *et al.* 2005). Bayarjargal *et al.* (2006) note that drought frequency and intensity has increased in Mongolia in recent decades; Bohannon (2008) states the last ten years has seen four of the country's worst droughts. As warming has been identified in high-latitude locations (Nandintsetseg *et al.* 2007), rainfall patterns in Asia may be similarly influenced by global weather trends that affect drought occurrence in Mongolia (Gong and Wang 2000). Continued fluctuations in precipitation amount, timing, and magnitude coupled with temperature increases associated with climate change create an unsettled environment where variability and extreme events transpire (Tebaldi *et al.* 2006). Recurring drought events and the implied randomness of weather factors in the steppe non-equilibrium ecosystem challenge climate-dependent pastoral livelihoods. In drylands water shortage limits plant growth, reduces grassland productivity, and when combined with anthropogenic factors can lead to degradation. On the steppe this is a major concern where potential mitigating forces to natural hazards, such as government support or access to emergency fodder

or transport, is limited (Fernandez-Gimenez 1999). Documentation and up-to-date assessment of drought will improve management and human-nature interaction in Mongolia.

Chapter V

Vegetation dynamics and piosphere degradation on the Mongolian steppe

Troy Sternberg, David Thomas, Nick Middleton

Submitted to: Journal of Arid Environments, February 2009.

Abstract

The Mongolian plateau in East Asia is part of a new hotspot of land cover change. Recent human activity and natural forces have degraded grasslands in northern China with southern Mongolia similarly vulnerable. Examining vegetation patterns at piospheres can identify pasture conditions and degradation trends. Through fieldwork and remote sensing this paper examines plant density and species richness at water points to establish land cover patterns in two Mongolian provinces where overgrazing is thought to be a major cause of degradation. In contrast to normal piosphere patterns, vegetation was greater near water points and decreased with distance. This suggests that livestock are not concentrated at water points in Mongolia and that piosphere dynamics are more influenced by precipitation and edaphic factors. It implies that pastoralism, with mobile livestock management, is a suitable adaptive strategy to the low forage capacity of steppe grasslands.

Key words piosphere, pastoralism, degradation, Mongolia, vegetation, NDVI

5.1 Introduction

The enduring limitation of water in arid zones defines human interaction within such environments. Sustainable use of water and land for livestock, agriculture, and development often contrasts with perceived needs and behavior of local populations. Tempered by climate and biophysical traits, human activity can cause excessive depletion of ecological resources and may negatively impact the environment across spatial and temporal scales. Land degradation and the more serious implications of desertification connote a loss of capacity and reduced land productivity (Gunin *et al.* 1999; Batterbury *et al.* 2002; Vetter 2005; Okayasu *et al.*, 2007). Since Lamprey's (1975) work on the expansion of the Sahara desert and the first UN Conference on Desertification in 1977 the subject, elusive in definition and documentation, has been well studied, with much degradation research focused on the complexities of varied African drylands (Perkins and Thomas 1993; Nicholson *et al.*, 1998; Thomas *et al.*, 2000; Todd 2006). Findings can be applicable to susceptible regions around the world (Dougill *et al.*, 1999); research methods and procedures have been established that can be replicated and implemented globally through local fieldwork and remote sensing techniques to strengthen and broaden the desertification debate. Lepers *et al.*, (2005) state that the African Sahel is no longer a desertification hotspot, that Asia now has the greatest concentration of rapid land cover change. Growing awareness of how climate change, land management, and socio-economic processes in arid and semi-arid zones can be detrimental to the East Asian environment encourages the use of standard methodologies to study regional degradation (Zha and Gao 1997; Nicholson *et al.* 1998; Fernandez-Gimenez and Allen-Diaz 2000; Li et al 2006; Zhang *et al.* 2007).

Dryland degradation focuses on land cover change in defined areas and impacts on local environments and populations, involving anthropogenic and biophysical processes that negatively impact the environment (Reynolds and Stafford Smith 2002). Detrimental processes occurring at the micro-scale can expand to be part of macro-scale patterns. This is the case of the Mongolian plateau in East Asia where climate, the environment, and human activity create an area at high risk of desertification (Batjargal 1997; Yang *et al.* 2005; Lepers *et al.* 2005; Huang and Siegert 2006). Local land cover change impacts the greater region as current research suggests soil particles in southern Mongolia and northern China are the source of Asian desert dust, which has a significant influence on regional and global environments, including atmospheric systems (Murayama *et al.* 2001; Xuan *et al.* 2004; Akata *et al.* 2007; Normile 2007). As the impact of perceived degradation processes in East and Central Asia is transported beyond borders to Japan, Korea and further afield, the identification of local processes becomes key to understanding regional land cover change. Addressing ground-level conditions that draw international concern needs local environmental knowledge, updated biophysical insight, and an appreciation of dryland ecological and socio-economic systems (Herrmann and Hutchinson 2005; Veron *et al.* 2006; Reynolds *et al.* 2007).

As a region that has been inhabited for millennia (Johnson *et al.* 2006), humans have strategically adapted to ecological conditions on the Mongolian plateau. More recently alternative patterns of development – communism and collectivization – and government-driven land dictums have given way to market-oriented systems (Fernandez-Gimenez 1999; Zhang *et al.* 2007). The region, framed by the Gobi desert, encompasses southern Mongolia and northern China. The two countries share biophysical and climatic conditions yet different development and social patterns,

government inputs, and populations that create separate environments and social-political systems. The steppe ecosystems in this arid and semi-arid continental/temperate climate zone are ecologically fragile and sensitive to climate change and human disturbance (Jun Li *et al.* 2007). Though a dynamic region there are limited reports on land system change in the cold drylands of China and Inner Asia (Li et al 2006; Sugita *et al.* 2007).

China is one of the world's most desertifed countries (Zha and Gao, 1997; Zhao et el. 2005; Yang *et al.* 2005). Surveys show an increase in desertification from an annual rate of 1,100 km^2 in the 1960's, 2,260 km^2 in the 1990's, to 3,600 km^2 today, with 861,000 km^2 now desertified (Li et al 2006; Normile 2007). The Chinese government assesses 2.6 million km^2, an area the size of Kazakhstan, as the potential area of desertification (Huang and Siegert 2006). In northern China degradation is driven by livestock grazing, agricultural practices, inappropriate land management decisions, population pressure, mining and erosional processes (Chen and Tang 2004; Kawamura *et al.* 2005). A new openness encourages discussion and research of land degradation, efficacy of past management decisions, and how to address agricultural and livestock production challenges (Nicholson *et al.* 1999; Yang *et al.* 2005; Zhang *et al.* 2007). Across the border in Mongolia efforts to address land cover change concentrate on government and international agency reports (World Bank 2002; Asian Development Bank 2005; UNCCD 2006). The national response to the United Nations Convention to Combat Desertification (UNCCD) (2002) states 78% of the vast steppe grassland is degraded with overgrazing a primary cause. UNEP (2002) cites 70% while Li *et al.* (2006) identify 75% of Mongolia as affected by desertification. Yang *et al.* (2005) places 640,000 km^2 at risk of desertification while pasture vulnerability rates are as high as 90% (Batjargal 1997). Low population

density, negligible agriculture due to unproductive soils, a lack of private tenure, as well as limited livestock production inputs, capital, and state support create different grassland conditions in Mongolia than in China (Johnson *et al.* 2006).

In arid and semi-arid environments livestock grazing is often considered a major cause of land degradation (Sneath 1998; Nangula and Oba 2004; Zhao et al 2005; Okayasu *et al.* 2007). Potentially negative impacts center on overgrazing, fragility vs. resilience in dryland ecosystems, persistence of "irrational" traditional herding practices and whether human activity (stocking strategies) or natural conditions define grassland productivity (Perkins and Thomas 1993). High rangeland degradation rates are cited in Mongolia though little research has attempted to define current conditions at a localized scale. Communal land stewardship, resource restraints, and weak rural governance means pastoralists determine their environmental interactions – deciding stocking rates, livestock composition, location, and mobility patterns. Efficacy and impact of this laissez-faire approach to rangeland is unclear and contrasts markedly to the government-structured intensified system of grassland use in China (Zhang *et al.* 2007). With two management approaches in one ecosystem the Mongolian plateau provides the opportunity to investigate how differing human dimensions and strategies create distinct grassland conditions (Sneath 1998). A decline in rangeland functionality and an increase in desertification in China and Central Asia makes understanding vegetation dynamics a prerequisite to addressing regional environmental conditions (Yang *et al.* 2005; Li *et al.* 2006).

5.1.1 Mongolian Rangelands

Grasslands cover approximately 80% of Mongolia's 1.56 million km^2 where for four thousand years nomadic and transhumanent pastoralism has been an effective manner

of harvesting forage resources in the dry, cold, low-fertility environment (Fernandez-Gimenez 1999; Yu *et al.* 2004). Steppe and desert-steppe high plains comprise more than half of the territory. In the countryside 40 – 50% of the population is dependent on pastoralism for its livelihood (Johnson *et al.* 2006). Livestock in Sheep Equivalency Units consist of camel = 7, horse = 6, cattle/yak = 5, sheep = 1, goat = 0.9 (Geographical Atlas of Mongolia 2004) with the previously dominant sheep now exceeded in number by goats, economically favoured for their cashmere. Since 2002 the national livestock herd has increased from 24 to 34 million (Statistical Yearbook 2006). Rainfall decreases from north to south with a national mean average precipitation of 224mm. Drought, a regular occurrence, can together with extreme winter weather create *dzud*, the country's worst natural disaster – a condition when snow and ice prevent livestock from obtaining adequate forage. Surface water is scarce in the southern half of the country where groundwater is the principal water source. Rural water resources declined from 1990 to 2000 as the number of engineered wells dropped by 80% to 1500 and the number hand wells decreased from 35,000 to 20,000 (Tanaka *et al.* 2005).

Changes in livestock production from a collectivizatized to a privatized system, coupled with reduced government support has impacted rural environmental conditions. Concern about potential overgrazing, land degradation, and desertification have led to efforts to identify pasture and vegetation conditions through satellite remote sensing (Erdenetuya 2004; Javzandulam *et al.* 2005) and field research (Fernandez-Gimenez and Allen-Diaz 1999; Stumpp *et al.* 2005). One noted change has been the impact of livestock on piospheres. Mearns (2004) identified vegetation degradation around remaining wells and Okayasu *et al.* (2007) stressed the difficulty

of data collection prevented accounting for the effect of well sites in their efforts to address land degradation in Mongolia by satellite imagery alone.

The steppe grasslands of Mongolia are integral to the regional land degradation debate. More research has been undertaken in China, yet assessing large-scale land cover requires plateau-wide knowledge. Through investigation at the most basic human pasture organization structure – the piosphere - we examined grassland dynamics in Mongolia, focusing on vegetation coverage and species richness patterns along a gradient to determine range productivity and grazing impact on pasture conditions (Todd 2006). Studying piospheres – the zone of ecological impact around livestock watering points - can differentiate the long-term effect of livestock on vegetation from that of other environmental factors around water sources (Andrew 1988). Previous piosphere studies in dryland regions show livestock impact to be greatest near water points with influence diminishing with distance from water source (Perkins and Thomas 1993; Fernandez-Gimenez and Allen-Diaz 2000; Nangula and Oba 2004; Adler and Hall 2005). The piosphere effect can create a 'sacrifice zone' immediately surrounding the water point where grazing and trampling result in bare ground. Changes in ground cover and plant composition may result from water-centered grazing and have potentially severe consequences as piosphere development can be the first stage of the desertification process (Andrew 1988; Landsberg *et al.* 2003). In this study our objective was to examine vegetation dynamics and cover at piospheres and identify degradative processes at water sources. We hypothesized that the common global pattern of a water point being 'the centre of its own little desert', with lowest vegetation cover at the source, would occur in Mongolia. Second, we assessed the importance of overgrazing as a proximate cause of degradation in the steppe ecosystem through vegetation surveys.

5.2 Methods

5.2.1 Study area

This study examines piosphere vegetation dynamics in Ovorhangai and Omnogovi Provinces in central and southern Mongolia (Figure 5.1). Framed by the Hangai Mountains to the north the Ovorhangai research area (46° N, 103° E) in central Mongolia encompasses semi-arid steppe and desert-steppe terrain. Bordering it to the southeast the second research area Omnogovi (44° N, 104° E) is dominated by desert-steppe environment with the Gurvan Saixan Mountains transecting the area. The surface morphology of the study region is typically that of a rolling gravel plateau ranging from 1000 to 2000m above sea level (Hilbig 1995). Similarly defined landscape covers over 50% of the country's land surface (Geographical Atlas of Mongolia 2004). Climate in these semi-arid and arid environments is characterized by short hot summers and long cold winters with unimodally distributed rainfall concentrated in summer (Yu *et al.* 2004). Province capitals have mean average precipitation of 234mm and 121mm respectively. In Mongolia highly variable precipitation and low soil fertility of the steppe grassland exhibits non-equilibrium characteristics, with edaphic and abiotic factors limiting plant growth (Fernandez-Gimenez and Allen-Diaz 1999; Begzsuren *et al.* 2004; Retzer and Reudenbach 2005; Munktstsetseg *et al.* 2007). This variability in timing and amount of rainfall and inter-annual fluctuation strongly influences plant and livestock communities. Ovorhangai's precipitation Coefficient of Variation (CV) is 27%, Omnogovi's CV = 34%, with their summer growing season monthly CV at 58% and 72%. Using the common threshold of less than 200mm annual precipitation and $\geq$ 30% Coefficient of Variation Omnogovi fits the non-equilibrium model whereas Ovorhangai is borderline (Vetter 2005; Begzsuren *et al.* 2004). In Mongolia interannual

precipitation variability can lead to considerable fluctuation in vegetation cover (von Wehrden *et al.* 2006). Pastoralism is the traditional livelihood with livestock dominated by small stock (sheep and goats) (Table 5.1).

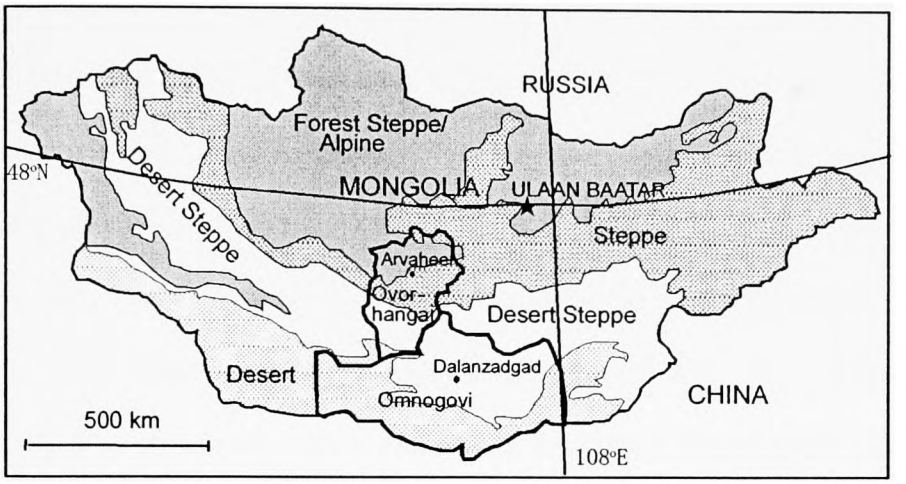


Figure 5.1 Map of Mongolia with vegetation zones.

Table 5.1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces.

Province		Ovorhangai	Omnogovi
Sites		55	55
Rangeland		Steppe - Desert Steppe	Desert Steppe
GPS		N 45.7-46.7, E 102.1-104.2	N 43.4-44.5, E 103.2-105.3
Elevation	Average	1678	1533
(meters)	Range	1389 - 2095	1092 - 2067
Mean annual	mm	235	121
precipitation	min-max	119-378	51-235
Mean	January	-14.4°C	-13.9°C
temperature	July	16.3°C	21.9°C
Water point	% well / surface	87 - 13	93 - 7
Herders	% population	57%	49%
Livestock	type	Sheep, Goat, Horse , Cattle	Goat, Sheep, Camel, Horse
Livestock	2002	1,665,000	909,000
numbers	2006	2,623,300	1,155,700

5.2.2 Methods

Little desertification research has been undertaken in Mongolia (UNCCD 2002; Okayasu *et al.* 2007). Locally, degradation has been identified as a decline in vegetative cover or decreased biomass with the resultant loss of grassland

productivity and livestock resources (Sneath 1998; Javzandulam *et al.* 2005). Degradation of vegetation cover is considered to be a main form of desertification; Huang and Siegert (2006) cite coverage assessment as the favored method to identify desertification. Additionally, knowledge of species composition and plant palatability are important factors in evaluating degradation (Middleton and Thomas 1997). Local concern in desert-steppe regions is that the loss of vegetation coverage will leave soils vulnerable to wind erosion. Previous study in Mongolia found total vegetative cover the most consistent response to grazing, and that nomadic herders primarily use cover to assess pasture conditions (Fernandez-Gimenez and Allen-Diaz 1999). Two methods of assessment were undertaken to address the objectives of establishing vegetation parameters, identifying coverage and potential ecological change over time (Batterbury *et al.* 2002; Okayasu 2007). First, the line-transect method was used to examine vegetation dynamics along a 1 km gradient (Thomas *et al.* 2000; Nangula and Oba 2004). Second, remotely sensed data was employed to add an historical perspective to grassland evaluation (Huang and Siegert 2006).

In this study 110 transects, with 55 sites in both Ovorhangai and Omnogovi Provinces, were surveyed to identify piosphere vegetation dynamics in Mongolia's steppe and desert-steppe regions. The extensive spatial and numerical scale of this investigation increases study applicability and expands pasture knowledge across a substantial grassland area. Prior investigation by Gunin *et al.* (1999) identified high land degradation rates in the region - 50% severely and 40% moderately degraded in Ovorhangai with 10% severely and 28% moderately degraded in Omnogovi.

Due to remoteness and lack of study we are aware of one previous study that combines field data with remote sensing to assess land cover in Mongolia (Javzandulam *et al.* 2005). Previous vegetation studies relating to water points in

Mongolia focused on plots (Fernandez-Gimenez 1999; Wesche and Retzer 2005) and line-transects. In Omnogovi Stumpp *et al.* (2005) examined soil characteristics along 4 transects while Sasaki *et al.* (2007) reviewed plant composition in plots along a single transect.

Within an approximate 1° latitude by 2° longitude field area in each province sites were randomly selected to encompass spatial and ecosystem variability. Water points were located through visual inspection and in consultation with local herders. All sites were currently used by livestock, determined by fresh dung at the piosphere, adequate source-water availability, tent dwellings in the vicinity, and herder confirmation when possible. Fieldwork was carried out during the April to October plant growth season in 2006-2007.

At each water point data were collected along 1 km transects to encompass zones of extreme degradation (up to 0.5 km) identified in prior research (James *et al.* 1997; Ludwig *et al.* 1999). To ensure sampling randomness all piosphere transects were due north except when visible barriers (terrain, abodes) prevented this. Vegetation measurements were taken at 25, 50 100, 200, 500, and 1000 metres from the water source. At each distance three 30 metre sections were examined, each separated by a 30m interval. Sections were located to the left, center, and right of the transect. Percentage of plant basal coverage for each metre along the line was recorded. At each site all plant species growing within the transects were collected to establish species composition and richness by water point. Plants were dried for later identification in the Geo-Botany lab of the Mongolian Institute of Geography. At each piosphere field information (latitude and longitude, elevation, temperature) and water data (depth, temperature, pH, total dissolved solids, electroconductivity) (HM Digital Inc, Culver City, Ca.) were recorded to analyze with vegetation data.

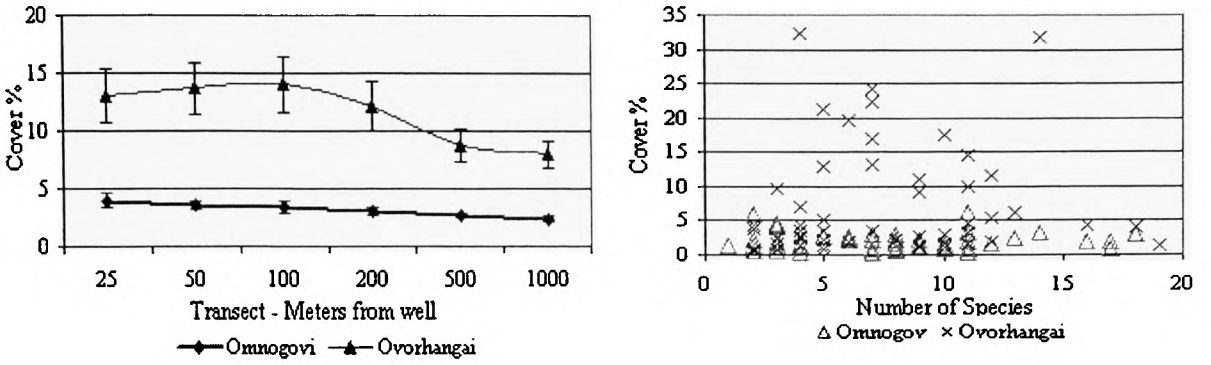
Statistical analysis was used to interpret and explain the collected data. Pearson's correlation coefficient was selected to identify the strength and direction between variables. P value (significance) and r^2 (proportion of variability in the data set) indicated relationship and the predictive strength of the data to highlight correlations and variance between factors. Detrended correspondence analysis, a multivariate tool, was used to reduce the volume of data into two main axes. In this manner multiple factors (*e.g.* species, site, distribution) could be evaluated to develop greater understanding of ecological processes and potential association between vegetation and water points. Analysis was done with SPSS 14 (SPSS Inc. Chicago, Il.) and CANOCO (Ithaca, N.Y.).

Multi-temporal SPOT-4 satellite imagery was used to assess Normalized Differential Vegetation Index (NDVI) at each piosphere. NDVI is a commonly used vegetation index derived from remotely sensed measurements that is a normalized ratio of the NIR and red bands $NDVI = NIR\text{-}Red/NIR+Red$ where *NIR* and R*ed* are the spectral reflectance in near-infrared and red wavelength respectively. Research has established that NDVI, sensitive to vegetation cover and photosynthetic capacity, is highly correlated with biophysical parameters such as vegetation coverage and biomass (Yu *et al.* 2004). Thirty-day images were used from 1 April through October 30, 1998-2006 time series of observations. The months were selected to encompass the potential growing season and peak precipitation period. Similar to other regional studies, a 1 kilometre spatial resolution was used to generate pixel values on a scale equivalent to the line transects (Khuldumur and Erdenetuya 2002; Huang and Siegert 2005; Okayasu *et al.* 2007). Data were used to derive NDVI monthly and annual coverage values throughout the time period. As NDVI is an inexact measurement it provides an approximation of land cover over time that may not always be reliable.

Additionally, the growth stage 'greenness' measured can vary between April and October. By using several years' data it lends an historical perspective to vegetation coverage and change in the region.

5.3 Results

Water points studied demonstrated no 'piosphere effect' of increased ecological impact from livestock around water sources on the Mongolian steppe and desert-steppe environment. Transect measurement showed vegetation cover decreased with distance from the water point in both provinces (Figure 5.2*a*). Though plant cover differed between the two provinces species richness was similar (Figure 5.2*b*) with composition dominated by perennial grasses and forbs. Satellite imagery from 1998-2006 years reflected low vegetation cover and both inter- and intra-annual variability in land cover. Site factors, such as elevation and latitude, were predictors of vegetation dynamics. The inverted vegetation density, where lowest values were furthest from the water point, suggest piosphere overgrazing does not strongly influence plant coverage or species richness.



a *b*

Figure 5.2 (*a*) Field measured vegetation coverage by distance from water point with standard error, and (*b*) species richness in Ovorhangai and Omnogovi by site. Average, 55 sites each, 2006/2007.

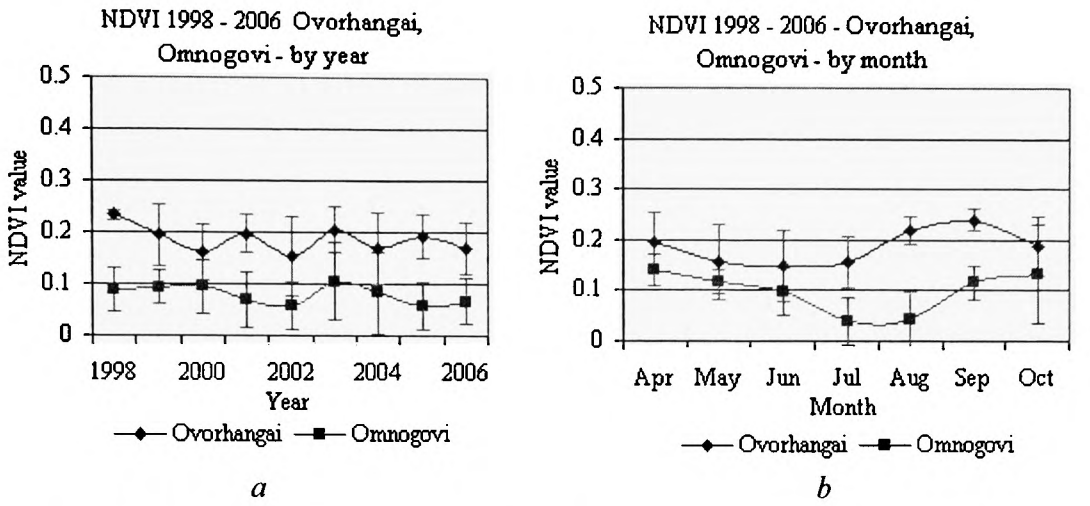
Plant density in Omnogovi declined at each measurement with distance from water points. Average coverage ranged from 4% at 25m to 2% at 1000m ($r^2 = 0.98$). This is sparser than previously recorded in the desert steppe region (Fernandez-Gimenez and Allen-Diaz 2000). In Ovorhangai vegetation coverage increased slightly from 25m to 50m, peaking at 100m distance from the water point. Cover then decreased at 200m and 500m, with 1000m having the lowest vegetation density. Maximum average coverage in Ovorhangai was 14% at 100m and minimum was 7.8% at 1000m ($r^2 = 0.74$). Coverage was significantly correlated (P=0.01) with elevation and NDVI throughout the study. It tracked latitude (P=0.01), mirroring the steppe to desert steppe gradient of the region.

Number of species present were similar in both provinces, ranging from 2 to 19 plant types per site in Ovorhangai, with an average of 7.9, and 1 to 18 species with an average of 7.8 in Omnogovi. Species richness was not correlated with vegetation

coverage but was strongly associated with elevation (P=0.01). Richness and NDVI were significantly related (P=0.01) in Omnogovi but not in Ovorhangai.

NDVI values at piospheres for 1998 to 2006 had low annual cover of between 0.06 to 0.10 in Omnogovi and 0.15 to 0.23 Ovorhangai. NDVI trends illustrated the variability of the steppe environment and modifications in land cover over time. Average province-wide intra-annual variability was 40% and 27% respectively, with inter-annual fluctuation of $\geq$ 30% in both provinces (Figure 5.3). At individual sites there was great variability between and within years, >400% in Omnogovi and >300% in Ovorhangai. Such pronounced change points to the role of precipitation affecting land cover.

To verify the relationship between groundcover and NDVI we compared fieldwork data with NDVI values. There were significant correlations (P=0.01) between NDVI and observed vegetation coverage at the sites. This enabled us to look at NDVI data to derive an historical land cover perspective. Examining 4 year intervals found 1998 was a wet year, reflected in higher NDVI values. 2002 was a severe dry year with the low land cover values, resulting in a 35% decrease in NDVI. By 2006 precipitation rebounded to slightly above normal, seen in a 38% NDVI rise over this period, though this was still 11% below 1998 levels. Figure 5.4 identifies decreasing cover, suggesting reduced pasture resources over the 9-year timespan. NDVI was also correlated with elevation (P=0.01), reflecting increased coverage in interspersed mountainous terrain, and was similarly related to latitude (P=0.01).



a *b*

Figure 5.3 1998-2006 province average annual NDVI (*a*) and average monthly NDVI values (*b*) for Ovorhangai and Omnogovi, with standard deviation.

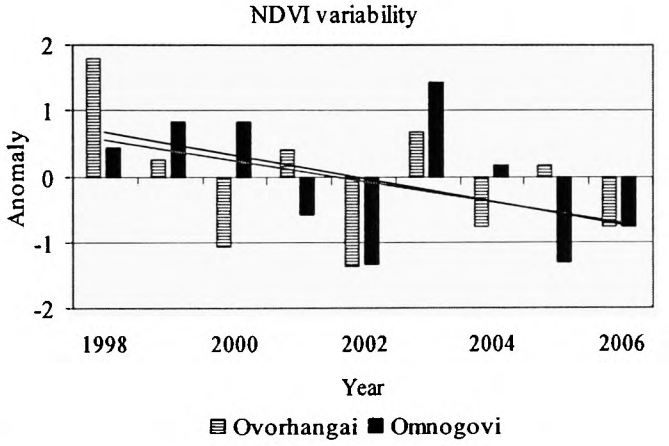
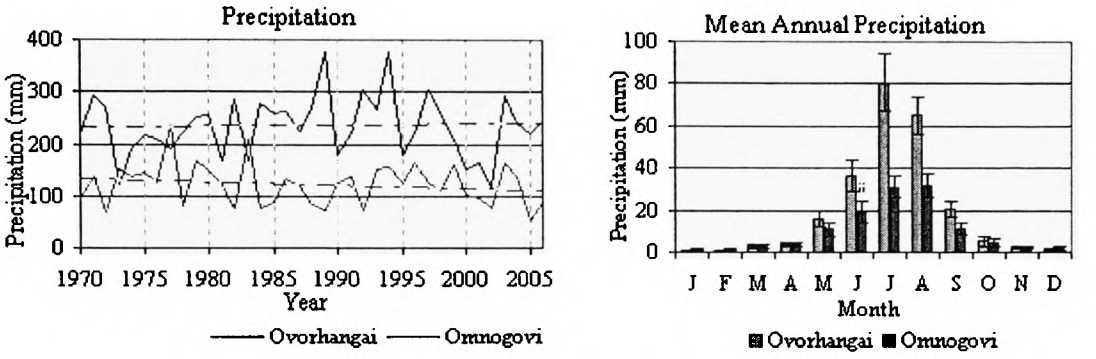


Figure 5.4 NDVI trends from 1998 to 2006 (Ovorhangai $r^2 = 0.19$; Omnogovi $r^2 = 0.23$; anomaly from normalized distribution, with trendline).•

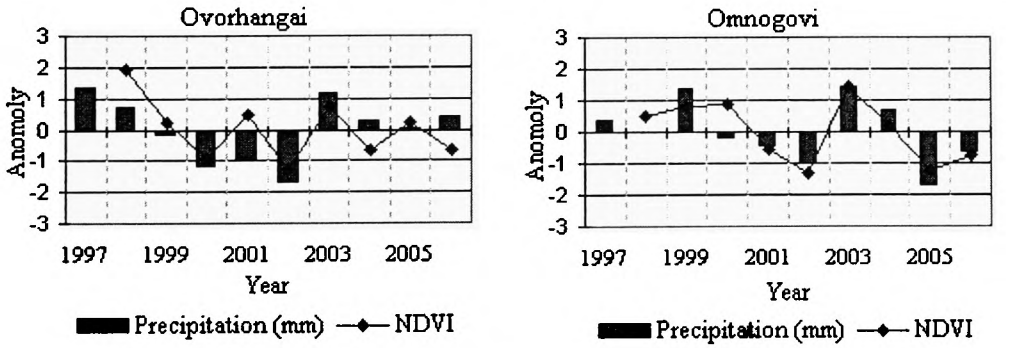
To further investigate land cover change we examined the relationship of NDVI and precipitation in the two provinces. In both provinces precipitation was concentrated in summer, with >67% in June, July and August and >85% from May through September (Figure 5.5). This mirrors the short plant growth season of 90-130 frost free days (Begzsuren *et al.* 2004). Rainfall records and NDVI had a significant

correlation (P=0.01) in Omnogovi whereas the two factors were not strongly related in Ovorhangai (Figure 5.6). Temperature was not correlated with NDVI.



a *b*

Figure 5.5 Average annual precipitation (*a*) 1970-2006 in Ovorhangai (r^2= 0.001) and Omnogovi Provinces (r^2 = -0.03); average monthly precipitation (*b*) 1970-2006 in Ovorhangai and Omnogovi Provinces with standard error.



a *b*

Figure 5.6 NDVI and precipitation patterns in Ovorhangai (*a*) and Omnogovi (*b*), 1998-2006.

The study recorded 86 plant genus and 120 species. Species composition was dominated by forbs and perennials with distribution following: *growth* – grass 22%, forbs 60%, shrub – 18%; *life form* – annual – 14%, biennial - 8%, perennial - 60%,

shrub - 18%; *palatability* – 78%. In both provinces less than half (45%) of the genus were at >2 sites; several species had single site distribution - 33% in Ovorhangai and 39% in Omnogovi (Table 5.2). The major plant species (31), comprised 69% of the total presence, are a sample of steppe vegetation (Table 4).

Table 5.2 Genus and species total and presence by province.

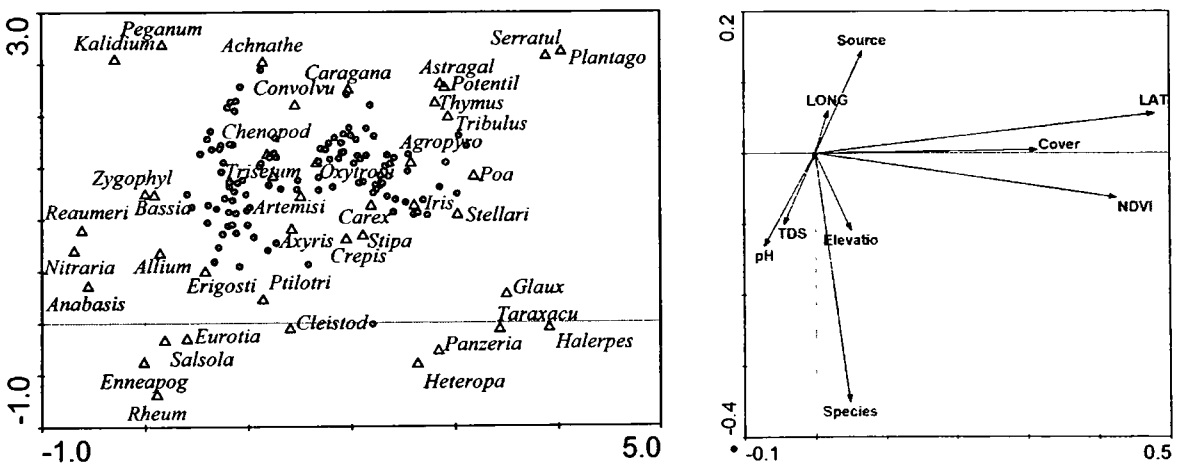
	GENUS	*Presence*	SPECIES
Ovorhangai	61	Total	82
	28	≥3 sites	46
	13	2 sites	13
	20	1 site	23
Omnogovi	61	Total	85
	27	≥3 sites	47
	10	2 sites	12
	24	1 site	26
Total	86	Total	120
In both provinces	34	In both provinces	38

Table 5.3 Major plant species by growth, form, livestock palatability, # sites, and province, and relative presence (total sites = 110 - 55 each province).

Plant Species	Growth	Life form	Palatability	Sites	Ovorhangai	Omnogovi	Presence %
Caragana pygmaea	Shrub	Shrub	Palatable	47	34	13	42.7
Achnatherum splendens	Grass	Perrenial	Palatable	39	15	24	35.5
Chenopodium album	Forb	Annual	Palatable	34	18	16	30.9
Iris bungei	Forb	Annual	Palatable	33	22	11	30
Peganum nigellastrum	Forb	Perennial	Non	32	6	26	29.1
Agropgron christatum	Grass	Perennial	Palatable	31	27	4	28.2
Convolvulus ammanii	Forb	Perrenial	Palatable	30	17	13	27.3
Potentilla bifurca	Forb	Perennial	Palatable	29	29	~	26.4
Artemisia frigida	Shrub	Shrub	Palatable	22	13	9	20
Erigrostis minor	Grass	Biennial	Palatable	22	6	16	20
Allium pollyrrhizum	Forb	Perennial	Palatable	21	~	21	19.1
Bassia dasyphylla	Forb	Biennial	Palatable	20	2	18	18.2
Artemisia sp	Shrub	Shrub	Palatable	17	13	4	15.5
Panzeria lanata	Forb	Perennial	Non	15	11	4	13.6
Trisetum sibiricum	Grass	Perennial	Palatable	14	6	8	12.7
Artemisia sericea	Forb	Perennial	Palatable	14	~	14	12.7
Axyris hybrida	Forb	Annual	Palatable	14	5	9	12.7
Allium mongolicum	Forb	Perennial	Palatable	13	~	13	11.8
Anabasis brevifola	Forb	Perennial	Palatable	13	~	13	11.8
Ptilotrichum canescens	Forb	Perennial	Palatable	13	5	8	11.8
Artemisia macrocephala	Forb	Annual	Palatable	11	3	8	10
Cleistogenes squarrosa	Grass	Perennial	Palatable	11	11	~	10
Cleistogenes soongorica	Grass	Perennial	Palatable	11	~	11	10
Salsola passerina	Shrub	Shrub	Palatable	11	~	11	10
Thymus gobicus	Shrub	Shrub	Non	11	11	~	10
Stipa krylovii	Grass	Perennial	Palatable	10	9	1	9.1
Artemisia santolinifolia	Forb	Perennial	Palatable	10	4	6	9.1
Chenopodium sp	Forb	Annual	Non	9	2	7	8.2
Heteropappus hispidus	Forb	Biennial	Non	9	6	3	8.2
Crepis crocea	Forb	Perennial	Non	9	9	~	8.2
Artemisia adamsii	Forb	Biennial	Non	9	9	~	8.2

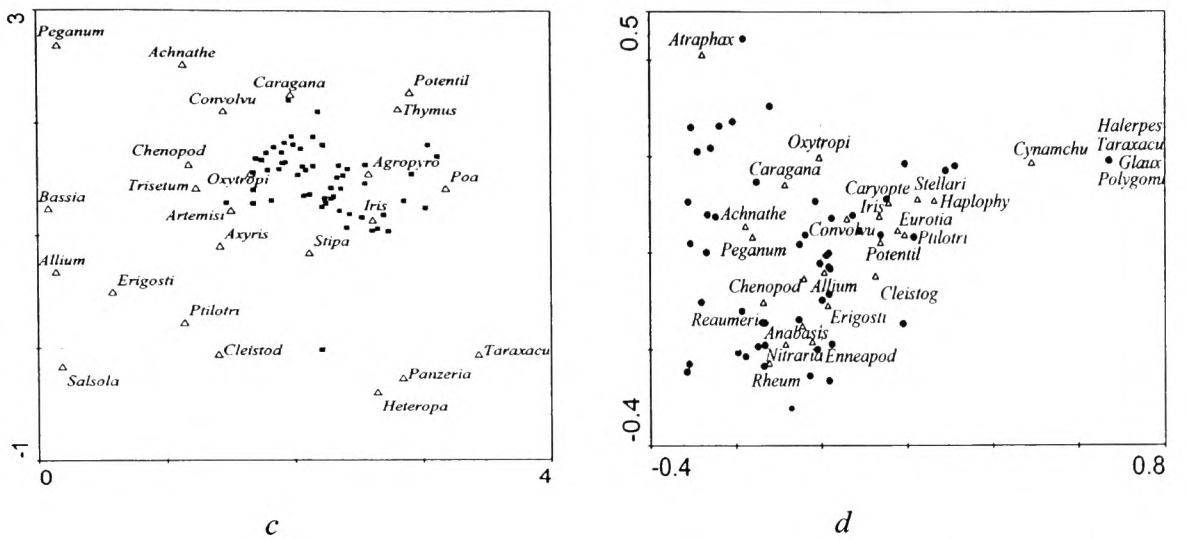
To examine basic vegetation patterns and relate them with environmental and site factors we used canonical correspondence analysis (CCA) where the lengths of a particular axis gives an estimate of diversity (Fernandez-Gimenez and Allen-Diaz 2000). Eigenvalues of the two main axes were 0.383 and 0.229, explaining 61.2% of community variance. Examining all sites the first axis explained 4.1% of species variability with the axis correlated with site characteristics ($r^2 = 0.87$) (Figure 5.7*a*). The second axis added 2.4% species variance; combined the axes explained 6.5% of

species variability. The general distribution suggests an ongoing variation in species distribution and therefore not distinctly defined vegetation types in the data. When compared with correspondence analysis the species-environment variance relationship (21%) suggests measured site variables are somewhat responsible for plant composition variation. The two axes accounted for 33.6% of the species-environment relationship. Environmental and site characteristics are scattered and low-scale (to 0.5) with latitude, cover percentage, and NDVI associated and pH and TDS grouped (Figure 5.7*b*). The provinces reflected similar disparate composition trends with Ovorhangai having greater variance along a main axis (to 3.5) than Omnogovi (to 0.75). Omnogovi's species distribution was not along a single dominant axis (Figures 5.8 *a, b*).



a *b*

Figure 5.7 CCA ordination. *a.* Major species (genus) and sites distribution at all sites, *b.* main environmental and site characteristics.



c *d*

Figure 5.8 CCA ordination. *a.* Ovorhangai – genus, sites, *b.* Omnogovi – genus, sites (dot = site, triangle = species).

As piospheres are centered on water points basic knowledge of water quality is relevant to understanding local conditions. Testing simple measurements of pH and total dissolved solids (TDS) found water quality was generally good for human consumption using levels established by the World Health Organization (WHO 2007) (Figure 5.9). TDS ratings at 95% of sites were within safe drinking limits, with highest TDS levels only suitable for livestock. pH was satisfactory though somewhat elevated in Omnogovi. Both TDS and pH were negatively correlated with NDVI (P=0.01), thus lower (better quality) water values were associated with higher NDVI land cover. Positive relationships existed between these water parameters and latitude (P=0.05), and between TDS and elevation (P=0.01).

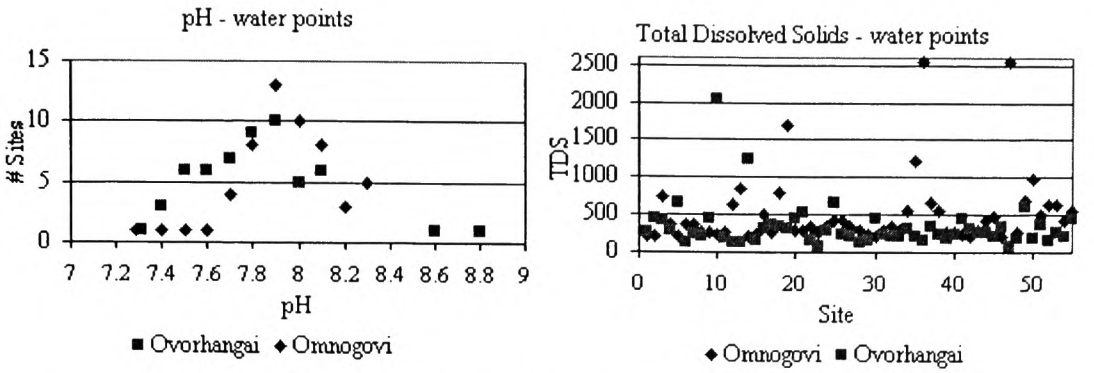


Figure 5.9 pH (*a*) and total dissolved solids (*b*) at water points.

5.4 Discussion

The results of this study indicate that piosphere vegetation cover is higher near water points and decreases with distance, suggesting that grazing is not concentrated around drinking sources to the detriment of the environment. Coupled with high variability in NDVI land cover and precipitation this implies that climate factors have greater impact on vegetation dynamics in southern Mongolia than livestock grazing. This infers that degradation is an inappropriate term around piospheres, that extremely low cover values are endemic in the Gobi steppe region. NDVI values question if thresholds have been crossed – the great fluctuation in land cover may reflect natural forces, particularly precipitation, as wet episodes enable areas devegetated in dry periods to recover sufficiently to be productive. Additionally, livestock, through urine and faeces deposition, may elevate soil nutrients and affect vegetation composition and density around a water source (Fernandez-Gimenez and Allen-Diaz, 2000). The idea of pasture continuity is supported by increasing provincial livestock numbers over the study period despite variegated land cover values. Recent studies on the Chinese side of the Mongolian plateau have established degradation criteria for the region. Desertification thresholds there begin at <50% vegetation coverage, with between 10-30% vegetation cover considered severe and <10% very severe

desertification (Yang *et al.* 2005; Li *et al.* 2006; Huang and Siegert 2006). According to these standards study sites in Mongolia are severely degraded. However, this rating does not adequately consider the sparse vegetation conditions extant in Mongolia's drylands. All distances surveyed were within these levels yet low cover alone is not proof that the ecosystem has declined or lacks the resilience to remain stable or improve as abiotic factors change. NDVI data identifies systemic fluctuation over time, therefore to conclude Mongolia has been desertified, as opposed to experiencing ongoing dryland conditions, is incorrect. As Warren (2002) emphasizes degradation is contextual, thus what is identified as degradation in China's human-modified system may be part of normal variance within Mongolia's more traditional pastoral approach.

Vegetation coverage in Omnogovi was a fraction that of Ovorhangai, the neighboring province. This may reflect a zonal shift between a steppe ecosystem in the north and the desert steppe environment to the south. Species richness was similar throughout the survey though composition varied – 60% of the genus and 68% of the species were unique to a province. Piosphere communities were dominated by a limited number of plants – the top 10 accounted for 45% of species presence. Plant distribution was not widespread – in Omnogovi 72% and Ovorhangai 63% of species were present only once or twice, <4% of surveyed sites. Ordinations showed Omnogovi had notably scattered species composition patterns and less plant association than Ovorhangai. Plant patterns are limited by soil productivity and moisture regimes, including depth of water penetration. Grazing intensity is also known to affect species composition with historic livestock use potentially forming plant communities. This is suggested by the dominance of forbs over grasses, which has been noted as a response to livestock pressure (Fernandez-Gimenez and Allen-

Diaz 1999). Long-term grazing and human impact are intertwined with vegetation presence on the steppe (Hilbig 1995).

5.4.1 Steppe grassland and pastoralism

This study addresses the land utilization debate in Mongolia. Greater vegetation density within 100m of piospheres than at 500m or 1000m suggests that herders are not overusing accessible areas around water points to the neglect of pasture further removed. Results from this study contradict the prevalent "overgrazing causes desertification" school of thought on the Mongolian plateau (Gunin *et al.* 1999; Sasaki et al 2005; Zhao *et al.* 2005; Kawamura *et al.* 2005; Lise *et al.* 2006). They support the hypothesis that in this arid ecosystem grazing may have a marginal effect on piosphere vegetation coverage and richness. It questions the concept that pastoralism has a negative impact on environmental productivity and suggests customary usage patterns that maximize low pasture resources through extended livestock forage areas, limited concentration around water points, and access to several different pastures are appropriate. Instead a more non-equilibrium focus is suggested of climate, precipitation, and soil factors influencing grassland condition. To expand this study's implications, other natural zones of the country should be surveyed and species composition differentiated within piosphere transects to determine the community structure relationship with distance from a water point.

Differentiating between human-induced and climate-affected degradation is a challenge in drylands (Evans and Geerken 2004: Veron *et al.* 2006). Herder piosphere overgrazing is characterized as creating sacrifice zones around water points of low vegetation coverage and productivity with percentage of cover increasing with distance from a water point (Thomas *et al.* 2000). The steppe and desert steppe

regions surveyed contrasted with this conventional rangeland pattern. Several studies in northern China identify the role of poor land management, inappropriate human activity, and livestock practices as factors in desertification (Kurschner 2004; Yu *et al.* 2004; Chen and Tang 2004; Zhang et al 2007). Mongolia, through collectivization and since 1990 a weak government structure, has not experienced China's recent intensified land pressures. Previous work has identified different vegetation systems within the steppe (Fernandez-Gimenez and Allen-Diaz 1999) and degradation from limited plot studies (Javzandulam 2005). This survey goes further to conclude that in Mongolia overgrazing, and thus herder pasture usage and decision-making, is not the cause of low vegetation coverage or species richness around piospheres. It suggests that in this environment, climatic variability characterizes non-equilibrium systems and edaphic factors control land cover (Thomas and Leason 2005). This is exemplified in the study by variable precipitation and fluctuating NDVI values that separate vegetation coverage patterns from livestock and piosphere sacrifice zones. Findings leave the herder, through insight, tradition, or limited alternatives, operating in a manner that is sustainable given environmental restraints.

Unlike some rangelands that have not had long-term exposure to grazing, such as Australia, the Mongolian environment has evolved with domesticated livestock for millennia (Fernandez-Gimenez 1999; Landsberg *et al.* 2003; Sasaki *et al.* 2008). This posits that continual interaction between livestock and vegetation may have contributed to today's landscape where grazing, limited water supply, stable species richness, and variable plant distribution patterns coexist. Sasaki et al (2007) suggest that due to a long history of livestock use Mongolia's vegetation is relatively resistant to grazing. Few places have had such longstanding human/nature interactions that make a distinction between the two either impossible or inappropriate (Dearing 2006).

Perhaps a phenomenon that looks random, and thus in China is labeled desertification, is in Mongolia incorporated into pastoral vegetation dynamics. While China's varied land management and usage patterns over the last 50 years have stressed a move away from transhumanence, Mongolia's grassland usage continues an uninterrupted tradition that has provided basic sustenance and range sustainability over a very long time. Rather than causing degradation herder interaction with the steppe environment extracts benefit for the livestock without lasting damage to the land. Recent articles on desertification emphasize the nomad's effective use of natural resources, opportunistic grazing strategies, and the importance of mobility in arid and semi-arid herding (Sayre and Fernandez-Gimenez 2003; Veron *et al.* 2006; Hermann and Hutchinson 2005). Zhang *et al.* (2007) state that Mongolian nomadic culture stresses sustainable utilization and ecological stewardship of land which generally prevents desertification. Wesche and Retzer (2005) found that the nomadic lifestyle was a "crucial" aspect of sustainable land use in southern Mongolia. Absence of sacrifice zones and higher coverage values near the piosphere suggests pastoralist grazing strategies on the steppe are not harmful to the ecosystem and that the role of transhumance in Mongolia is an ongoing adaptation to limited forage potential and an effective means to extract benefit from the sparse environment. Zhang *et al.* (2007) argue nomadic culture should have a leading role in China; it has that "deserved position" in Mongolia – because of mobility and adaptation to a harsh, dry environment with limited precipitation and low forage resources.

This shifts local land use debate from mitigating the harm of indigenous practices (Shaoliang et al 2007; Jun Li *et al.* 2007) to how customary livestock grazing pratterns can be maintained, a process that may be applicable to other dryland regions. In Mongolia the essentials are disbursed water points in productive grasslands and the

ability to migrate to areas with adequate forage. Management and development that stresses adaptability to fluctuating grassland and climatic conditions will limit anthropogenic impact on the environment. This can enable herders to continue present livelihoods without sacrificing future opportunities or incurring high ecological costs.

5.5 Conclusion

In contrast to piosphere studies in other regions this paper found vegetation cover was greater near water points in Mongolia. The absence of other productive land uses beyond livestock raising, such as agriculture or industry, suggests that customary herding patterns continue to be an effective practice and that mobile pastoralism is one of few, perhaps the only, enduring land use strategy in Mongolia's steppe and desert steppe. Pastoralism can be considered as a way to combine communal land stewardship, low external supports, and individually-determined land management and tenure as a viable livelihood approach in an otherwise difficult environment. Across the Mongolian plateau the Chinese development arc has industrialized livestock production with fodder, fencing, transport, and intensified land use, but at a cost to the environment that is not seen in the survey ecosystem in Mongolia. To continue the ecologically-suited Mongolian approach more water points and movement appears warranted, with policies that encourage dispersed livestock grazing rather than concentration around fewer water points. The steppe is fragile and human impact is lasting, as exemplified by degradation incurred from past management policies and intense land use in adjacent areas in China that require extensive rehabilitation (Zha and Gao 1997; von Wehrden *et al.* 2006; Jun Li 2007; Normile 2007). Mongolia can not afford this – as Reynolds *et al.* (2007) stated

regarding rangeland, "don't break what there is no money to fix". In Mongolia it is prudent to maintain a naturally resilient transhumanent system rather than replace it with models from elsewhere, even across the border in China, that may have dubious or detrimental effects on the environment.

Chapter VI

Tracking Desertification on the Mongolian steppe through NDVI and field-survey data

Troy Sternberg, Renchin Tsolmon, Nicholas Middleton, David Thomas

Submitted to: **International Journal of Digital Earth, February 2009.**

Abstract

Changing environmental and socio-economic conditions make land degradation a major concern in Inner Asia. This study examines 33 grassland water points using vegetation field studies and remote sensing techniques to track desertification on the Mongolian plateau. Findings established a significant correlation between same-year field observation (line transects) and Normalized Difference Vegetation Index (NDVI) data, enabling an historical land cover perspective to be developed from 1998-2006. Results show variable land cover patterns in Mongolia with a 16% decrease in plant density over the time period. Decline in cover indicates degradation; however continued annual fluctuation suggests desertification – irreversible land cover change – has not occurred. Further, *in situ* data documenting greater cover near water points implies livestock overgrazing is not causing degradation at water sources. In combination the two research methods strengthen findings and provide an effective way to track desertification in dryland regions.

Key words desertification, piosphere, NDVI, Mongolia, overgrazing

---

6.1 Introduction

The significant potential of remote sensing is its ability to generate information to help understand the physical nature of our world (NASA 1999). The challenge is that to benefit the global community this data has to be relevant on the local scale, applicable to environmental and/or socio-economic concerns, appropriately disseminated, and comprehensible to those who can benefit from the insight satellite imagery provides (Rindfuss and Stern, 1998). There is an inclination towards "armchair geography", where data and images, often generated and evaluated from afar, inform management and development decisions without essential field verification and local understanding. Remote sensing, de-coupled from its natural setting, supplies data but can fail to provide sufficient detail to illuminate the area of research. A proper understanding of ecosystem processes derived from *in situ* field observation is needed for effective use of satellite imagery. *In situ* verification can strengthen findings from remote sensing studies to provide accessible and timely assessment of land cover changes (Dougill and Trodd 1999; Kogan *et al.* 2004; Okayasu 2007).

This paper investigates the relationships between field survey data and remotely sensed vegetation indices in Ovorhangai Province, Mongolia. We examine vegetation cover, a standard measure of degradation (Gunin *et al.* 1999; Huang and Siegert 2006), on the steppe from 1998-2006 using Normalized Difference Vegetation Index (NDVI) data (Javzandulam *et al.* 2005; Bayarjargal *et al.* 2006), and line transect measurements along a gradient from a water source (Dougill and Trodd 1999; Thomas *et al.* 2000; Todd 2006). The investigation focuses on a key pasture marker – the piosphere, defined as the zone of impact around a water point, the smallest rangeland management unit. We hypothesized first that NDVI data would correlate

with field surveys on vegetation coverage, and that remote sensing could establish 9 year land cover and degradation trends on the steppe. Second, we expected that the piosphere degradation in Mongolia would follow the global pattern of being concentrated at water points with greater vegetation cover with distance from water source to exist in Mongolia.

6.1.1 Land degradation on the Mongolian plateau

Across the Asian steppe desertification – an irreversible loss of land productivity - is a major regional issue, with Asia, not Africa, now identified as the hotspot of land cover change (Lepers *et al.* 2005). In particular the semi-arid and arid Mongolian plateau, stretching from southern Mongolia through northern China, is increasingly experiencing high degradation rates and socio-economic pressure (Batjargal 1997; Purevdorj et al 1998; Chen and Tang 2005; Yang *et al.* 2005). China is already one of the world's most desertified countries (Zha and Gao 1997; Zhao et el. 2005), with 3600 km^2 of unproductive land added annually and 2.7 million km^2, an area the size of Kazahkstan, considered at risk (Normile 2007). UNEP (2002) identifies 70% of Mongolia's grassland degraded, while Li *et al.* (2006) label 75% desertified, with 640,000 km^2 vulnerable (Yang *et al.* 2005). Regionally there are several causes of degradation. In China these include poor land management, livestock practices, erosion, and population pressure, whereas in Mongolia concern focuses on overgrazing (Chen and Tang 2005; Erdentuya 2004; Lise *et al.* 2006). Local land cover change impacts the greater region. Current research suggests soil particles in southern Mongolia and northern China are the source of Asian desert dust, with this having a significant influence on regional and global environments (Middleton 1991; Xuan *et al.* 2004; Akata *et al.* 2007; Tsolmon *et al.* 2008). Consequently, a

paramount concern is identifying land cover and monitoring the plateau's fragile ecological system (Huang and Siegert 2006; Jun Li *et al.* 2007).

China is currently assessing the causes and impacts of land cover change in their dryland regions using remote sensing as an integral part of the effort (Yu et al 1999; Huang and Siegert 2006). In Mongolia use of remote sensing is less widely used and field observation is constrained by limited resources (Iwasaki 2004). Understanding regional dynamics is important as Sneath (1998) and Johnson *et al.* (2006) report there may be lower land degradation rates in Mongolia than China. Prior investigation by Gunin *et al.* (1999) identified high land degradation rates in the region with 50% severely and 40% of the land moderately degraded in Ovorhangai Province. These degradation values suggest a method to assess environmental processes across the steppe region is essential. One such much method, NDVI, has been widely employed and proven an effective method of identifying land cover change (Kogan *et al.* 2004; Okayasu 2007; Propastin and Kappas 2008). This paper takes a direct approach to the analysis of desertification by combining multi-temporal NDVI data with a ground-based ecological survey to address the issue of desertification in Mongolia, a strategy recently employed in other dryland regions (Washington-Allen *et al.* 2008). This approach, centered at piospheres, documents vegetation cover percentage at individual water points while average values, both for the study area as well as a series of years, is provided by NDVI, successfully used as a proxy for pasture biomass in other countries (Ishiyama *et al.* 2001; Kogan *et al.* 2004; Kawamura *et al.* 2005). If the statistical significance of the match between the two datasets is significant then NDVI should provide an historical perspective to land cover trends. This is particularly useful for discerning patterns clarifying whether land cover changes have crossed a negative threshold, suggesting desertification, are

currently in flux, or show vegetation increase over time in this highly variable dryland ecosystem (Begzsuren *et al.* 2004; Munkhtsetseg *et al.* 2007).

6.2 Study Area

Situatated on the vast grasslands that comprise 80% of Mongolia's 1.56 million km^2 territory, this research was carried out in Ovorhangai Province (N°46.3, E°106.3) in central Mongolia (Figure 6.1). The province, bounded by the Hangai Mountains to the north (2978m) and the Gobi desert to the south, is a rolling gravel plateau ranging from 1000 to 2000m a.s.l. (Hilbig 1995). The province covers a transitional zone between the steppe and desert-steppe ecosystems that defines >50% of the country's land surface. Field area vegetation is dominated by palatable perennial forbs such as *Iris bungei, Chenopodium album* and *Caragana pygmea* and *Artemisia sp* shrubs. The harsh continental climate experiences high annual (-35°C to 35°C) and diurnal (30°C) temperature fluctuations and low, unimodally distributed precipitation with >70% falling in the summer months (Table 6.1). The mean annual precipitation over the study period was 196 mm. The precipitation Coefficient of Variation (CV; CV = Standard Deviation/Mean x 100) is 27%, with variability in the summer months increasing to 72%. The province has a short growing season of ~110 frost-free days (Geographical Atlas of Mongolia 2004).

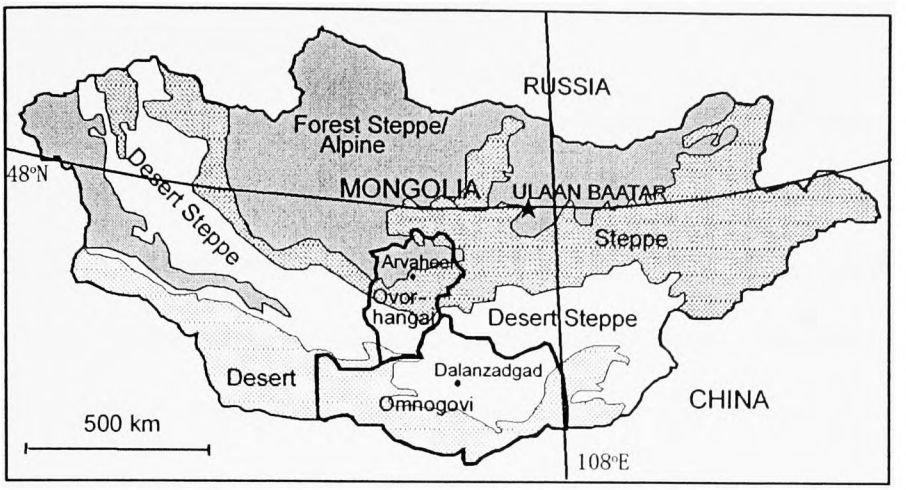


Figure 6.1 Map of Ovorhangai Province, Mongolia.

Table 6.1 Climatology 1998-2006 at Arvaheer meteorological station, Ovorhangai Province with Correlation of Variance (CV).

	Precipitation (mm)				Temperature (C°)			
Month	Mean	Max	Min	CV	Mean	Max	Min	CV
January	0.8	2.1	0.2	119	-14.1	-9.9	-16.7	14
February	1.1	3.4	0	117	-10.4	-7.1	-18.9	16
March	1.5	3.5	0	160	-4.7	-2.7	-9.5	6
April	3.7	9.0	0	430	4.9	9.0	1.6	2
May	20.9	56.2	2.0	69	10.3	11.9	8.9	17
June	24.6	37.9	16.0	178	16.1	17.6	14.4	10
July	79.3	150.8	23.9	52	18.3	20.4	16.6	40
August	44.6	79.5	13.0	54	16.1	19.2	13.8	35
September	13.6	34.8	0	70	10.9	12.6	8.4	18
October	3.8	4.5	0.3	93	2.4	3.9	-1.1	4
November	1.8	4.4	0	73	-6.1	-3.9	-11.6	5
December	1.2	2.4	0	70	-12.2	-10.0	-15.4	14
Annual mean	196.9				2.6			

6.3 Data

The spatial and numerical scale of this investigation increases study applicability and pasture knowledge across a substantial area. Grassland monitoring requires robust, repeatable techniques that provide accurate and timely vegetation information for spatial and temporal coverage (Purevdorj *et al.* 1998). In this study both *in-situ* work and satellite observation techniques were used.

6.3.1 In-situ observation

Fieldwork was carried out during the July to September, 2006 plant growth season based on a 1° north-south and 2° east-west grid in central Ovorhangai Province. Thirty-three piosphere (water point) sites were randomly selected within the area to supply a representative sample of environmental conditions. Identification took place through visual inspection and herder consultation with all water sources currently used by livestock as noted by dung presence, adequate water supply, herder confirmation and personal observation. Vegetation data were collected along 1 kilometre transects at every site (Dougill and Trodd 1999; Thomas *et al.* 2000) with vegetation measurements taken at 25, 50, 100, 200, 500, and 1000 metres from the water point. At each increment three 30 metre sections, separated by a 30 m interval, were examined and percentage of plant basal coverage for each metre along the line was recorded. To ensure sampling randomness all piosphere transects were due north except when visible barriers (terrain, abodes) prevented this.

6.3.2 Satellite imaging

Multi-temporal SPOT-4 satellite imagery was used to assess NDVI at each piosphere. NDVI is a commonly used vegetation index derived from remotely sensed measurements that is a normalized ratio of the NIR and red bands $NDVI = NIR\text{-}Red/NIR+Red$ where *NIR* and Re*d* are the spectral reflectance in near-infrared and red wavelength respectively. NDVI represents the contrast between absorbance in the visible wavelengths and reflectance in the near-infrared wavelengths that uniquely characterize the presence of photosynthetically active vegetation (Wessels *et al.* 2004). Research has established that NDVI, sensitive to vegetation density and

photosynthetic capacity, is highly correlated with biophysical parameters such as vegetation coverage and biomass, and that seasonal totals of multi-temporal NDVI data are strongly correlated with vegetation production in arid and semi-arid regions (Yu *et al.* 2004). NDVI data have found to give the best estimates of vegetation cover over a wide range of grass densities and has been successfully used as a proxy for pasture biomass (Purevdorj *et al.* 1998; Kogan *et al.* 2004).

Spot-4 vegetation 1-km NDVI data were both geometrically and radiometrically corrected in standard projection. A time series of observations was established comprised of the maximum value within thirty-day composites of three 10-day datasets from 1 April through October 30, 1998-2006. The months were selected to encompass the potential growing season and peak precipitation period. Similar to other regional studies, a 1 kilometre spatial resolution was used to generate land cover values on a scale equivalent to the line transects (Khuldumur and Erdenetuya 2002; Huang and Siegert 2005; Okayasu *et al.* 2007). From this data NDVI monthly and annual coverage values were derived from the area under each growing season curve. Results from the 2006 30-day composite data were then matched with 2006 field sampling findings. Using several years' remote sensing data lends an historical perspective to vegetation coverage and change in the region. However, as NDVI is an inexact measurement it provides an approximation of land coverage over time. Another drawback is that NDVI provides values for total vegetation and cannot distinguish species composition or identify palatable/unpalatable forbs (White and Nackoney 2003).

6.4 Results

Results identified a strong correlation (P = 0.01) between vegetation coverage derived from NDVI digital numbers and 2006 line transect field data in (Figure 6.2). This establishes a connection between the two measurements and suggests that in Ovorhangai Province NDVI can be used as a proxy measurement for pasture vegetation cover over time in the region. Field data identified low vegetation cover at piospheres in Ovorhangai province (Figure 6.3) with plant density increasing slightly from 25 m to 50 m, peaking at 100m distance from the water point. Cover then decreased at 200 m and 500 m, with the lowest vegetation density at 1000 m. Maximum average coverage in Ovorhangai was 20% at 100 m and minimum was 10.7% at 1000m ($r^2 = 0.70$).

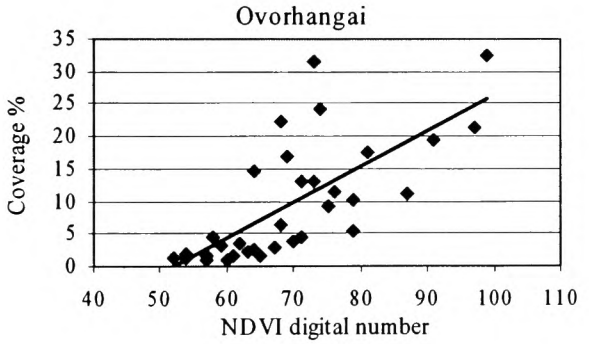


Figure 6.2 Relationship of NDVI and vegetation coverage in 2006 ($r^2 = 0.48$).

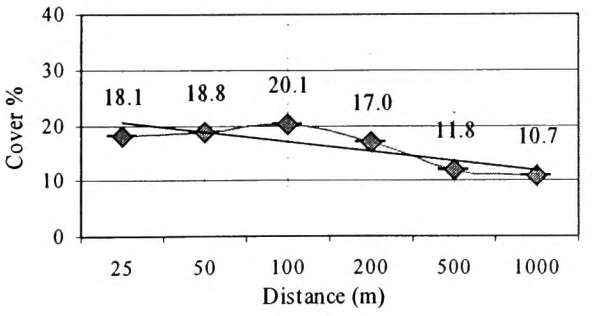


Figure 6.3 Average percent vegetation cover with distance from water point.

NDVI data showed a 16% decline in land cover over the study period (Table 6.2). Remotely sensed data show variable annual patterns, exemplified by highest values in 2001 and 2003 whereas 2002 has the lowest cover (Figure 6.4). Similar to yearly results, monthly NDVI averages also fluctuated, being lower in late spring, then increasing after the elevated summer precipitation period (Figure 6.5). Cover values varied with 5 years showing decreases of between 8.8% to 15.9% and 3 years having increases of 7.4 to 18.9%. Precipitation has an impact on NDVI values; thus land cover change in drylands is related to rainfall variability (Diouf and Lambin 2001). Tracking NDVI with precipitation indicates a significant correlation (P = 0.05), identifying rainfall as a major factor determining cover in the region (Figure 6.4). This relationship is important as a weak association between precipitation and NDVI is a sign of degradation (Propastin and Kappas 2008). Since 1998 there is a decreasing trend in NDVI land cover values, noted by the anomaly from the mean value (Figure 6.6). Examined over time, NDVI data indicates today's pasture resources are lower than in previous years, a state that may identify degradation. However, variegated NDVI values in the study imply the land has not crossed a negative threshold; rather it continues to respond to variable moisture conditions.

Table 6.2 Change in NDVI from 1998 and from prior year; mean annual precipitation.

Year	NDVI change % prior year	% since 1998	precipitation (mm)
1998	~	~	263.8
1999	-8.8	-8.8	209.8
2000	-10.1	-18.0	151.4
2001	13.8	-6.6	163.2
2002	-15.9	-21.5	119.5
2003	18.9	-6.6	293.5
2004	-10.5	-16.4	238.1
2005	7.4	-10.3	221.3
2006	-7.1	-16.6	111.5

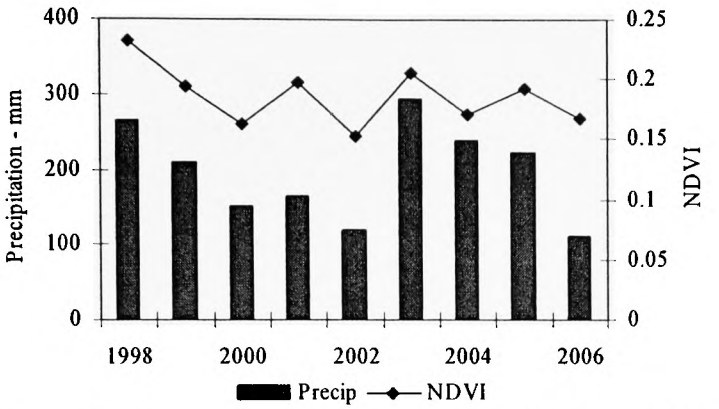


Figure 6.4 Annual precipitation and NDVI values, 1998-2006.

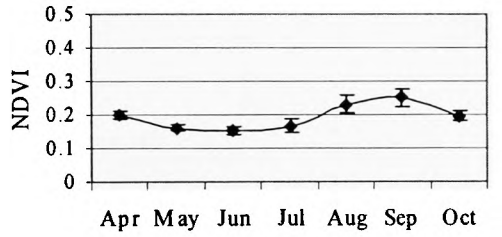


Figure 6.5 Monthly average NDVI values 1998-2006, with standard error.

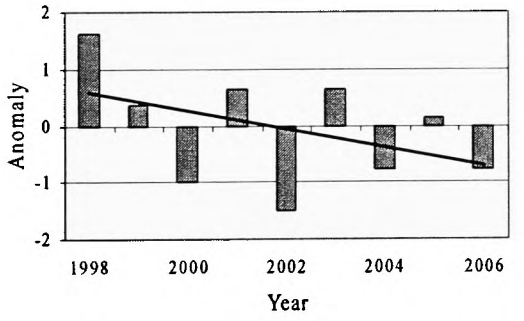


Figure 6.6 NDVI anomaly from mean value (r^2 =0.20)

The change in land cover identified by NDVI is visible in satellite images of the province with 1998 representing the peak cover year (Figure 6.7) with notably less vegetation cover in 2000 that reflects an 18% decrease in coverage over 2 years. While 2001 had increased NDVI values 2002 had the lowest coverage, with 2004 and 2006 at similar levels. Findings suggest that low precipitation in 2006 should result in decreased land cover in 2007.

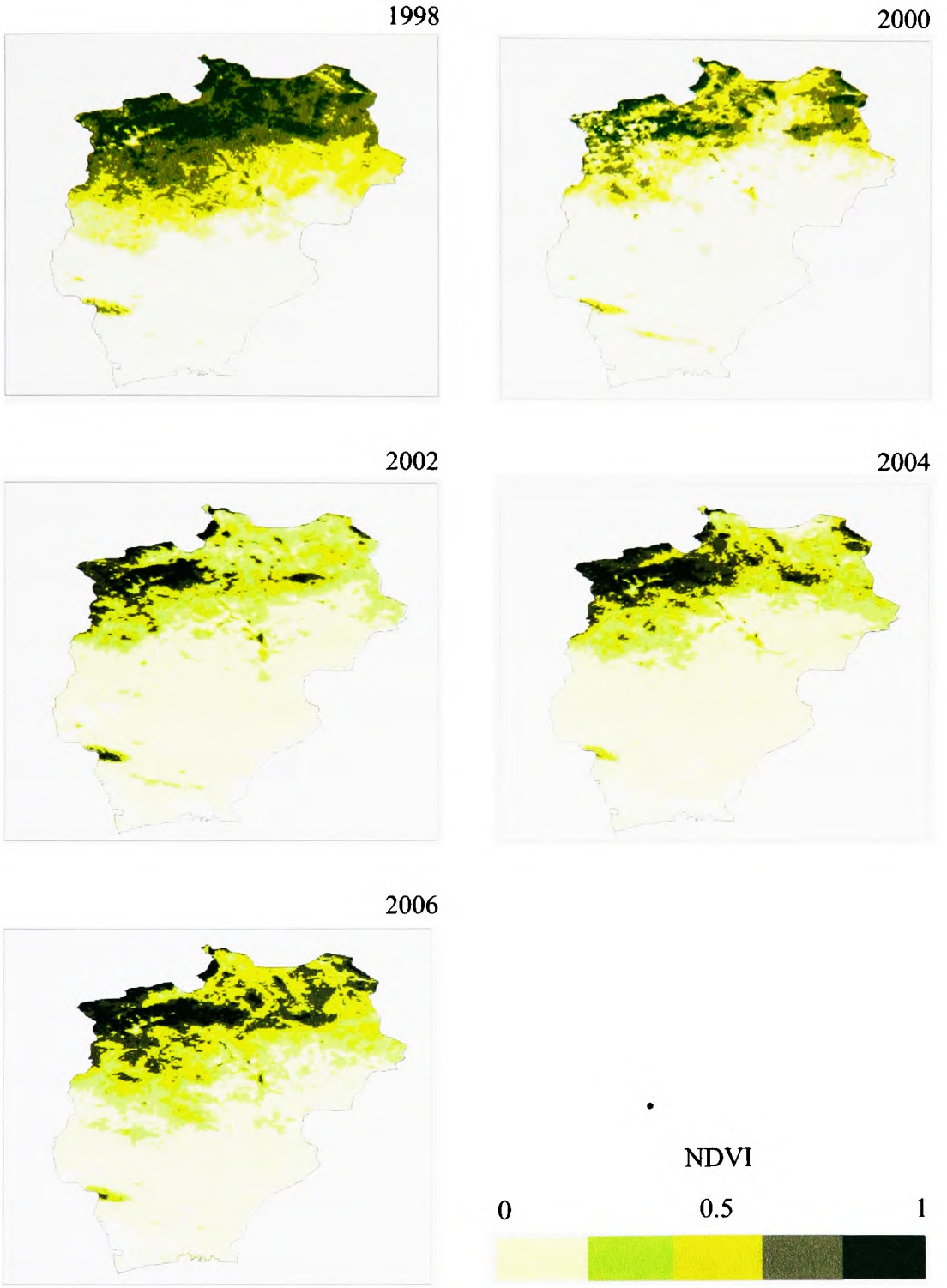


Figure 6.7 Bi-annual maps of NDVI, Ovorhangai Province, 1998-2006.

6.5 Discussion

The combination of remotely sensed NDVI data and fieldwork revealed annual variations in plant cover in Ovorhangai Province and declining vegetation density with distance from water points, a result conflicting with previous piosphere studies elsewhere (Perkins and Thomas 1993; Adler and Hall 2005; Todd 2006). Additionally, the NDVI perspective, while necessarily less detailed than the field study, showed a general decline in vegetation cover over the 9 years covered by the data.

Use of a combined methodology is particularly important in dryland areas where indices based on satellite imagery alone have been found to be insufficiently precise for landscapes with sparse (<15%) vegetation cover (Cao *et al.* 2007; Pettorelli *et al.* 2005). The strength of employing two analytical methods to monitor land cover change is that they compliment each other (Dougill and Trodd 1999; van Leeuwen 2006; Liu *et al.* 2005*a*). For example, plant composition and palatability can only be studied through fieldwork. Although, as Washington-Allen *et al.* (2008) and White (2007) point out, the time, effort, and cost of repeated field sampling in remote drylands or at regional levels is a considerable obstacle, NDVI provides at least a partial remedy for the challenge, being spatially and temporally effective and replicable (within the 9-year timeline of the study). However, the coarser NDVI spectral images were insufficiently detailed to define greater vegetation cover near water points and fieldwork was required to show that overgrazing or human use had little or no major impact on plant cover at the piospheres. Examining the two data sets also established a strong link between the NDVI data and the 2006 line-transect

vegetation cover, with the robust correlation (P=0.01) between factors confirming that multi-annual NDVI data can be used as a proxy for cover over time on the steppe.

Our results clarified two environmental processes. First, they showed that the present low vegetation cover is endemic in the landscape. Second, the highly variable, non-equilibrium ecosystem (Munktsetseg *et al.* 2007) indicates ongoing resilience as years of disturbance (decrease in cover) are followed by modest grassland regeneration (increase in cover), a finding supported by other studies (Washington-Allen *et al.* 2008). Thus, grassland recovery on the steppe in the years 2001, 2003, and 2005 indicates that there has not been progressive land degradation (Diouf and Lambin 2001). Rather, the overall decline in pasture resources indicated by NDVI data may be the result of bio-physical factors, such changes in precipitation, edaphic characteristics, or land use practices leading to cover variability. Continued monitoring can identify the severity of the decrease in land cover over time and to assess the potential of the ecosystem for crossing a negative threshold leading to desertification.

On marginally productive pasture a number of factors including physical conditions, human use, and livestock grazing can place stress on the environment with this leading to land degradation, an ongoing concern on the Mongolian plateau (Li *et al.* 2006; Zhang *et al.* 2007). Limited vegetation cover here implied the vulnerability of the ecosystem to climate factors.

Mongolia covers a large territory and has limited research resources to evaluate and address range conditions. Development of a basic understanding of large-scale patterns, both spatially and temporally, in an efficient and economical manner, could provide a strong management tool for monitoring vast pasture areas. Information, if communicated to land users, (in this case pastoralists that are dependent on range

resources for their livelihood) could impact decision-making regarding livestock numbers and composition, migration, fodder needs, and location of winter camps.

For communities to benefit from greater ecosystem knowledge and respect inherent grassland limitations requires effective interpretation and dissemination of data on local scales. In Mongolia this could be done through outreach by national institutes such as universities and government research laboratories with access to remote sensing data, through existing district and local structures, or as part of the efforts of international NGOs (such as the World Bank) working on rural development.

6.6 Conclusion

Environmental change and its impact on land cover is an important global issue and there is an increasing need to detect, understand, and predict ecosystem functioning (Pettorelli *et al.* 2005). This study shows that the combination of remote sensing and *in-situ* field research provides more robust findings than the use of a single method alone. Fieldwork places data in its physical environment; NDVI presents images of the selected area over time. In concert the methods enable a comprehensive understanding of the landscape.

In this area of already low vegetation cover NDVI and ground-based measurements were significantly correlated showing a decline in cover of 16% since 1998. However, due to the documented variable nature of regional land cover, with alternating years of increase and decrease, findings indicate that desertification, with a permanent loss of productivity, has not occurred. Decreasing land cover over the 9 year study period suggests degradation at the 1 km NDVI scale, though plant density patterns established at piospheres do not indicate reduced cover close to water points.

Instead, vegetation cover decreases with distance from the point, indicating livestock overgrazing was not affecting piospheres.

The results suggest that bio-physical processes, not human use patterns, impact the rate of land cover on the steppe. Although the ground-based survey established vegetation cover levels in 2006, further multi-annual field measurements are needed to reinforce the study findings.

The field observation and remote sensing methodologies employed in this study could be replicated across Mongolia and throughout Inner Asia to strengthen understanding and monitoring of environmental conditions. Due to geographical similarity, the Chinese and Mongolian sides of the shared plateau provide and excellent opportunity for future coordinated research to track desertification in both countries. Identification of differences or similarities in land cover across the border could lead to an evaluation of broader factors, positive and negative, affecting the environment, such as political, economic, and livelihood forces (Sneath 1998; Yang *et al.* 2005). This could contribute to system-wide ecological understanding and inform efforts to identify desertification or rehabilitate degraded lands.

Chapter VII

Pastoral mosaic: livelihood, mobility, differentiation, and environmental engagement on the Inner Asian steppe

Troy Sternberg

Book chapter accepted in: Contemporary Mongolia: Transitions, Development and Social Transformations. To be published by Brill, 2009.

Abstract

Throughout its long history on the Inner Asian steppe pastoralism's adaptive livelihood strategies have ensured its viability. Today changing environments, socio-economic factors, and herder motivations challenge traditional pastoralism in Mongolia. To understand current processes in the countryside knowledge of herder livelihoods and behaviour is essential. Through extensive on-site interviews this survey establishes herder-livelihood approaches and interaction with the physical landscape. Results emphasize the importance of both number and distance of moves on herder welfare. In contrast to collective-era homogeneity herders now act independently, employ varied livelihood strategies, are motivated by economic factors, and do not see herding as a career choice for their children. At the same time traditional foundations – communal land stewardship, independent decision-making, and mobility remain valued. Pastoral differentiation occurs along several dimensions, including age, education, number and type of livestock, and location. Concerns are both physical - lack of water sources, variable pasture quality, low precipitation – and socio-economic – limited income sources, expenses, evolving perceptions and motivations, and a lack of government support. Interaction with modern society,

including access to vehicles, technology, and education, is viewed as contributing to pastoral viability in the 21st century. For current and future policy, management, and development efforts to be effective identified herding realities need to be acknowledged and addressed.

Key words pastoralism, mobility, livelihood, differentiation, environment, Mongolia, steppe

---

7.1 Introduction

Pastoralism has thrived on the Mongolian plateau for millennia with recent luminescent dating techniques indicating gazing effects for 6,500 years (Mandzy-Herring 2008). Throughout this long history traditional subsistence patterns have evolved through major political and economic shifts. In the last century herding dynamics moved from a feudal to Soviet collective system and since 1990 has transitioned to a market economy (Fernandez 2006). Mongolian herding has seen dramatic shift in herders, livestock, motivation, and economics as pastoralism functions within socio-economic necessities and ecological parameters that impact human-nature interactions. Recent research documents either social or ecological aspects of the ongoing pastoral transition without clarification of human-physical interactions (Fernandez and Batbuyan 2004; Sneath 1998; Mearns 2004; Okayasu *et al.* 2007; Bohannon 2008; Sternberg 2008). As tradition meets modernity this paper examines pastoralists in their environment, herder interaction with the physical landscape, livelihood practices, and the future direction of pastoralism on the steppe.

To examine today's pastoral practices requires recognition of contemporary forces shaping the Mongolian countryside. Animals, water, and migration are inseparable from personal motivations and decisions, income sources, expenses, and concepts of the future. Changing determinants – government role, need for cash, land tenure, children's future – make previous frameworks instructive but outdated. Real-time perception and information is essential for any assessment or programme aimed at a livelihood serving 50% of Mongolians (Johnson *et al.* 2006).

The assumption, implied by government neglect, that "all-is-well" or at least that "all-is-OK" in the countryside (Suttie 2005) is a sign of relative maturity, signifying that the transition from collectivization to private ownership has occurred without notable societal disruption. Since 1990 the number of herding households has increased 225%, from 75,000 to 168,000, showing pastoralism's continuing viability on the steppe despite, or because of, limited government attention and support (Mongolian Statistical Yearbook 2002; *ibid.* 2006). Issues that dominated domestic and international attention post-1990 such as rural subsistence, livestock privatization, and addressing basic pastoral productivity have given way to concerns about civil society, alternate income sources, the effect of mining, and national development - issues removed from daily herding exigencies (Swift and Mearns 1993; PALD 1993; UNDP 2007). The conundrum is that though livelihood crises have been avoided, the challenges extant in 1990 remain a critical part of the pastoral landscape as new socio-economic and physical variables impact pastoralism (Asian Development Bank 2004; Johnson *et al.* 2006).

From the outside, pastoralists have been widely regarded as a relatively homogenous group, though herders are now drawn from a broad cross-section of society. The key elements of pastoralism – livestock, mobility, low ecological impact,

and a self-sufficient subsistence approach – while integral, have evolved. The system of open pasture, private responsibility, and declining government involvement now encompasses changing motivations, forms of land tenure, economic pressure, increasing livestock numbers, ecosystem change, and herder differentiation. To document pastoral trends, determine relevant policy and management approaches, and address disparities an understanding of today's pastoral realities is essential.

As current research, often in concert with western academics, focuses on social factors such as migration, mining impact, economics, and education or physical traits like climate change, degradation, water and soil characteristics, remote sensing, and livestock the cohesive whole is subsumed into specificities (Fernandez-Gimenez 2000; Steiner-Khamsi and Stolpe 2004; Farrington 2005; Lise et al 2006; Sasaki et al 2007; Tsolmon *et al.* 2008). This provides greater distilled knowledge yet neglects the core issue – pastoralism itself, and with it the pastoralists' thoughts and action that define their physical and social environments (Fernandez-Gimenez 2000). Pastoral patterns from collectivization and the 1990's transition give way to the immediacy of today's issues and work. This study examines herders, their livelihood practices, and the future implications of ongoing pastoral processes. Pastoral dimensions are assessed in their natural setting – the herder's *ger* (tent abode) – to ascertain what comprises herding today. I hypothesized that herders are not an homogenous group but represent varied approaches and motivations that comprise the nomad of the present. Through interviews a narrative emerges about herders (section 7.3.1, 7.3.2), their environment (7.3.3), mobility patterns (7.3.4), socio-economic factors (7.3.5), and future direction.

7.2 Area & Methods

7.2.1 Study Area

This study investigates pastoralism in Ovorhangai and Omnogovi Provinces in central and southern Mongolia (Figure 7.1). Framed by the Hangai Mountains to the north the Ovorhangai research area (46° N, 103° E) in central Mongolia encompasses semi-arid steppe and desert-steppe terrain. Bordering it to the southeast the second research area Omnogovi (44° N, 104° E) is dominated by a desert-steppe environment with the Gurvan Saixan Mountains transecting the area. The surface morphology of the study region is typically that of a rolling gravel plateau ranging from 1000 to 2000m above sea level (Hilbig 1995). Similarly defined landscape covers over 50% of the country's land surface (Geographical Atlas of Mongolia 2004). Climate in these semi-arid and arid environments is characterized by short hot summers and long cold winters with unimodally distributed rainfall concentrated in summer (Yu *et al.* 2004). Province capitals have mean average precipitation of 234 mm and 121 mm respectively. In Mongolia highly variable precipitation and low soil fertility of the steppe grassland exhibits non-equilibrium characteristics, with edaphic and abiotic factors limiting plant growth (Fernandez-Gimenez and Allen-Diaz 1999; Begzsuren *et al.* 2004; Retzer and Reudenbach 2005; Munktstsetseg *et al.* 2007). Differences in timing and amount of rainfall and inter-annual variability strongly influences livestock and plant communities and can lead to considerable fluctuation in vegetation cover (von Wehrden *et al.* 2006). Pastoralism is the traditional livelihood in these provinces with livestock composition dominated by sheep and goats (Table 7.1).

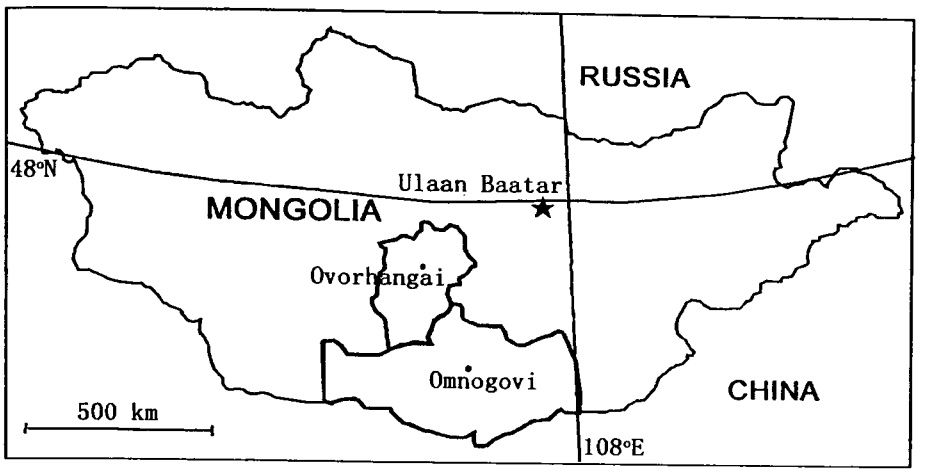


Figure 7.1 Map of Mongolia with study regions.

Table 7.1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces.

Province		Ovorhangai	Omnogovi
Sites		56	56
Rangeland		Steppe - Desert Steppe	Desert Steppe
GPS		46° N, 103° E	44° N, 104° E
Elevation - metres	Average	1707	1484
Mean annual	mm	235	121
precipitation	min-max	119-378	51-235
Mean Temperature	January / July	-14.4°C / 16.3°C	-13.9°C / 21.9°C
Water point	# well / surface	40 - 16	50 - 6
Herders	% population	57%	49%
Livestock	type	Sheep, Goat, Horse , Cattle	Goat, Sheep, Camel, Horse
Livestock numbers	2002 / 2006	1,665,000 / 2,623,300	909,000 / 1,155,700

7.2.2 Survey

The survey was designed to identify pastoralist's interaction with the environment by following a grounded theory approach which developed greater focus as research progressed. Limited prior study in the region made this an effective strategy as ecological validity improved as data was gathered. This method generated systematic data collection while allowing flexibility in research direction. Thus key points that emerged through the inductive process could be developed into relevant concepts and

categories. In this way a theoretical framework emerged that was rooted in the data (Gomm 2004; Robson 2002).

From June to October 2006 and February to May 2007 field surveys were conducted with herders in the two study areas. These provinces were selected to represent a transitional gradient from desert-steppe conditions in the south to steppe grasslands in the north. Fieldwork commenced in the provincial capital from where dirt tracks were followed towards a selected district and along the way *gers* were visually located for herder interviews. This led to a stepping-stone process where abodes were spotted and visited along a general trajectory towards the town. This procedure was continued to cover approximately a 1° latitude by 2° longitude area in each province. In this way herders from different districts were selected by physical location rather than social criteria. Assessments (n=112, 56 in each province) were undertaken to determine herder concepts of pastoralism to ascertain how livelihood and environment interactions have evolved since 1990 (Lee and Zhang 2005). Surveys focused on: 1) herder composition and characteristics, 2) environmental interaction, particularly present and past water resources and pasture use, 3) mobility patterns, and 4) socio-economic factors. Additional issues included livelihood practices, the role of government, herder differentiation, and the future implication of present processes.

Pastoralists were asked standardized questions that were not conditional on prior answers. Interviews were conducted through a translator in the pastoralist's habitation after cultural formalities were observed with handwritten notes taken at the time of the interview. Analysis synthesized responses with results reflecting herder responses and estimates. When possible, herder reports were verified by personal observation of water sources, pasture, and number of livestock. This process develops

understanding of herding livelihoods, economic impacts, land use, and claims of degradation in published reports (Mearns 2004; Middleton and Thomas 1997; MNE 2002; Asian Development Bank 2004). Answering a set of semi-structured questions about pastoral practices allowed respondents to express personal ideas and behaviour, though not all answered all questions. Common themes relevant to daily pastoral life in the Mongolian countryside emerged from interview data.

To provide a secondary source of information Normalized Difference Vegetation Index (NDVI) data were derived using Spot-4 1 kilometre resolution satellite data available from 1998 to 2006. Regional NDVI data have been found to significantly correlate with ground vegetation coverage obtained through on-site investigation (Sternberg *et al. in review*). Thirty-day digital number values were calculated at all sites in each province for April through October, matching the maximum potential vegetation growth period. Results were averaged to provide a yearly NDVI value. While NDVI has limitations (Richard and Poccard, 1998), it is used here to provide an estimate of vegetation density and land cover over time that relate to herder perceptions of vegetation and precipitation.

Following a grounded theory design data analysis identified patterns and developed relevant explanations of pastoral processes (Robson 2002). This was done by collecting and evaluating the large volume data to discern conceptual categories from the field notes. Using open coding pastoral dynamics were grouped by major themes, including herder characteristics, environmental interaction, mobility, and socio-economic factors. Further breakdown was by factors such as age, site, education, number of livestock, years of experience and frequency of moves. The multiple categories were then examined to establish relationships between factors both within and between groups with natural comparisons emerging (*e.g.* mobility and livestock

numbers, vegetation and precipitation). Using statistics data were further analyzed using SPSS 14.0 (Chicago, Il) to determine significant correlations among 80 variables. Dominant factors were then re-examined to evaluate their impact on variance within categories. Principal Component Analysis (PCA) and linear regression were applied to the data to identify key determinants for each variable (Field 2005). PCA differentitated the findings along axes which reflected how well survey variables explained associations.

In the study livestock numbers and Sheep Equivalency Units (SEU) were used to account for type of animal. In this way large animals (camel = 7, horse = 6, cattle/yak = 5) are given more weight than small livestock (sheep = 1, goat = 0.9) to better reflect herd composition (Geographical Atlas of Mongolia 2004). Livestock, as a herder's main asset, can serve as a proxy for income/wealth, with increased livestock/SEU numbers symbolizing greater economic success (Johnson *et al.* 2006).

7.3 Results

7.3.1 Herders

Within the herding community there is significant diversity in personal characteristics and herding practices. Age, experience, number of livestock, moves, distance moved, education, and outlook reflected a marked divergence among pastoralists. The variability within respondents leads to differentiation in practice, wealth, and perception among herders. While approaches may vary there is strong agreement on core issues affecting livelihoods. Thoughts on privatization, access to water, control of movement, and the role of government are united and unequivocal. Findings indentify livestock, movement, migration distance, education, and vehicle ownership

to be key inputs. Quality of life is independent of measures of wealth, being instead a function of age and years herding.

7.3.2 Herder Characteristics

The age profile of herders shows a bias towards the older end of the age range of the general Mongolian adult population (Figure 7.2). 14% of herders were ≥ 70 years old, whereas the age group comprises 2.5% of the total population. Table 7.2 shows nearly half (48%) of herders had 5-8 years of education. Herders now receive more schooling than during the socialist era, reflected in a significant negative correlation between age and education ($P = 0.01$). The number of years herding shows more than half (58%) of respondents became herders after the transition from collectivization to capitalism in 1990 (Table 7.3). Years herding was negatively associated with education and vehicle ownership and long-time herders were more inclined to pursue tenure rights. *"Before there were no cars or motorcycles"* (female, 52, Omnogovi) – now private vehicles are owned by 73% of herder households with motorcycles (44%) more common than cars and trucks (29%). Ownership has become more accessible with the introduction of low cost Chinese motorcycles and to a large extent has replaced the camel's transport role in the desert steppe. Land contracts, commonly available in the countryside as tenure for winter camp, potentially between 0.5 – 0.7 hectares (Fernandez-Gimenez and Batbuyan 2004), were possessed by 52% of herders. Contracts increased with years herding ($P = 0.05$), but were negatively related to livestock, SEU, and education ($P = 0.01$).

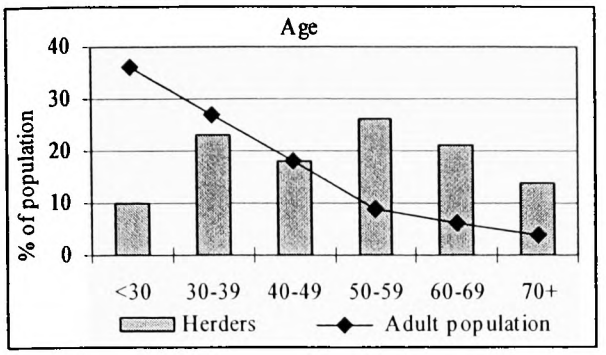


Figure 7.2 Herder and adult population by percentage of age group.

Table 7.2 Herder education

Education (years)	%
None	7
1 to 4	17
5 to 8	48
9 to 10	13
Some college/ technical	9
University grad	5

Table 7.3 Years herding

Years herding	%
<10	16
10 - 19	42
20 - 29	14
30 - 39	8
40 - 49	12
>50	8

Livestock data identify 47% of surveyed herders have <200 animals, an amount considered to be a marginal livelihood (Figure 7.3). 33% of respondents, possessing 200-400 livestock, are moderately successful whereas the 20% with >400 animals are highly successful (Janzen and Barzagur 2003; Johnson *et al.* 2006). When examined by SEU, the number of marginal herders decreases to 24%. Species composition favored sheep in Ovorhangai, whereas goats were the dominant livestock in Omnogovi (Figure 7.4). Age is negatively correlated with number of animals ($P = 0.01$) and Sheep Equivalency Units (SEU) ($P = 0.05$), thus older herders own fewer livestock. The number of livestock, a perceived sign of wealth, suggests as age

increases income decreases yet older herders ascribe the highest quality of life to herding (P = 0.05), observing, "*herding life is beautiful. We have hard times, beautiful times. I can move anywhere.*" (female, 86, Omnogovi). A quarter of herders expressed that herding was "beautiful or very good" with 58% identifying it as a "good life", 8% "OK" and 9% as "difficult".

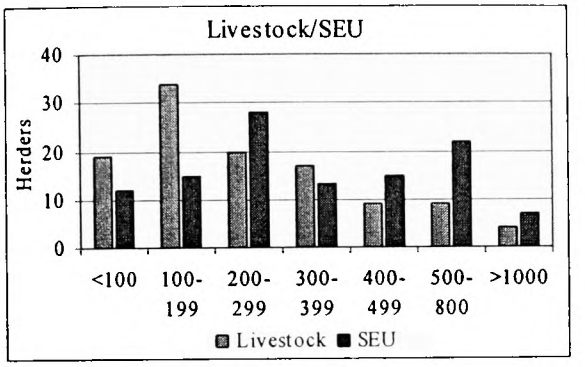


Figure 7.3 Livestock number and Sheep Equivalency Units.

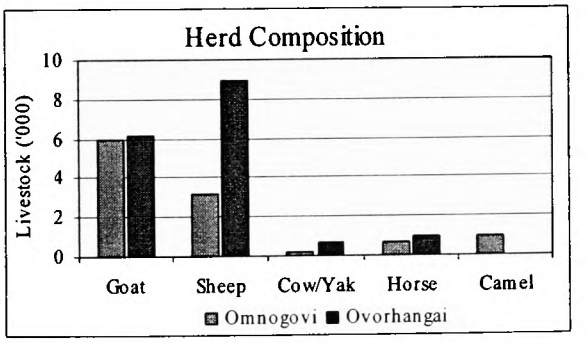


Figure 7.4 Herd composition.

7.3.3 Environmental Interaction

Academic literature is united in characterizing the steppe environment as providing limited resources within a sparse landscape (Fernandez-Gimenez 2000; Suttie 2005). Herder perceptions of pasture quality varied with a third identifying good quality and half citing bad or very bad conditions; precipitation was viewed as overwhelmingly

bad (Table 7.4). Grass composition/condition over the last decade was perceived as declining by 84% of herders whereas 7% described pasture trends as improving.

Table 7.4 Perceived pasture quality and precipitation

	Pasture - %	*Precipitation - %*
Very good	1	0
Good	31	6
OK	20	11
Bad	40	73
Very bad	8	10

"In Sant district I dreamed of water. Now here I dream about water in Sant district." (male, 44, Ovorhangai) Water is a key pastoral need and motivates migration. Distance to water shows the concentration of herders near water points. Almost half (47%) live less than a kilometre, and 70% are within 2 kilometres, of a water source (Table 7.5) with a large majority (Omnogovi - 89%, Ovorhangai – 71%) obtaining water from wells. This herder convergence reflects an intensification of families and livestock at water points with an average of 1435 livestock using an individual water source (Table 7.6). The clustering effect is notable at surface water sources (P = 0.01) where vegetation, determined by NDVI, is greater (P = 0.01), and altitude is higher (P = 0.01). Over 80% of herders identified water sources in the area as drying, with surface water – streams and springs – disappearing more often than wells (Figure 7.5), as reflected in, *"when I was a child there were many mountain streams with much water. Now these streams have little water and small streams have dried up."* (male, 38, Omnogovi). Broken wells, lack of rain, disappearing streams and springs, global warming, and the impact of mining processes were cited as reasons for reduced water points. The drying of water sources and a decrease in the number of engineered (- 80%) and hand (- 40%) wells between 1990 and 2000 (Tanaka *et al.* 2005) are possible causes for pasture and livestock intensification, increased grassland degradation, and the perceived decreased pasture capacity.

Table 7.5	Distance to water
Km	%
< 0.5	37
0.5-1	10
1 to 2	24
2 to 3	11
3 to 4	13
5+	6

Table 7.6 Families and number of livestock at water points

Families per water source	# Water points	Livestock per source	Livestock per family
1	16	285	277
2	18	462	228
3	16	880	294
4	7	1207	248
5	16	1715	334
6	10	2167	311
7	4	2500	405
8	3	1967	150
10+	8	2536	247
20+	7	6000	217

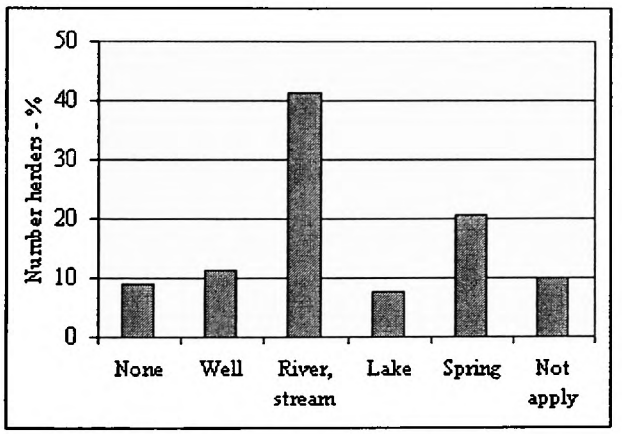


Figure 7.5 Herder identification of drying water sources

The government plays a limited role in rural water provision. As one herder said, "*I never heard of the government building a well anywhere!*" (male, 74, Ovorhangai). The government is viewed as having no water regulatory role as 98+ % of respondents state herders assumed responsibility for maintenance and repairs of water points. Water is considered a free good; the only perceived price attached to water may be a charge for motor fuel at engineered wells.

Distance from a herder's home to a water point affected how a herder conceived the amount of territory available. Those further from water claimed greater areas as their personal herding sphere. A corollary of this was that these herders had significantly higher SEUs ($P = 0.05$), as opposed to livestock numbers, than those nearer water. This may reflect emphasis on large livestock, and thus the need for greater foraging range, by those further from water points.

The physical environment, as characterized by NDVI, and precipitation, recorded in the province centre, provides a comparison with herder perspectives (Figure 7.6). Land cover values are relatively consistent over the last 9 years, with the lowest cover in 2002. This implies a moderate fluctuation between years in vegetation levels. However, citing poor grass conditions may point to herders' discerning not only amount of grass but type, composition, grass height, and palatability that serves livestock needs. Though the two provinces had different rainfall patterns, with Ovorhangai notably wetter, perceptions of precipitation were identical. In both provinces 83% of herders identified precipitation as bad or very bad. This was at a time when average precipitation was somewhat elevated in Ovorhangai and below normal in Omnogovi.

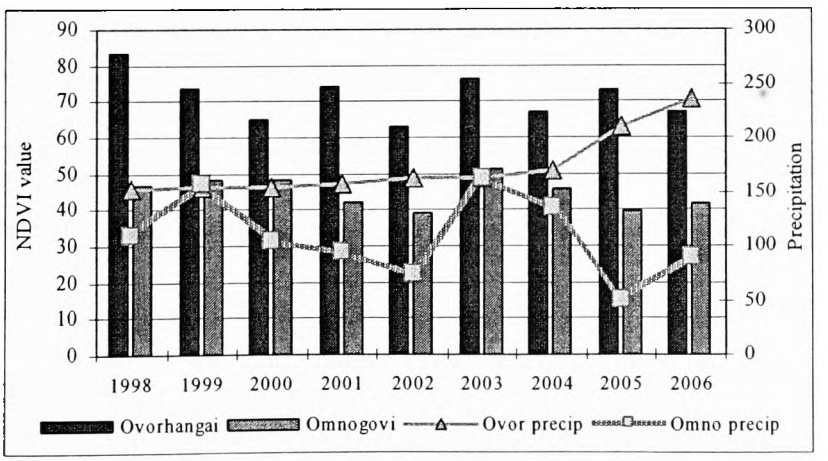


Figure 7.6 Precipitation and NDVI records, 1998-2006 (NDVI range 0-255).

An additional indicator of rangeland condition were perceptions of sand – herders' views on accumulation, impact on livestock, pasture, and working conditions, and as sandstorms, particularly during spring (Okayasu *et al.* 2007). When asked, 70% identified sand as a growing issue, citing increasing amount and distribution of sand, impact on livestock, detrimental effect on grasslands, increasing and intensifying sandstorms, and the presence of sand where previously it had not been noted (Table 7.7). 26% said sand was not a problem whereas none cited sand effects as improving. The belief that sand was a worsening problem was dominant among herders with land contracts whereas 39% of herders with no land contract, three times the figure of those with contracts, cited no problem with sand. Those who perceived no problem with sand moved less often but further than other herders.

Table 7.7 Sand intensity - % respondents

	All	Omnogovi	Ovorhangai	land contract	no land contract	# moves	distance moved
No problem	26	23	29	13	39	3	51
Better	0	0	0	0	0	~	~
Same	4	6	2	6	2	7	32
Worse	70	71	69	81	59	4	39

7.3.4 Mobility

"Mongolians are nomadic so where there is pasture and rain we have moved" (male, 50, Ovorhangai). Mobility is a key feature in maintaining a viable, low-imput pastoral system (Sayre and Fernandez-Gimenez 2003). Research examined frequency and distance of migration, transport, past patterns, government control on migration, potential conflict, and the role of perceived land tenure on movement. Several factors were significant indicators of mobility with greater livestock numbers, and thus increased income, being the most important correlation (Table 7.8). Higher education levels, perhaps reflecting greater understanding of current livelihood conditions, and

vehicle ownership contributed significantly to migration rates and moving greater distances. NDVI, water source, and altitude were also predictors of migration; herders in areas with lower NDVI vegetation cover as well herders dependent on wells were more likely to move. Reflecting positive altitudinal vegetation gradients on the steppe, herders at higher elevations moved less.

Table 7.8 Significance of number of moves and herding variable.

Significance (P=)	Livestock/SEU	Distance	Vehicle	Education
Number of Moves	0.01	0.01	0.01	0.01
	Water source	NDVI	Age	Moves 10 years ago
	0.05	0.05	0.05	~

"Moved so many times I can't count the number" (male, 67, Omnogovi). Though many herders were uncertain about past movement patterns or were not previously herding, 62 recalled migration patterns from a decade ago. Of these, 58% had increased annual moves with 21% reporting a decrease. While 4 was the median number of moves per year, 42% of herders migrated twice or less and one-sixth did not move, implying transhumanent pastoralism has shifted to settled livestock raising for this group (Table 7.9).

Table 7.9 Number of moves

Moves	today %	10 years ago %
0	16	19
1 - 2	26	21
3 -5	36	48
6 - 8	10	12
10 - 12	10	0
14 +	3	0

Distance moved (Table 7.10) was an important predictor of both livestock numbers and vehicle ownership and related to education and distance from a water source. Herders residing farther from a water point and those with higher education levels

were more likely to move. Half of the respondents moved less than 20 kilometres annually while 31% migrated over 50 kilometres per year. The method of movement was not correlated (P = 0.05) with vehicle ownership - though three-quarters of herders own a vehicle the same percentage hire transport to migrate. Past modes of migrating – livestock (9%) and tractors (4%) - were little used.

Table 7.10 Distance moved

km	%
0	16
1 - 5	16
6 - 9	4
10 - 19	14
20 - 49	19
50 - 99	17
100 +	14

Mongolians view grasslands as communal property, thus available for grazing. Tenure rights for winter camps are spatially limited thus do not constrain pasture. There was a clearly expressed opinion that all rangeland was open to herders as needed, particularly during extenuating circumstances such as drought or extreme winters. The idea of control of movement was an anathema and seldom taken seriously as 91% of herders stated there was no government control of migration. A small minority recognized the need to obtain permission from local authorities to move into another district, usually described as paying a tax, and 2% stated herders controlled area movement. There were some instances of herders attempting to limit new herders from coming to their area but this was the exception. A more common sentiment was, *"I don't have the courage to tell others to leave because it will be our turn when there is no grass"* (male, 70, Omnogovi).

7.3.5 Socio-economic factors

The social framework within which pastoralism occurs and the economic factors that drive decision-making are key livelihood determinants. A balance emerges between income generated and expenses. Across the spectrum of herders interviewed the major income source is goat cashmere (Figure 7.7). 95% of herders receive income from cashmere; for two-thirds it is their main income source. After cashmere revenue source and main income diverge. Wool – sheep and camel - is the second most common money earner but does not have high value so is seldom a main income source. Pensions are a more important primary income, with 19% of herders dependent on them, and a third of households containing a pensioner. Livestock is the herder's most valuable resource but few (7%) use animals as the major income source. Meat and dairy, while a key factor for herder subsistence and self-sufficiency, are not dominant revenue generators. External work was cited by 4% of households, suggesting herders have little outside support for livelihood needs. The majority of herders (58%) state income is "normal" whereas twice as many claim income is bad (28%) rather than good (14%). Different main income sources did not have notable correlations with other factors.

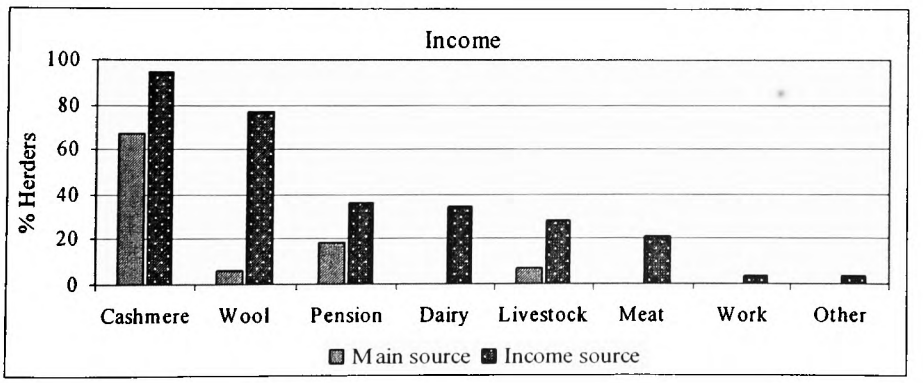


Figure 7.7 Herder income sources.

Herder expenses were lead by basic items – food and clothes, then children's education and petrol (Figure 7.8). Then came herding-related costs for fodder, migration, and livestock-related expenses. While the five most common expenses were broadly shared the main expense identified was split between food (35%), education (26%), and petrol (23%). Food is the most cited expense; the prevalence of education and petrol as major costs suggest recent shifts in pastoral livelihoods. Educational expenditure may reflect increased primary and secondary enrolment in both provinces (>33%) over the last decade and increased university enrolment, which requires tuition fees, by rural students (Mongolian Statistical Yearbook 1989-2002: *ibid.* 2006). Education was also expressed as a way for children to qualify for future jobs in town that are regarded as better than herding. Increased educational levels were correlated with owning large (camel, cattle, horse) livestock (P = 0.01).

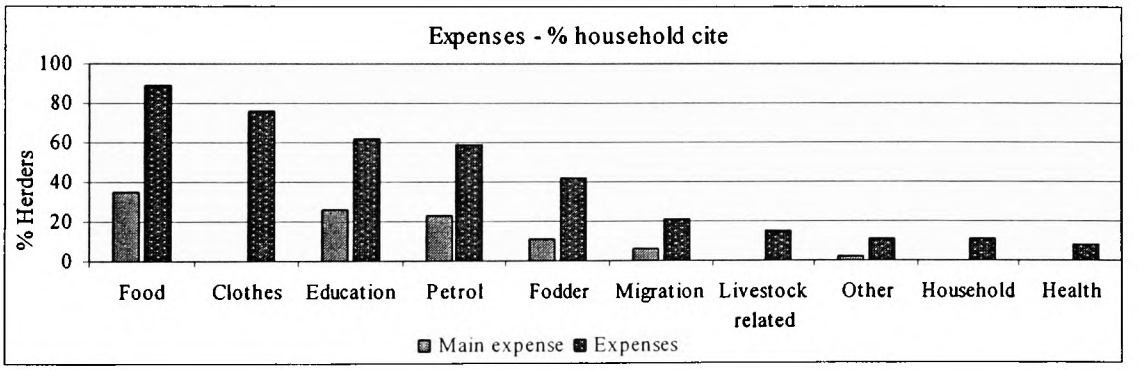


Figure 7.8 Herder expenses.

The need for petrol, cited by 60% of the herders, shows the change in approaches to pastoralism where now a vehicle has become a standard input. As one man stated, "*before herders looked after livestock by horse, now we herd by motorcycle*" (male, 27, Ovorhangai). The major expense of petrol results from the quick acceptance of vehicles - a three-fold increase over 6 years (1999-2005) – and operating costs, as at

the time of fieldwork a litre of petrol was more expensive in Mongolia than in the US. Vehicle ownership was related (P = 0.05) with identifying a large herding territory. Secondary expenses reflected core livelihood needs – fodder for animals, migrating costs, care of livestock, and household expenditures.

"Who helps you? Does Enkhbayar (the President) help you? (laughs) There is nothing" (male, 50, Omnogovi). Questions about the role of government proved perplexing because respondents did not conceive of government as having a participatory role in herding. The memory of socialist times was of government "taking care of everything". In comparison to the past, current government engagement is perceived as collecting tax with minimal services provided despite it providing pensions and education. Control over pasture resources is viewed as being exercised by herders rather than the government, such as access to privately-owned wells and limiting the number of herders moving into an area. Because of an absence of clear government programs or support for pastoral concerns the state was regarded as somewhat irrelevant to daily life. Thus a question on the role of government was interpreted as "what should the government do?" The standard answer was first that the government does nothing, followed by several suggestions for what it could do (Table 7.11). The overwhelming concern was with water sources, particularly building and fixing wells. This was seen by most herders as beyond their capability and thus it should be the major focus of government work (Sternberg 2008). A distant second concern was for winter fodder, then general assistance, a hoped-for payment to herders to help cover living expenses. 12% viewed herding as best without any government involvement and did not want a state role in their livelihoods, saying, *"we are countryside people and don't need much from the government"* (male, 64, Ovorhangai) Pastoralists saw a need to protect environmental factors, such

as pasture and springs, because, *"the environment changes by human hands"* (male, 38, Omnogovi), and wanted the government to "shoot the clouds" for rain, a practice reported in neighboring China. A small minority of respondents hoped for assistance with the cost of petrol.

Table 7.11 Role of government - %
(answered as it should provide...)

Does nothing	77
Water	69
Fodder	28
Aid	17
Want nothing	12
Protect environment	12
Shoot clouds (for rain)	9
Petrol	6

Changing mobility and land use practices, the retreat of the government from a regulatory role, and competition for pasture and water access has been viewed as increasing pastoral conflict (Oyuntseteg 2006). In contrast, the study did not find conflict to be an important herder concern. Of 112 interviewees 8 listed potential conflicts. These were disputes with herders about pasture usage (4), clashes with "ninja" small-scale miners over mining impact on water supply (2), and arguments with tourist camps that restricted access to deep wells (2). 93% of herders did not think conflicts were present in their livelihoods. However, herders felt strongly that land privatization would lead to conflict.

7.4 Analysis

7.4.1 Principal Component Analysis/Linear Regression

Data were analyzed to determine how effectively the results explained the dominant factors that engage pastoralists. Principal Component Analysis (PCA) was used to reduce the large data set to a more practical size. PCA organized the internal

structure of data into main groupings in a number of independent axes that in decreasing order explain variance in the findings. In this survey the first component accounted for 31% of data variance while the three main components cumulatively explained 72% of survey variance (Table 7.12). Dominant factor associations explaining nearly a third of data variance in component one are relationships between moves, SEU, and vehicles as a positive grouping and NDVI, altitude, and province as a negative set. The second component found livestock and SEU as a more positive cluster and moves, vehicle, and education as less positive. In the third component education, followed distantly by moves and NDVI, were grouped while SEU and livestock formed a negative pair.

Table 7.12 Principal Component Analysis

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.51	31.37	31.37	2.51	31.37	31.37
2	2.22	27.75	59.12	2.22	27.75	59.12
3	1.05	13.15	72.28	1.05	13.15	72.28
4	0.76	9.44	81.71			
5	0.59	7.41	89.12			
6	0.49	6.10	95.22			
7	0.26	3.28	98.50			
8	0.12	1.50	100.00			

Component Matrix

	Component		
Factor	1	2	3
aimag	-0.63	0.57	0.08
SEU	0.38	0.81	-0.30
move	0.66	0.25	0.32
NDVI	-0.70	0.50	0.29
education	0.39	0.23	0.78
vehicle	0.59	0.24	0.14
altitude	-0.68	0.34	0.19
livestock	0.28	0.84	-0.35

Taking the correlated factors for each variable a linear regression was run to see how well these variables explained key features (Table 7.13). The r^2 value represents

how well the survey data explains individual factors. The number of livestock (r^2 = 0.94) and Sheep Equivalency Units (r^2 = 0.80) had high r^2 values, indicating that the components listed were responsible for most of the category variance. In addition to the correlation of the two as different measures of the same variable, the significant measures for livestock were drying water sources (P = 0.01), livestock concentration at water point (P = 0.01) and number of moves (P = 0.05). For SEUs, which accounts for size of animal, a vehicle (P = 0.05), not having a land contract (P = 0.05), and distance to water (P = 0.07) were major explanatory factors. Differences between provinces (r^2 = 0.83) were also well described by the data though no single component was dominant with NDVI (P = 0.07) important but not significant.

Major factors for altitude (r^2 = 0.61) were a lack of surface water (P = 0.05), fewer moves (P = 0.05), no sand-related problems (P = 0.05), and higher NDVI values (P = 0.01). NDVI (r^2 = 0.51) had a dominant association with altitude (P = 0.05). Vehicle ownership (r^2 = 0.51) was negatively related to years herding (P = 0.05) and how people moved (P = 0.01). Education (r^2 = 0.43) was highly correlated with number of moves (P = 0.01) and fewer years of herding (P = 0.01). Number of moves (r^2 = 0.41) was significantly related to education (P = 0.01) and distance of moves (P = 0.05).

High r^2 values in the linear regression tables show the interview data does a strong job of explaining livestock numbers, SEUs, and province effect. The survey provides insight into major factors but other measurements are not as effectively defined by the collected data. Thus to better understand the characteristics that reflect lower r^2 values, such as education or number of moves, more information beyond the survey content is needed.

Table 7.13 Linear regression for major pastoral factors.

LIVESTOCK

$r^2 = 0.94$	Beta	significance
age	-0.010	0.83
distance moved	0.206	0.14
drying sources	0.642	0.00
families at water pt	-0.054	0.26
km moved	-0.153	0.27
land contract	0.000	1.00
livestock at water pt	0.200	0.00
move	0.085	0.05
privatization	-0.029	0.42
SEU	0.236	0.00
vehicle	-0.047	0.24

AIMAG

$r^2 = 0.83$	Beta	significance
children's future	-0.056	0.86
drying sources	-0.615	0.386
families at water pt	-0.297	0.579
herder life	-0.067	0.803
km moved	-0.449	0.105
livestock	0.489	0.485
livestock at water pt	0.285	0.565
move	-0.061	0.837
NDVI	0.700	0.068
sheep	0.808	0.266
territory	-0.091	0.674
water source	-0.443	0.349
yak-cow	-0.197	0.605

NDVI

$r^2 = 0.51$	Beta	significance
altitude	0.289	0.016
children's future	0.156	0.139
families at water pt	0.199	0.219
livestock at water pt	0.171	0.263
move	-0.137	0.214
territory	-0.116	0.251
vehicle	-0.013	0.904
water source	0.089	0.443

EDUCATION

$r^2 = 0.43$	Beta	significance
Age	0.107	0.294
distance moved	-0.102	0.343
land contract	-0.091	0.283
move	0.310	0.005
vehicle	-0.048	0.576
years herding	-0.586	0.00

SHEEP EQUIVALENCY UNIT

$r^2 = 0.80$	Beta	significance
distance moved	0.063	0.824
distance to water	0.151	0.072
drying sources	-0.042	0.857
km moved	-0.096	0.732
land contract	-0.187	0.022
livestock	0.753	0.002
move	-0.049	0.612
private	-0.007	0.929
vehicle	0.232	0.020

ALTITUDE

$r^2 = 0.61$	Beta	significance
water source	-0.229	0.018
families at water pt	0.225	0.068
livestock at water pt	0.199	0.076
move	-0.167	0.049
NDVI	0.403	0.000
sand	-0.180	0.024
territory	-0.153	0.062
vehicle	0.001	0.986

VEHICLE

$r^2 = 0.44$	Beta	significance
altitude	-0.204	0.162
distance moved	-0.201	0.584
drying sources	0.498	0.112
education	0.072	0.606
how move	-0.270	0.010
km moved	0.142	0.685
livestock	-0.379	0.250
move	0.196	0.141
NDVI	-0.143	0.391
NDVI 2006	-0.100	0.442
sand	-0.138	0.241
SEU	0.200	0.324
years herding	-0.257	0.049

MOVES

$r^2 = 0.41$	Beta	significance
altitude	-0.005	0.965
distance moved	0.604	0.037
education	0.254	0.005
km moved	-0.246	0.388
livestock	0.126	0.475
NDVI	-0.271	0.070
SEU	-0.063	0.711
vehicle	0.085	0.413
water source	-0.086	0.397

7.4.2 *Differentiation*

The analyzed information provides a general picture of pastoralism on the steppe; the data can be further broken down to draw out differences among herders. What may appear homogeneous from the outside becomes differentiated by key livelihood factors. Four variables were examined – Sheep Equivalent Units, age, education, and differences between provinces to better understand herding dynamics reflecting economic, demographic, and geographic pastoral inputs. Variables for selected categories were broken down into three groups comprised of the top, middle, and bottom 20% of the interviewee population. As not all respondents answered each question the percentage of respondent replies is given.

7.4.2.1 Sheep Equivalency Units (SEU)

"The rich can move, have transport, property, capital. The poor have many problems" (female, 38, Omnogovi). The crucial livelihood variable of SEU reflects clear separation between three groups. The bottom 20% has one-tenth the animal units of the top level and less than a third of the middle group (Table 7.14), with average age of this tier being 13 years greater than the other groups. Movement, education level, and vehicle ownership is lower and they are more apt to have a contract for land and identify food as their main expense. Despite this they are the most satisfied group, citing the herding life as "very good". The variables are ordered from high SEU's to low on several factors, such as number of moves, distance moved, education, vehicle ownership, and inversely for age, land contracts, pension, and dominance of food as the major expense. The top tier moved more often, migrated further, had higher education levels, and more vehicles yet were least positive on herding quality of life. This suggests that SEUs are a predictor of economic related

factors (income, vehicles), mobility, and livelihood concerns (land contracts, satisfaction).

7.4.2.2 Age

"Cannot take more livestock. It is too hard at our age" (female, 74, Omnogovi). Breakdown by age separates pastoral tendencies. Older herders, who began working during communism when few alternatives were available, had more positive livelihood views (satisfaction, recommend for children), had fewer livestock, moved less often and less distance, and averaged 4 years of schooling (Table 7.14). Pensions were their major income and half owned a vehicle. Younger herders identified pastoralism as their main work option, often expressing that they were unqualified for other jobs. This group overwhelmingly depended on cashmere for income, were most likely to have a vehicle, had greater livestock numbers, and had food and petrol as major expenses. Middle-aged herders moved the most and the furthest per year, were similarly educated as younger herders, and three quarters owned a vehicle. Cashmere was the dominant income source with education and food major expenses.

7.4.2.3 Education

"My children will get an education – they will not be herders!" (male, 43, Ovorhangai). Pastoralists with higher education levels had greater livestock numbers, undertook more annual moves, migrated longer distances, and had high vehicle ownership (86%), and land possession (72%) rates (Table 7.15). This group had herded fewer years, was less positive about the work than those with less schooling, and identified food and fodder as greater expenses than education. The least-educated group, of which a third had no schooling, was older, had herded much longer, and

was most content with the pastoral lifestyle. This classification relates to educational opportunity and motivations as the older group grew up during communism when basic schooling was stressed, whereas higher education options have increased since the transition to democracy. Cashmere was the main income source across schooling levels with pensions important in the most- and least-educated groups. Education was the major expense of the middle group yet third amongst highly educated herders, after food and fodder.

7.4.2.4 Province

Herder characteristics differed in the two provinces, with Ovorhangai pastoralists having on average 35% more livestock, particularly small stock, and 14% greater SEUs, perhaps due to higher precipitation and NDVI levels (Table 7.15). Expenses differed with petrol, then food, the most frequently cited main costs in Omnogovi, whereas food and education were dominant in Ovorhangai. Omnogovi herders moved more often and migrated greater distances, potentially reflecting the province's drier climate and limited water availability, particularly surface sources. Land possession rates and herder satisfaction were higher in Omnogovi. Results highlight differences by degree of latitude within the Gobi desert region.

Table 14. Differentiation between top, middle, and bottom 20% of herders by Sheep Equivalency Units and age.

		SHEEP EQUIVALENCY UNITS			*AGE*		
Variable (average)	All herders	Bottom 20	Middle 20	Top 20	Youngest 20	Middle 20	Oldest 20
SEU	410	92	316	948	452	398	366
livestock	271	86	201	584	296	293	181
age	50.8	59	46	45	29.6	50.6	73
moves	4	2	4	6	4	4.9	2.4
km moved	42	10	27	66	34	45	23
education (grade)	6	3	5	6	6	6	4
year herd	22	26	22	22	11	21	42
vehicle (%)	70	50	68	90	86	73	50
land contract (%)	50	70	50	32	54	54	45
herding life	good	very good	good	good-OK	good	good+	good++
child herd - yes (%)	10	18	0	15	6	7	33
main income (%)	68 - cashmere	59 - cashmere	59 - cashmere	68 - cashmere	95 - cashmere	80 - cashmere	59 - pension
income	19 - pension	27 - pension	23 - pension	14 - livestock	5 - wool	10 - livestock	32- cashmere
income	7 - livestock	9 - livestock	14 - wool	9 - wool	~	10 - other	9 - other
main expense (%)	34 - food	63 - food	41 - food	32 - petrol	47 - food	33 - education	45 - food
expense	26 - education	16 - fodder	14 - education	23 - education	42 - petrol	33 - food	25 - petrol
expense	23 - petrol	21 - education	14 - migrate	23 - food	11 - fodder	24 - petrol	10 - education
expense	11 - other	~	14 - petrol	23 - other	~	10 - fodder	10 - migration

Table 15. Differentiation between top, middle, and bottom 20% of herders by education and province.

		EDUCATION			PROVINCE	
Variable (average)	All herders	Bottom 20	Middle 20	Top 20	Omnogov	Ovorhangai
SEU	410	412	421	440	383	437
livestock	271	221	284	323	230	311
age	50.8	66	43.3	49	51.3	50.3
moves	4	3	2.8	5.8	5	3
km moved	42	38	29	60	51	33
education (grade)	6	2	6	some college	6	5
year herd	22	40	18	11	21	24
vehicle (%)	70	55	77	86	73	73
land contract (%)	50	41	32	72	60	43
herding life	good	good++	good+	good	good+	good-OK
child herd - yes (%)	10	22	6	6	9	13
main income (%)	68 - cashmere	45 - cashmere	86 - cashmere	55 - cashmere	68 - cashmere	67 - cashmere
income	19 - pension	45 - pension	14 - other	27 - pension	16 - pension	22 - pension
income	7 - livestock	9 - wool	~	19 - livestock	11 - wool	9 - livestock
main expense (%)	34 - food	41 - food	43 - education	35 - food	34 - petrol	45 - food
expense	26 - education	32 - petrol	43 - food	24 - fodder	28 - food	23 - education
expense	23 - petrol	14 - fodder	14 - petrol	18 - education	17 - education	13 - fodder
expense	11 - other	14 - other	~	18 - petrol	11 - fodder	13 - petrol

7.5 Discussion

Pastoralism today is not the homogeneous model of the collectivized era. Since 1990 Mongolian herders have reoriented themselves and their interactions with their livelihood and land. They act independently of one another, are motivated by economic factors, and do not see herding as a career choice for their children. Pastoralism is now a job based on income, replacing its former role of meeting basic needs. Livestock are the currency – to accomplish livelihood goals, herders make practical, economically-driven decisions about animal numbers and herd composition. Results from this study indicate that frequent moves and migration over extended distances are key factors in number of livestock and SEUs, both measurements of economic well-being. Secondly, findings document differentiation among herders along several dimensions, including SEUs, age, education, number of moves, province, and altitude, with herding motivations varying depending on age, education, and wealth. Major issues are economic and environmental sustainability, demographics, perspectives on livelihood viability/satisfaction, and the role of government. Unspoken were the over-arching structural issues that impact herders - product markets, transport, water availability, government role, and livelihood organization affecting well-being.

A theme that emerges from the interviews is that herding is practical work – herders want similar opportunities to other Mongolians, and if these are not available they may abandon this form of livelihood. Economic pressures determine much herder behaviour, with increased rural poverty rates reflecting the impact the market economy has had on herding (Sneath 2003). If pastoralism can provide a standard of living perceived as comparable with other facets of society then herding will be evaluated on its own terms. With conveniences and improvements over time herders

can focus on benefits – income, independence, and tradition. Then customary travails – climate, drought, and extreme winters can be moderated and the enduring strengths of herding may gain recognition. It is the more vulnerable herders that will struggle with physical threats. Human changes in land use, infrastructure, and mobility, motivated by livelihood concerns, reflect how decisions in today's market economy can impact tomorrow's pastoral resources.

Perceived economic pressure and personal motivation creates demand for higher income. Additional livestock will remain the only way to increase earnings unless there is a paradigm shift from present trends. Potential adaptations include improving livestock products (high quality cashmere, achieving international meat/milk standards), organizing marketing and distribution (infrastructure, delivery, promotion), making value-added goods (cheese, leather goods), and developing new markets (China, Japan, Korea). Without leadership from government or development agencies organized pastoral change is unlikely. Lacking advance planning, immediate livelihood needs and inclinations suggest herders will continue to react to changing economic and environmental conditions.

Declining water sources, pasture quality concerns, and herding practices can challenge grassland sustainability. Livestock intensification, mobility patterns, concentration at water points, and a shift to goats are potential sources of degradation that can impact livelihoods (Perkins and Thomas 1993; Thomas *et al.* 2000; Tumorjav 2003). These combine with climate change and bio-physical factors to affect pasture resources and productivity and long term sustainability, potentially impacting herders' future economic well-being. Essential to ensure adequate environmental conditions are maintainance of existing coping mechanisms, such as mobility patterns and seasonal grazing, evaluation of new parameters, such as forms

of land tenure, and addressing ongoing problems – drying water sources, broken well infrastructure.

Demographics will affect herding's future on the steppe. The average herder is 12 years over the national age level (average adult herder age – 51 years; adult population – 39 years) with the number of over 60-year-olds herding 5.5 times more than their percentage in the adult population. Families play an important role in shaping pastoralism as 91% of herders with school-aged children (62 families) stated they did not want their children to herd. Parents encourage education, noting improved job prospects with schooling. There is an idea that employment in a town is a more dependable income source than herding and requires less work and less risk. Settlements draw herders for perceived better income opportunities, with greater development, education, and health levels available in population centers. Particularly for youth there is a gravitation towards global lifestyle and cultural norms, such as electricity, mobile phones, internet usage, and vehicle ownership. Additionally, satisfaction was significantly related to age and years' herding ($P=0.05$), identifying a difference in perception of the quality of herding life between older and younger herders.

"Government has no role. If I tell them what they should do they would not do anything. No need to tell – they might put the money in their pocket" (male, 33, Ovorhangai). The role of government showed divergence between concepts and reality on the ground. Though it was clear that government played little role in pastoralism, herders still looked to it to solve larger problems, most notably water supply and assistance, as it did during the collective era, despite evidence to the contrary (Ynkhanbai *et al.* 2004). This perception highlights the lack of organization in the countryside and the need for better cooperation - *"if herders work together that*

is better, like in the Negdel (collective) time. It will be more profitable together" (male, 42, Omnogovi). The breakdown of collective pastoralism leaves individuals or small family groups responsible for creating livelihood opportunities. This limits the means and scope to raise livestock quality, develop product markets, or improve infrastructure. Implicit in the remark, *"government does not care for herders or wells"* (male, 57, Ovorhangai) is the question of the role of the state in rural areas - if citizens' needs are not being met is the government relevant?

Another part of the debate regards future pastoral policy and management. Implementation and changes to land laws, such as granting possession of winter camps, will affect the countryside (Fernandez-Gimenez and Batbuyan 2004). The increasing importance of mining as a revenue and tax source and foreign donor advice (Asian Development Bank 2005; Bolormaa *et al.* 2006) could alter state perspective towards rural policies, particularly on land privatization. This is regarded as "impossible in Mongolian conditions" by 96% of herders because of the implication of potential restrictions on herder movement in a non-equilibrium environment and the resulting tension and conflict that would ensue. Herders, despite their numbers, lack political influence since issues are decided by an emerging political class in the capital with development and personal agendas that differ from rural livelihoods. Awareness among herders of potential outcomes is reflected in the remark that, *"rich people will take a lot of land but poor people cannot"* (male, 70, Ovorhangai).

Pastoralism has changed greatly since the collective era ended in 1990. The combined factors of an aging herding population, the trend away from herding as a recommended livelihood, lower satisfaction among younger herders, and an evolving physical context questions pastoralism's future direction. Consideration of past

patterns and current realities provide a context to consider future possibilities on the steppe. Conceivable developments include small-scale herders losing viability and working for others, returning to a more subsistence-based approach, or increasing dependence on outside work. More mobile and successful herders may take advantage of less-used, extended pastures or build private wells to ensure personal water access. With increased forms of land tenure and possession (seasonal camps, wells, grazing areas) it is possible that settled and even fenced livestock raising may occur, loosely modelled on the Chinese approach in Inner Mongolia, or that ranches with absentee capital and owners employing labour will lead to large-scale herding. Another development could be that pastoralism dwindles to a niche profession practiced by dedicated individuals or those with limited alternatives. This would have social impact, affecting urban food supply and creating excess labour. Alternatively, herding could continue in the uncertain status quo or become a hybrid of the other scenarios, varying by region, ecosystem, and proximity to population centres. If this happens, today's concerns – economic and environmental - will continue to affect pastoralism. In whatever context herding takes place the ability to pursue a mobile, nomadic way of life will remain an essential condition for steppe sustainability (Wesche and Retzer 2005).

An example of future implications for pastoralism is the U.S. Government's $285 million Millennium Challenge Corporation assistance package to Mongolia that concentrates on rail transport, property rights, vocational education, and health care (U.S. State Department 2007). All are worthy aid targets yet that such a large sum chooses not to address pastoral livelihood issues, such as water, infrastructure, or economic development, affirms that the countryside is not viewed as a national priority and that herders will remain responsible for their livelihood concerns. Survey

results suggest pastoralism will continue to evolve at a rapid pace as issues such as degradation, water availability, pasture use patterns, herder differentiation, poverty, and mining impact will remain pastoral challenges in the future and are unlikely to be addressed at the household level. Current uncertainty about herding as an economic and job creation endeavour will persist.

7.6 Conclusion

"If weather is bad herding life is hard, difficult. If weather is good, with rain and sun, then herding life is very good" (male, 60, Omnogovi). Mongolian pastoralism continues to be an integral livelihood on the steppe after the political and socio-economic transitions after 1990. This is through the efforts of herders rather than institutions and is driven by income needs and a perceived lack of alternatives on the part of the herders. Previously weather conditions and livestock well-being dominated herding concerns. While these remain, water resources, pasture productivity and degradation, income generation, and livelihood expenses are now major pastoral concerns. As pastoralism continues to become a work rather than lifestyle choice the fewer needs and higher satisfaction of older herders are being replaced in young herders by the desire to incorporate modern amenities into the herding mainstream. The future direction of pastoralism depends on how herders are able to adapt to market structures and the role government policy and management may play in the future. This survey finds that the traditional approach of higher mobility over greater distances results in greater livestock numbers and wealth. Efforts that enable and encourage such customary practices will best serve the pastoral population.

Chapter VIII

Discussion

8.1 Introduction

The Mongolian steppe is part of the rapidly changing Inner Asian landscape. Natural and human forces, within and beyond country borders, influence the physical and social environment. Notable regional land cover change (Leper *et al.* 2005) is matched by socio-economic and political transition and livelihood development (Bilskie and Arnold 2002). In Mongolia knowledge of environmental processes lags behind system change, resulting in uncertainty about ecological conditions across a vast region and reliance on past data and under-researched conclusions for ecosystem evaluation. In evolving from a Soviet to market-oriented approach, Mongolia finds itself between two worlds: past certainties no longer apply yet present conditions are seldom defined. This factual void creates a singular opportunity that this thesis embraces by engaging with three key physical factors in the Gobi Desert – drought, *dzud*, and degradation - and examining the role of human impact on the land. The goal of this thesis has been to investigate how bio-physical factors and herder action determine the pastoral environment in the Gobi Desert, Mongolia.

The thesis presents primary scientific documentation of drought in the region, increasing environmental understanding that can directly benefit herders by quantifying a major pastoral hazard. Concurrently, findings contrast with local perceptions by de-coupling drought and *dzuds* (Shinoda *et al.* 2005). Investigating claims of degradation through measuring piosphere vegetation did not find effects of overgrazing (through reduced cover) in the immediate vicinity of water points, suggesting that bio-physical factors are important determinants of land cover in the

Gobi Desert. Examination of remote sensing data in conjunction with field observation shows ongoing landscape variability in a sparse environment, not a permanent loss of vegetation cover. Research of physical factors documents current processes, provides robust new ecosystem data, and shifts discussion of environmental issues beyond institutional reports (*e.g.* World Bank, United Nations) and commentary to evaluation based on scientific analysis. This process is encouraged by the translation into Mongolian and local publication of Chapter VII in the Mongolian journal *Geographical Problems* (Appendix A). Findings call for a re-evaluation of steppe understanding and may stimulate further research in the Gobi and promote application of research tools to other regions of Inner Asia.

Rather than using an ethnological approach that focuses on pastoralists, this research places herders in an environmental context to gain insight into their interaction with natural systems. The outcome is a broader understanding of pastoralists' perceptions of how ecological forces influence livelihoods and awareness of how herder decision-making and actions impact the landscape. Findings show that natural factors - water, precipitation, hazards - not socio-economic forces, are perceived as defining pastoralism. Results suggest that traditional practices, particularly mobility, remain effective livelihood strategies and that management and policy that enables water access, migration, and adaptability to changing physical and social dimensions can contribute to pastoral viability. Herder motivation, differentiation, livelihood development, and future direction become relevant concepts as human dynamics are examined in conjunction with, rather than in isolation from, bio-physical conditions.

Several significant themes emerge from the research. The first identifies physical aspects of the Gobi, measured through fieldwork that focused on dryland climate and

land cover parameters and assessment of human interaction with the environment. Second, the idea of resilience informs the social and physical aspects of the thesis. This is seen in the variable environmental conditions and the adaptive strategies of the pastoralists that coexist in the sparse landscape. Third, the thesis has established new data and provides analysis of environmental processes that question local preconceptions and at times contrasts with findings in other global dryland systems. This highlights that previous assertions may be inadequate to address steppe range conditions. Fourth, results recognize how evolving pastoral dynamics, human action, and reduced government role coupled with regional climate and land cover change create new challenges in the countryside. Ultimately, the task has been to distil a myriad of factors to derive the essence of the Gobi Desert environment from both physical and human perspectives. Examining environmental conditions on the Mongolian plateau enables comparison with northern China and expands pastoral debate to include Mongolia's cold desert dynamics within the global drylands context where research has commonly been concentrated in high temperature arid regions.

8.2 Degradation

Numerous reports link pastoralists, drylands, and degradation through bio-physical, socio-economic, and management contexts (Veron *et al.* 2006; Reynolds *et al.* 2007 Zhang 2007). Degradation and desertification are claimed to be widespread and increasing on the Mongolian plateau with determinations based on international or government reports and limited fieldwork (UNCCD 2006; World Bank 2004; UNEP 2002; Yang *et al.* 2005). A lack of adequate land cover research in Mongolia makes such claims problematic and stresses the urgent need for direct investigation. Policy and development initiatives link herding, overgrazing, and degradation; today the

issues have become conflated with differing perspectives rarely discussed. The critical but neglected process of establishing reliable data to assess degradation is a key part of this thesis. Piosphere and NDVI findings do not identify desertification in the Gobi Desert; they document a highly variable ecosystem. This contradicts limited prior research, questions current perceptions in the country, and invites further research on the topic (UNEP 2002; Li *et al.* 2006). The significance of results is that through field observation and analysis the thesis contributes new scientific data to the country's ongoing degradation debate.

Whereas in China multiple sources influence degradation (Chen and Tang 2004; Yang *et al.* 2005), in Mongolia overgrazing is identified as the primary cause of degradation (World Bank 2002; Lise *et al.* 2006). Measuring vegetation cover in piospheres around water points investigated degradation where potential livestock use and impact is high. Field observation established that piospheres are not "centres of degradation" as would be expected in a degraded pastoral environment. Instead, vegetation cover was greater at water points and decreased with distance from wells. This differs from the global norm that documents less vegetation near water points (Perkins and Thomas, 2003; Nangula and Oba, 2004; Adler and Hall, 2005; Todd 2006) and challenges the cited impact of overgrazing in Mongolia (Mearns 2004; Okayasu *et al.* 2007). First, results indicate that livestock concentration at water points does not cause lower plant cover in the immediate vicinity. Decreased cover with distance from water suggests that claims of degradation may not be the consequence of livestock grazing patterns. Causes of land cover change may include bio-physical and edaphic conditions, changing climate parameters, precipitation amount and seasonality as well as human and livestock use patterns. Results question the occurrence of high degradation levels and the role of overgrazing cited in

Mongolia. Second, the term desertification, signifying permanent negative land cover change, may be inappropriate as variability predominates in the Gobi. Survey NDVI data indicated highly variable inter-annual land cover patterns rather than continued yearly cover decline that would support the idea of desertification. Cover values by themselves do not equate to degradation – thus in the local context low vegetation cover alone does not signify a permanent loss of productivity. Additionally, vegetation cover below 20%, as established in the *in situ* survey, can affect the accuracy of satellite techniques (Pettorelli *et al.* 2005; Cao *et al.*, 2007). Thus prior reports based on remote sensing alone (Erdenetuya 2004; Bayarjargal *et al.* 2006) may inadequately measure vegetation and lack sufficient ground-truthing to determine land cover.

As climate and precipitation variability influence ecosystem functioning and resource availability, reflected by land cover, assessing degradation must consider long-term patterns as range productivity transitions. A degradative state may change as resource productivity increases or declines with precipitation. When human action irreversibly alters the land in Mongolia, for instance as a result of roads or mining (Okayasu 2007; Farrington 2005), degradation can be identified. However, the scope of this survey gives time-limited data; a case for desertification would require further investigation to assert that future changes in precipitation could not rehabilitate the land. Otherwise claims of desertification in Mongolia should be viewed with caution as the application and measurability of such a term is ambiguous.

Placing livestock in the degradation debate identifies the role of pastoralists in the environment, shifting the issue from physical factors to include socio-economic forces. Relevant are herding practices and mobility patterns, livelihood motivations, water availability and government support, issues that reflect herder interaction with

the land. Piosphere findings suggest that customary adaptive strategies, particularly migration, can limit human and livestock ecological impact, a result that exemplifies herders' paramount concern with environmental factors (Fernandez-Gimenez 2000). While herding has evolved considerably since the transition to the market economy, findings imply that in the Gobi Desert herder action has not notably degraded the land despite pastoralism being cited as ecologically detrimental at the national level (UNCCD 2006). This point is reinforced when examining the Chinese portion of the plateau where different land use patterns are documented as contributing to higher degradation rates than in Mongolia (Sneath 1998; Chen and Tang 2005; Yang *et al.* 2005).

8.3 Drought

In dryland regions drought can have a major impact on the environment and human livelihoods (Hughes *et al.* 1999; Sonmez *et al.* 2005; Wu *et al.* 2007). Widely studied in other arid zones, drought has received little investigation in Inner Asia, making it a poorly understood phenomena on the Mongolian plateau. Quantifying drought in the Gobi Desert identified its endemic nature, variegated severity, and its occurance at multiple timescales. Developing knowledge about a recurring natural hazard is integral to understanding the steppe environment and grounds local observation in empirical facts.

The key concept is that in a selected location there is systemic variability, thus lack of precipitation relative to a site's normalized distribution creates anomalies that, when negative, cause periods of meteorological drought. Findings develop an historical record of drought from 1970-2006, establishing drought parameters on the steppe and the iterative nature of the phenomenon. This is important for

comprehension of ecosystem dynamics and highlights how awareness of negative rainfall anomalies can inform broader environmental concerns. It provides a perspective on degradation, enabling associations to be made between dry climate conditions and perceived land cover change. Drought events impact forage; thus multi-scale drought identification can provide perspective on pasture resources in relation to normal ecosystem states.

The social importance of drought identification is to provide pastoralists with information on grassland conditions and improve range management. Knowledge of drought status can inform herder migration, livestock practices, and decision-making. Second, the research clarifies the presumed link between drought and *dzud,* documenting a lack of a causal relationship between the two hazards in Omnogovi (Batima *et al.* 2005). This contradicts government and development agency assumptions about the role of drought in the countryside (Asian Development Bank 2005). It encourages separating *dzud* from drought when addressing the impacts of extreme winter. The two hazards are endemic; mitigation efforts require social (emergency relief, coping strategies) as well as physical attention. Further, research findings suggest that the *dzud* of 1999-2001 was not concurrent with drought. Thus other factors – changing climate patterns or human roles - may have contributed to the episode's severity and need to be considered when examining *dzud.* Effective identification, as presented in this thesis, and dissemination of drought data can benefit livelihoods and encourage similar research in differing climatic and geographical zones of Mongolia.

8.4 Significance of Water

Though water was not a focus of this thesis its absence became a defining feature in the Gobi Desert. The multiple manifestations of water include precipitation, surface water, wells, pasture growth, competition for access and limited availability to the impact of snow and ice in creating *dzud* conditions. Its dominance cannot be overstated as water is the organizing point in a pastoral system and characterizes the physical environment. Acknowledgement of its scarcity anchored the research into the Gobi landscape.

For pastoralists water is the crucial factor as it limits or enables their livelihood (Scoones and Graham 1994). Necessity locates camps near water sources, concentration finds livestock and herders at functioning water points, migration centres on adequate pasture in areas with water access. Ongoing reduction in surface and underground water points since transition from a communist development model to a market-oriented approach (Tanaka *et al.* 2005) coupled with an increase in livestock numbers has had and will continue to have several impacts on herders. These include intensification of livestock raising, competition for resources, and implication for mobility in a region that has not been able to maintain or expand water resources. As the key pastoral determinant water access and rights will be critical in the future. The outcome of any changes in land tenure, particularly privatization, and land use, such as mining, may alter or restrict water availability. On the steppe precipitation variability constrains herder interaction with the environment, determines pastoral resources, influences livestock viability and weight gain, migration patterns, and ultimately income and livelihood success.

A broader concern about water relates to the impact of climate change in the Gobi Desert where little topical assessment has taken place. Noted are greater inter-annual

precipitation variability, increasing temperatures, and shifting permafrost zones in the country (Nanditsetseg *et al.* 2007; Batima *et al.*, 2005). How such changes may influence the water resources and environment is unclear. Pastoral productivity and viability will continue to be uncertain as precipitation patterns, seasonality, temperature, forage growth, and natural hazards, and vary over time.

8.5 Resilience

Rangelands have been characterized as complex adaptive systems that can experience disturbance, such as grazing or drought, yet are able maintain functioning due to the flexibility of biophysical and human systems that enable continued range productivity (Walker and Abel 2002). The concept of resilience is applicable to several of the key research findings of this project because it addresses how a pastoral system copes with variability to operate within stable state (Walker 2004; Folke 2007). Results suggest fluctuating pasture conditions, variable climate patterns, and repeated drought events occur without significantly altering the physical landscape. Human resilience enables shifting herding forces and livestock numbers to be encompassed. Both physical and human systems adjust to often serious perturbations (drought, *dzud*, political and economic change) on the steppe, a process that allows the environment to maintain sufficient productivity in its dryland setting for pastoralism to continue as a viable livelihood.

The Gobi Desert's sparse ecosystem, while subject to climate and human influences, varies over time within a sustainable range. Drought and *dzud* episodes recur, precipitation is erratic, cover is variable, and land use patterns change yet the pastoral system continues to funciton as the ecosystem copes with perturbation (Johnson *et al.* 2006). Data from the piosphere study indicate pasture durability near water points

rather than a loss of productivity. Equally, changing precipitation patterns, warming temperature, and reduced water points have not significantly differentiated the environment. On the steppe continued land cover variability represents fluctuation rather than a move to an altered state.

The nature of pastoral livelihood strategies emphasizes efficient use of limited physical resources and systemic resilience as pastoralism adapts to the country's transitioning socio-economic conditions. Today herders incorporate economic pressures, evolving social perspectives, and a loss of government support with traditional mobility patterns, water access, and herd composition decisions that accommodate existing resources. Whereas a rigid system would have limited coping abilities, pastoralists' flexible livelihood approach maintains productivity in a fluid environment and a range of volatile conditions. Socio-economic processes include a shift to goats for income generation, adjustment to a lack of infrastructure or emergency fodder through personal adaptation and expense, a move away from herding as a career choice, greater herder differentiation, and increased expenses. Concurrently natural and human-influenced perturbations abound in pastoralism (Suttie 2005). Identified vegetation cover fluctuation, drought episodes, and drying surface water sources combine with reduced wells and increased livestock numbers to affect the grassland. Despite these challenges, the countryside has seen the expansion of herds and the continued dependence of a large percentage of the population on pastoralism as herders adjust livelihoods to maintain viability (Johnson *et al.* 2006).

The concept of resilience, "bending but not breaking", is relevant in the Gobi as variable conditions are prevalent yet not disruptive in the environment (Walker and Abel 2002). This contrasts with vulnerability which identifies a system as reactive and having limited ability to cope with perturbations. The study did not find that

herding practices caused lasting degradation in a sparse environment, nor that physical factors threatened livelihoods. Findings suggests that natural and learned resilience is a pastoral strength in Mongolia.

Research on resilience in other dryland regions highlights the importance of maintaining ecological balance for landscape viability and pastoral coping skills, such as when dealing with drought (Reed and Dougill 2002; Sorbo 2003). Most rangeland regions are identified as undergoing rapid change with each rangeland facing localized physical and institutional conditions (Walker and Abel 2002). How Mongolia adapts to disturbance and reorganization will depend on forces (*e.g.* economics, precipitation) that shape the environment and policy that enables herding to be practiced at adequate spatial and temporal scales to maintain viability. Plummer and Armitage's (2007) assertion that resilience encompasses ecology, economics, and society are particularly relevant to findings in Mongolia.

8. 6 Steppe Sustainability

Resilience is an essential concept for addressing sustainability, the science that integrates research across disciplines to address key problems to provide a framework for sustainability (Clark 2007). One tenet is that natural capital (ecosystems, water) is critical for human well-being and that while system fluctuation can be episodic and unpredictable, human-nature interaction is dependent on ecosystem resilience (Gunderson and Hollings 2002; Brand 2009). As sustainability involves multiple disciplines it can also go beyond academia to engage with societal problems. This is important as single disciplines cannot fully capture and address a complex, dynamic world (Robinson 2007; Folke 2007). Though relatively uncommon (Cowling *et al.* 2008), this thesis used interdisciplinary research to increase knowledge of

environmental processes with results enhancing understanding of steppe sustainability.

In choosing an issue-driven research agenda this study addresses the functioning of human and natural systems in the Gobi across temporal and spatial scales (Gunderson and Hollings 2002). This approach contributes to ecological and social knowledge of the steppe while also informing academia through articles about evolving processes. In examining the Gobi pastoral environment this study is aligned with Clark's (2007, p.1737) 'use-inspired basic research' concept and Turner *et al.*'s (2007) call for coupled human-environment research relevant to environmental and societal problems that notes the lack of attention bio-physical factors have received. Insight on drought, mobility, and piosphere impact serves different research fields as well as being relevant to local and scientific communities.

Observations on resilience (section 8.5 above) segue into evaluating sustainability (Brand 2009). Exhibited resilience in the steppe pasture systems can be regarded as an important part of sustainability; Maler (2008) states that resilience and sustainable development share a single conceptual framework. The Gobi region exemplifies this cohesion as findings suggest the pastoral environment can continue to be productive. Challenges such as water access and economic pressures affect both sustainable development and future systemic resilience. In Walker and Abel's (2002) four stages of range development Mongolia is at the initial, extensive phase of livestock movement with low human and livestock density, self reliance, and strong ecological-household linkage. At this level the steppe shows sustainability; evolution beyond current range dynamics will call for new evaluation.

Prior work on sustainability in Mongolia highlighted uncertainty about the impact of policy, institutional support, and socio-economic pressures in the countryside.

Scientists stressed continued mobility, management flexibility, and communal rangeland use as key strategies as well as the need for herders to be involved with range management and regulation through a participatory process (Fratkin and Mearns 2003; Sayre and Fernandez-Gimenez 2003). Ojima and Chuluun (2008) identified ecologically-based land use, including redrawing administrative boundaries for better resource access, investment in infrastructure, building more wells to facilitate mobility and pasture access, and improved services as essential. Further, strengthening grazing regulation, related services, and economic viability are essential for sustainable rangeland use (Johnson *et al.* 2006).

Since political transition sustainability issues on the steppe have been consistent. Study findings broadly concur with prior research but go a step further to emphasize the coupling of human and environment systems in the Gobi and stress the intersection of the two (Turner *et al.* 2007). Further, strengthening customary management and encouraging cooperation among herders can support livelihoods and potentially ameliorate grassland conditions (Himmelsbach 2008). In the pastoral mosaic issues are clear; improvement remains the challenge.

Recognizing Mongolian herders have local environmental knowledge is essential for pasture management (Fernandez-Gimenez 2000; Reynolds *et al.* 2007). Developing sustainable resource management and collaborative efforts would benefit from herder involvement as stakeholders in evaluating rangeland conditions and improving management to limit ecological change and mitigate livelihood challenges as has occurred in other drylands (Reed and Dougill 2002). However, weak governance, low population and thus lack of competition from other sectors of the society reduces external interactions with pastoralists and limits outside concern about pasture resources, reflected in the herders' belief that government does not

support herding. In this study herder participation began in the pilot study (Chapter II) that set the research agenda by indentifying herding concerns as being interaction with the physical environment. This provided the focus for ensuing chapters, including refining pastoralists' engagement with water, pasture, and mobility. Ongoing pastoralist interaction with research, including further study, would capitalize on herder expertise and bring the community perspective into a discussion of the changing environment.

The global debate on sustainability often stresses the role of ecosystem services - resources and benefits received from natural ecosystems, including management and socio-economic valuation (Carpenter and Folke 2006, Cowling *et al.* 2008). Mongolia is not well-integrated into this discussion as pastoralists have limited interaction with government or other potential land users, such as farmers, that exist in other rural regions. Similarly, global ideas of co-management, while desirable, lack applicability when pastoralists do not identify other interested parties to engage with (Plummer and Armitage 2007; Cowling *et al.* 2008). As Mongolia's pastoral evolution continues it can over time be informed by knowledge and processes emerging from other dryland regions.

8.7 Pastoralist-Environment Dynamics

Herders define challenges in environmental rather than socio-economic terms with government action and economic forces viewed as secondary to ecological conditions. Water and pasture resources are dominant concerns and break down into water availability and access, precipitation, and forage quality and quantity. This outlook frames pastoralists' interaction with the grassland and drives decision-making to maximize limited resources through adaptive livelihood strategies, particularly

mobility. Findings identified how high migration rates correlate with higher livestock numbers, a measure of wealth, and reflected how mobility provides forage for livestock and limits intensification and potential degradation at piospheres. Management at multiple levels becomes a test of how practices that contribute to pasture sustainability can be maintained when transport, expenses, and pasture with adequate water are problematic.

Piosphere research suggests that enabling customary practices remains essential on the steppe. These include open water sources, mobility, and herder determination of livestock management and composition. Development that promotes migration and improves access to water points can contribute to pastoral viability. An important corollary is that actions that restrict established coping strategies may inhibit livelihoods. This identifies fencing, land privatization, lack of transport, and reduced water sources as potentially detrimental to herder well-being.

Pastoralist efforts to optimize productivity for economic reasons take place within environmental constraints. Herders choose livestock that provide the highest financial return and identify mobility as a way to deal with natural ecosystem limitations. Such interaction frames decision-making as income and costs compete, and often contrast, with low-impact sustainable use of grasslands. The lack of government participation in pastoralism leaves herders responsible to resolve or engage with environmental challenges. The limited state role questions why herders, through political rights (voting), do not pressure the government to engage with rural livelihoods. Additionally, pastoralists are now differentiated along several axes. The former collective approach limited the range of possibilities; now herders naturally separate along multiple tracks with livestock (wealth), age, and education clear divisions. An example is that personal motivation differs between a practical, work-

based orientation of younger herders to a more quality of life, subsistence approach taken by older herders on pensions. Results identify how livelihood motivation and expenses, access to transport, and distribution of water points also influence herder action. While pastoral factors are consistent, how the herder engages with climate and land, expenses, and motivations are determined personally.

8.8 Research Implications

As in other dryland pastoral regions, bio-physical factors determine livelihood viability on the steppe to a significant extent. However, unlike much of Africa, the Middle East, and neighbouring China, herding on the Mongolian steppe does not face contemporary external constraints, such as agricultural or population pressures, conflict, ethnic issues, or socio-political models that may impact ecosystem or livelihood viability (Fratkin and Mearns 2003; Nori *et al.*, 2008; Lesogorol 2006; Zhang *et al.* 2007). The traditional dominant role of pastoralism and continued high percentage of the population engaged in herding create a distinctive pastoral dynamic in Mongolia (Havstad *et al.* 2008). Open communal land, low population density, and strong traditions foster pastoral continuity in a region with few rural livelihood alternatives and limited formal sector work in cities. This places the country in a position to determine interaction between the herder and the environment with responsibility delegated to the citizens, society, and government.

National discussion on pastoral management and future directions can be informed by examining herding processes in an international context. Policy approaches to mobility and land regulation, the effect of infrastructure development, particularly wells, on the environment and livelihoods, and review of economic programs are critical issues in Mongolia that can gain insight from experience from other drylands

(Fernandez-Gimenez and Swift 2003; Mortimore 2005). Relevant topics include lack of information on herding knowledge and practices elsewhere, little capital and technical expertise, weak breeding and livestock standards, poor market development, and inferior transportation networks. Important questions Mongolia will face - privatization, fencing, rural support, settlement, and economic development have been examined at multiple scales. As pastoralism evolves societal forces can evaluate possibilities and develop a model that suits the country's particular conditions and conventions.

In a global context Mongolian pastoral concerns may be relatively less daunting than what those faced by herders in other countries and environments. Agriculture, population pressure, civil conflict, and political spheres do not impact pastoralism in Mongolia (Okoruwa *et al.* 1996; Jiang 2004; Meier *et al.* 2007). Issues focus directly on livelihoods, not impediments to livelihoods. Awareness of this position and clearer government goals for countryside development can frame the suitability of domestic and international efforts to benefit local pastoralism. Development will be most effective if pastoralists are part of a participatory process that stresses the role of current practitioners and their perceived goals and needs in today's setting (Reed and Dougill 2002). This can allow pastoralism to reach a semblance of stability rather than exist in flux or an externally created state, such as during communism, that may not have long-term sustainability. While multiple pastoral challenges have been discussed here, less reviewed are positive factors that favour Mongolian herding. These include political participation and a constitutional framework that buttresses pastoralism (Bilskie and Arnold 2002), openness to personal initiative and new inputs and management approaches, freedom of movement, low population density, access

to goods and information, and potentially, the lack of government participation, thus interference, in livelihoods.

Globally, China offers the most salient comparison as a common pastoral history shifts to settled livestock raising across the border, exemplifying how political and economic systems can impact pastoralism in a shared landscape. China represents an alternate range model potentially familiar to Mongolians, one that involves a marked change from open grazing to fenced enclosures and intensified practices (Chen and Tang 2005). It also identifies potential implications for ecosystem sustainability and livelihood well-being as dynamics focus on economic production in a well organized, government controlled pastoral system integrated into a larger society. Particular attention is given to poor management practices and high desertification rates in northern China that question the viability of this approach on the steppe (Sneath 1998; Liu *et al.* 2005*a*; Normile 2007). Though similar political and economic organization is unlikely to be duplicated in Mongolia's weak governance system, it points to existing forms of livestock development on the Mongolian plateau that may come to Mongolia in a modified form.

Research in northern China identifies several causes of recent land cover change. These include inappropriate land use, over-cultivation in marginal areas, irrational water use, climate change, resource exploitation, population pressure, property rights/fencing, and loss of traditional management strategies (Lee and Zhang 2005; Ma *et al.* 2007; Jun Li *et al.* 2007; Wang *et al.* 2008). Several factors (water, mining, land tenure, customary practices) are relevant; examination of the Chinese paradigm can inform discussion and action in Mongolia. By studying its neighbour's land use patterns and basing decisions on steppe conditions and bio-physical parameters the country can limit the need for future ecological restoration that is ongoing in China

(Zha and Gao 1997; Liu *et al.* 2005*b*). Chinese researchers have concluded that, "Mongolian nomadic culture has advantages over agrarian culture in ecology and environmental care, sustainable utilization of grasslands, and in sustainable human social economic development in the region" (Zhang *et al.* 2007, p. 19). This suggests that a combination of existing pastoral strengths with modern knowledge and skills can maintain ecological viability and socio-economic well-being in Mongolia.

A second regional point of comparison in Central Asia are the former Soviet states of Kazakhstan and Kyrgyzstan that share pastoral traditions, extreme winters, and Soviet legacy. In the decade after independence in 1991 both countries saw a dramatic fall in sheep numbers, from 33 million to less than 10 million in Kazakhstan and from 9 million to 3 million in Kyrgyzstan (FAO 2000), whereas numbers increased in Mongolia. This highlights the difficulties of transition from a collective to a market-oriented system with private livestock. Kerven (2003) states that decades of collectivization (>50 years) and greater dependence on external support, particularly imported livestock feed, led to a loss of adaptability in parts of Central Asia. Additionally, long-term overgrazing, an increase in farming, and the breakdown of transhumanance are cited as negative impacts on pastoralism (Ellis and Lee 2003). In contrast, Mongolia's low animal concentration during communism, shorter period of collectivization (~30 years), and continued dependence on outdoor pastures in winter made herding more resilient and reduced the shock of transition. These comparisons point to the regional exceptionality of Mongolian pastoralism that through strong tradition, perseverance, and perhaps lack of alternatives has managed to maintain an effective method of herding in a difficult environment. This signifies the value of customary practices and the potential for pastoralism's continued sustainability if resilient features are able to continue and evolve. Issues at hand – the

need for water sources, economic viability – should be considered within the larger herding and livelihood framework.

Further afield, Mongolia is removed from pastoral parallels in Africa and the Middle East by location, ecosystem, and social conditions. This limits exchange of ideas and advances; only projects with an international scope can bridge distances to bring new concepts and programmes to the steppe. Research highlights domestic processes and finds that pastoralism in the Gobi Desert stands apart from norms of competition and degradation patterns in other dryland regions. Thus widespread pastoral change (for better or worse) will be internally driven. Results suggest levels of desertification and environmental change are lower than previously cited and that social and political constraints are limited in Mongolia. As pastoralism evolves in the country the future will depend on herder motivation and action, including engagement with the environment and expression of needs and demands through participation in the political process. Unlike in Africa, it will not be agriculturalists, expanding populations, ethnic tensions, or external forces but a conscious process of decision-making at the individual, local, and national level that will determine pastoralism's direction in the Gobi Desert.

Chapter IX

Conclusions

9.1 Conclusion

This thesis examined how bio-physical factors and human action determined the pastoral environment in the Gobi Desert, Mongolia. The objectives were to investigate drought, degradation, and *dzud* and to survey piosphere degradation and vegetation dynamics. It then aimed to analyze of pastoralists' interaction with their environment, particularly relating to water, pasture, mobility in Omnogovi and Ovorhangai Provinces. The work consisted of six chapters, each of which was an article that has been submitted to a relevant academic journal.

The research provided a critical introduction to the Gobi Desert environment that emphasized the interplay between bio-physical and social worlds. Through investigation of local conditions the thesis presented topical issues to the broader academic community about forces shaping the local geography and gave a counterpoint to ecological and development conditions across the border in China. Because of the relative isolation of Mongolia from the research mainstream and limited access to scientific efforts (conducted in Russian) prior to 1990, pastoral parameters are commonly defined by government and international development agency assessments rather than academic endeavour. Due to a lack of investigation distinctive aspects of the Mongolian steppe are seldom considered within global dryland research.

This thesis used a research approach where physical and social data were complimentary in order to evaluate pastoral conditions as a unified whole rather than

in separated parts. On the steppe human engagement with ecological systems takes place in a dryland environment where conditions represent endemic natural and livelihood challenges. Investigation of human and physical factors that define the Gobi Desert environment is the critical contribution of this thesis.

Work on regional drought is long overdue and key to understanding processes that influence summer grassland productivity and extreme winter *dzuds*. Drought was documented as a natural hazard that impacts herders, exemplifying how physical and human realms interact. Additionally, the drought record established an ongoing hazard with severity and duration more salient factors than frequency. Understanding of herding livelihoods showed how drought impact can increase when adaptive strategies may no longer be employed because of structural (regulation, privatization), physical (limited water availability, forage), or social (poverty, lack of transport) factors. While results established a drought chronology, the data also demonstrated how changes to pastoral practices (lack of *dzud* relief, limited mobility) can be an impediment to herder well-being, in this case when the effects of drought, such as reduced forage resources, negatively affect livestock.

Degradation is a topical issue, often cited by herders and the government (UNCCD 2006), yet closer examination was needed to go beyond vegetation cover to determine potential causes, from climate change to overgrazing and poor management. Several articles have used different methodologies and levels of comprehensiveness to identify negative land cover rates in the region (Yang *et al.* 2004; Liu *et al.* 2005*a*; Javzandulam 2005; Okayasu *et al.* 2007). The study took a broad assertion – 70% of Mongolia is desertified (UNEP 2002) – and examined it *in situ*, using field observation and NDVI data to monitor land cover change. Though straightforward conceptually, it is vital to investigate and communicate research findings to broaden

the national debate beyond the dominant 'steppe desertification' perception. Equally, understanding herding approaches and agendas clarified interaction at water points, migration choices, and perceptions of pasture productivity and resource use, enabling discussion of pastoralists' role in the Gobi environment.

Piosphere water points did not show lower productivity than the surrounding terrain as cover decreased with distance from water points, indicating processes in the immediate source vicinity were not reducing vegetation. This implied that overgrazing – livestock use beyond capacity – did not occur and suggests that bio-physical conditions had a major impact on vegetation cover. This was an unusual finding compared to pastoral regions in other drylands and stressed the contribution of fieldwork in less-studied environments to a global discussion of pastoralism. The difference may point to the impact of a continental climate regime, unproductive soils, limitations in water availability, and precipitation timing and distribution in Mongolia that influence the regional ecosytem. Additionally, in this region of low vegetation cover (<20% plant density), the natural interaction between herders and the land, number of animals, herd composition, mobility, and water point use patterns may, through long experience, operate within the steppe's functional range. Study results suggested that since the transition from a Soviet to market-oriented development approach herders in the Gobi have been able to pursue livelihood goals in a manner that is not detrimental to the rangeland. As new elements are introduced, such as land tenure, economic forces, or increased regulation, further evaluation will be essential.

The well-established concept of increasing degradation, poor herder management, and livestock intensification (World Bank 2002) is not borne out in study findings. Given limited infrastructure (*e.g.* water sources) pastoralists used available resources in a manner that, while perhaps not ideal (competition for pasture and water), was not

documented as irreparably damaging range productivity. Degradation concerns may be more positively addressed through identifying basic inputs that contribute to a flexible pastoral system. This centres on adequate water points in productive pasture areas, or the corollary of fewer livestock - perhaps of greater value - where vegetation cover is limited. While livelihood motivations and customary herding practices may limit detrimental pasture use, a stronger approach would be to develop, publicly or privately, adequate water points that enable flexible pastoral strategies. Such an effort can increase productive pasture and reduce livestock concentration at functioning water points. Herders need to acknowledge present realities and responsibilities and limit expectations of government, deciding individually or locally how to address water shortage or limited pasture access.

This research confirmed that bringing methodologies from other drylands can be effectively employed in new regions (Dougill *et al.* 1999). Results assessed potential degradation in Ovorhangai and Omnogovi Provinces with methods that can be implemented in other parts of the country as well as in northern China and other Central Asian pasture lands in Kazakhstan and Kyrgyzstan. This can expand knowledge of dryland process, in this case adding study data from a cold, northern pastoral landscape. Improved utilization of global research approaches can further highlight environmental processes in a region that this study suggests may diverge from standard arid and semi-arid zone findings.

9.2 Future Direction

The Gobi Desert is a vast region where environmental processes and human-physical interactions are rarely studied, resulting in a lack of research, analysis, and dissemination of findings to the global dryland community. Recent physical and

social transitions create new pastoral dynamics that are seldom documented. By addressing key regional issues of drought, *dzud*, and degradation and assessing herder engagement with the steppe landscape my thesis highlighted forces shaping the pastoral environment. Expanding the theme of pastoral identification and evaluation can be continued in future research.

Research increases knowledge of physical processes present on the Mongolian plateau, how they can affect pastoralists, and how human action may impact the landscape. As rapid land cover change continues in Inner Asia documentation of trans-national events, natural hazards, and land cover change contributes to regional understanding. The importance of findings is in identifying ecological processes where previous documentation has been lacking. The survey covered two provinces; techniques employed can be replicated in other geographical and ecological regions nationally and internationally to identify conditions, seek explanation of observed patterns, and strengthen knowledge of the plateau ecosystem.

Much research in Mongolia has been dependent on international efforts and funding. Though relevant public and university departments exist, an organized, attainable research program on the environment could be implemented to address drought and degradation on the steppe, improve understanding of *dzud,* and clarify management and policy roles. Such efforts play to Mongolian strengths – a desire for education, improving capacity, a growing international perspective among younger members of society, and a reasonably open and democratic government system, factors that encourage and recognize the practical benefits of research. Efforts can include national and provincial government staff, particularly in the Ministry of Nature and the Environment, the Institute of Geography, and university departments of

Geography and Remote Sensing that can provide the skills and training for significant research.

Mongolia needs a broader outlook to better understand its position in the pastoral world, acknowledge its relative strengths and weaknesses, and to fairly evaluate environmental processes, livestock-raising, and related development issues. Currently China is viewed negatively for political and historical reasons and as not relevant to the country. A more constructive assessment would acknowledge its relative advancement and examine northern China's development arc and resultant environmental challenges and pastoral impacts. In a similar landscape China's experience – mistakes and successes – can be instructive to Mongolia's nascent development. This would clarify the impact of current livestock-raising techniques including the effect of fencing, *de facto* privatization, animal quality and intensification, over-extraction of groundwater, government support, improved infrastructure, economic organization and the resulting pastoral environment.

Rather than instinctively discrediting efforts, Mongolia could more rationally evaluate Chinese programs to determine factors contributing to sustainable pastoralism and differentiate between herding and settled livestock-raising. This can assess causes and effects of degradation on the plateau, consequences when mobility is restricted or eliminated, and livelihood viability. More positively, this can highlight the potential benefits of economic planning, infrastructure development, livelihood support, and access to markets.

These issues point to how a developing country can engage with a larger world and benefit from knowledge and experience of others nations in similar circumstances. Research, particularly by Mongolians, that bridges distances and histories can be of great benefit to the country by encouraging approaches that have been successful

elsewhere, maximizing rural investment, and avoiding failed programmes, with China as the obvious starting point despite cultural barriers. Relevant endeavours abound, such as livestock fencing in Botswana, irrational international development in Timbuktu, Mali, the cost of water and fodder delivery in the Middle East, productive local dryland management in West Africa, and the nature of third world land privatization that seldom renders an equitable result (Perkins 1996; Williams 2002; Gardner 2005; Mortimore 2005).

When deciding how to expend a small national budget, the government can look beyond the current rural-urban divide to more accurately judge the economic and social benefit of pastoralism and the implications of herding out-migration. In urban centres this includes a lack of employment opportunity, increased costs for services and education, and resultant housing and social challenges. A nuanced perspective might conclude that investment for rural livelihood improvements – additional hand wells, support for solar panels or mobile phones, improved emergency relief for *dzuds,* may be more efficient expenditures than coping with increased urban pressures and related costs. Further, this recognizes development challenges in a weak state and may encourage traditional Mongolian strengths and engender societal stability as herding provides a high percentage of national employment and serves as a social safety net when livelihood options are limited or in crisis; as occurred in the 1990's (Fratkin and Mearns 2003).

Study results suggest pastoralism faces an uncertain future. To create viability over vulnerability will take simple solutions – greater expectations are unreasonable. Research that informs this paradigm, contributes to livelihood improvement, encourages sustainable environmental use will be most relevant to herders.

This project was framed by the dryland environment and pastoral lives, moving research beyond data and details to understand the interaction of landscape and livelihood. Examining pastoral trajectories suggests the variable environment has not crossed a threshold into permanent decline, nor that social conditions have become part of an inexorable process that herders must accommodate new realities by reorientation and settlement. Research findings identified a sparse landscape that does not exhibit desertification, where minimal support for water development, opportunity for mobility, and continued use of adaptive strategies may maintain pastoralism. Expanding this knowledge both locally and nationally will be the lasting contribution of this D.Phil research.

References

Adiyasuren, T. 1998. *Environment and development issues in Mongolia.* Ministry of Nature and Environment, Ulaan Baatar.

Adger, W. 2006. Vulnerability. *Global Environmental Change.* 16: 268-281.

Adler, P., Hall, S. 2005. The development of forage production and utilization gradients around livestock watering points. *Landscape Ecology.* 20:319–333.

Akata, N., Hasegawa, H., Kawabata, H., Chikuchi, Y., Sato, T., Ohtsuka, Y., Kondo,K., Hisamatsu, S. 2007. Deposition of 137Cs in Rokkasho, Japan and its relation to Asian dust. *Journal of Environmental Radioactivity.* 95: 1-9.

Akiner, S. 1998. *Sustainable Development in Central Asia.* St Martin's Press, N.Y.

Al-Eisa., A. 1998. Changes in factors affecting Bedouin movement for grazing. In: Squires, V. and Sidahmed, A. (eds), *Drylands: sustainable use of rangelands into the twenty-first Century.* IFAD Series: Technical Reports, Rome, pp. 369-373.

Allen, T., Warren, A. (eds), 1993. *Deserts: the Encroaching Wilderness.* Mitchell-Beazley, London.

Andrew, M. 1988. Grazing impact in relation to livestock watering points. *Trends in Ecology & Evolution.* 3: 336-339.

Asian Development Bank. 2004. *Mongolia: country environmental analysis.* Manila.

Asian Development Bank. 2005. *Mongolia: country environmental analysis.* Manila.

Baasandorj, Y. 2008. Present status of desertification in Mongolia. *Nomadic IISNC.* 76: 5.

Banks, T. 2001. Property rights and the environment in pastoral China: evidence from the field. *Development and Change.* 32: 717-740.

Barfield, T. 1993. *The Nomadic Alternative.* Prentice Hall, New Jersey.

Batima, P., Dagvadorj, O. 2000. Climate change and its impacts in Mongolia. National Agency for Meteorology, Hydrology and Environmental Monitoring. Ulaan Bataar.

Batima, P., Natsagdorj, L. Batnasan, N. 2008. Climate change, vulnerability and adaptation in livestock sector of Mongolia. In: Leary, N., Conde, C., Kulkani, J., Nyong, A. and Pulhin, J. (eds), *Climate Change and Vulnerability.* Earthscan. London.

Batima, P., Natsagdorj, L., Gombluudev, P. Erdenetsetseg, B. 2005. Observed climate change in Mongolia. *AIACC Working Paper No. 12.* www.aigccproject.org

Batjargal, Z. 1997. Desertification in Mongolia. *RALA Report No. 200.* 107-113.

Batterbury, S., Behnke, R., Doll, P., Ellis, J., Harou, P., Lynam, T., Mtimet, A., Nicholson, S., Obando, J., Thornes, J. 2002. Responding to desertification at the national scale: detection, explanation, and responses. In: Reynolds, J. and Stafford Smith, D. (eds), *Global Desertification: do humans cause deserts?* Dahlem University Press. Berlin, pp 357-386.

Bayarjargal, Y., Karnieli, A., Bayasgalan, M., Khudulmur, S., Gandush, C., Tucker, C. 2006. A comparative study of NOAA–AVHRR derived drought indices using change vector analysis. *Remote Sensing of Environment.* Volume 105: 9-22

Bazargur, D. 2002. Territorial Organization of Mongolian Pastoral Livestock Husbandry in the Transition to a Market Economy. *Focus on Geography.* 47: 20-25.

Bedunah, D., Harris, R. 2002. Past, present & future rangelands in China. *Rangelands.* 24: 17-22.

Bedunah, D., Schmidt, S. 2004. Pastoralism and protected area management in Mongolia's Gobi Gurvansaikhan National Park. *Development and Change.* 35: 167-191.

Begzsuren, S., Ellis, J., Ojima, D., Coughenour, M., Chuluun, T. 2004. Livestock reponses to droughts and severe winter weather in the Gobi Three Beauties National Park, Mongolia. *Journal of Arid Environments* 59: 785-796.

Behnke, R. (ed), 2008. *The Socio-Economic Causes and Consequences of Desertification in Central Asia.* Springer, Dordrecht.

Bhuiyan, C., Singh, R. Kogan, F. 2006. Monitoring drought dynamics in the Aravalli region (India) using different drought indices based on ground and remote sensing data. *International Journal of Applied Earth Observation and Geoinformation.* 8: 289-302.

Bilskie, J., Arnold, H. 2002. An examination of the political and economic transition of Mongolia since the collapse of the Soviet Union. *Journal of Third World Studies.* 19: 205-218.

Blaikie, P., Brookfield, H. 1987. *Land Degradation and Society.* Methuen, London.

Bohannan, J. 2008. The big thaw reaches Mongolia's pristine north. *Science*. 319: 567-568.

Boken V., Cracknell A., Heathcote R. (eds), 2005. *Monitoring and Predicting Agricultural Drought*. Oxford University Press: Oxford.

Bold, B. 2001. *Mongolian Nomadic Society*. St. Martin's Press, New York

Bolormaa, O., Baasansuren, J., Kawasaki, J., Watanabe, M., Hattori, T. 2006. PIXE analysis of heavy metals in water samples from a mining area in Mongolia. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*. 243: 161-166.

Bordi, I., Fraedrich, K., Jiang, J., Sutera, A. 2004. Spatio-temporal variability of dry and wet periods in eastern China. *Theoretical and Applied Climatology*. 79: 81-91.

Brand, F. 2009. Critical natural capital revisited: ecological resilience and sustainable development. *Ecological Economics*. 68:605-612.

Brand, F., Jax, K. 2007. Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object. *Ecology and Society*. 12: 23.

Byun, H., Wilhite, D. 1999. Objective Quantification of Drought Severity and Duration. *Journal of Climate*. 12:2747-2756.

Cancelliere, A., Di Mauro, G., Bonaccorso, B., Rossi, G. 2007. Drought forecasting using the Standardized Precipitation Index. *Water Resource Management*. 21: 801-819.

Cao, B., Qin, Q., Zhu, L., Li, B. 2007. Simplified desertification monitoring approach based on K-TTCT: a case study in Guyuan County, Heibei Province, China. *Proceedings of SPIE – International Society for Optical Engineering*. 6790:spiedl.aip.org/getabs/servlet/GetabsServlet?prog=normal&id= PSISDG0067 9000000167900E000001&idtype=cvips&gifs=yes

Chen, Y. and Tang, H. 2005. Desertification in north China: background, anthropogenic impacts and failures in combating it. *Land Degradation and Development*. 16: 367-376.

Christensen, L., Coughenour, M.B., Ellis, J.E., Chen, Z. 2003. Sustainability of Inner Mongolian grasslands: application of the Savanna model. *Journal of Range Management*. 56: 319-327.

Chuluundorj, O. 2006. PhD Thesis. *A Multi-Level Study of Vulnerability of Mongolian Pastoralists to Natural Hazards and Its Consequences on Individual and Household Well-Being*. University of Colorado, Denver.

Clark, W. 2007. Sustainability Science: A room of its own. *Proceedings of the National Academy of Science*. 104: 1737-1738.

Cowling R., Egoh, B., Knight, A., O'Farell, P., Reyers, B., Rouget, M., Roux, D., Welz, A., Wilhelm-Rechman, A. 2008. An operational model for mainstreaming ecosystem services for implementation. *Proceedings of the National Academy of Science*. 105: 9483–9488.

Cruz, R., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C., Huu Ninh, N. 2007. Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. In: Parry, M., Canziaina, O., Palutikof, J., van der Linden, P., Hanson, C., (eds), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, 469-506.

Cutter, S., Boruff, B., Shirley, W. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly*. 84: 242-259.

Davi, N., Jacoby, G., Curtis, A., Baatarbileg, N. 2006. Extension of drought records for central Asia using tree rings: West-central Mongolia. *Journal of Climate* 19: 288-299.

De Sherbinin, A. 2002. Land-use and land-cover change. In: *A CIESIN Thematic Guide*. Center for International Earth Science Information Network of Columbia University, New York.

Dearing, J. 2006. Climate-human-environment interactions: resolving our past. *Climate of the Past*. 2: 187-203.

Diouf, A., Lambin, E. 2001. Monitoring land-cover changes in semi-arid regions: remote sensing data and field observations in the Ferlo, Senegal. *Journal of Arid Environments*. 48:129-148.

Dougill, A., Thomas, D., Heathwaite, L. 1999. Environmental Change in the Kalahari: Integrated Land Degradation Studies for Nonequilibrium Dryland Environments. *Annals of the Association of American Geographers* 89: 420–442.

Dougill, A., Trodd, N. 1999. Monitoring and modelling open savannas using multisource information: analyses of Kalahari studies. *Global Ecology and Biogeography*: 8: 211-221.

Ellis, J., Galvin, K. 1994. Climate patterns and land use practices in the dry zones of Africa. *Bioscience*. 44: 340-348.

Ellis, J., Lee, R. 2003. Collapse of the Kazakstan liveston sector. In: Kerven, C. (ed), *Prospects for Pastoralism in Kazakstan and Turkmenistan: from State Farms to Private Flocks*. RoutledgeCurzon, London. pp. 52-76.

Erdenetuya, M. 2004. Pasture productivity changes in Mongolia. *Map Asia Conference*. www.gisdevelopment.net/application/agriculture/yield/pdf /ma04175

Eriksen, S. 2001. Linkages between climate change and desertification in East Africa. Part 1: physical and social linkages. *Arid Lands Newsletter*. 49. ag.arizona.edu/OALS/ALN/aln49/aln49toc.html

Evans J., Geerken R. 2004. Discrimination between climate and human-induced dryland degradation. *Journal of Arid Environments*. 57: 535-554.

FAO (Food and Agriculture Organization). 2000. *FAOSTAT Database*. www.apps.fao.org

FAO (Food and Agriculture Organization. 2003. Transhumanent grazing systems in Temperate Asia. *Plant Production and Protection Series No. 31*. Fao.org/docrep/006/Y4856E/Y4856E00.HTM

FAO (Food and Agriculture Organization). 2006. *Country Pasture/Forage Resource Profiles – Mongolia*. Fao.org /ag/AGP/ AGPC/doc/Counprof/Mongol2.htm

Farrington, J. 2005. The impact of mining activities on Mongolia's protected areas: a status report with policy recommendations. *Integrated Environmental Assessment and Management*. 1: 365-373.

Fernandez-Gimenez, M. 1999. Sustaining the Steppes: A Geographical History of Pastoral Land Use in Mongolia. *The Geographical Review*. 89: 315-342.

Fernandez-Gimenez, M. 2000. The role of Mongolian nomadic pastoralists' ecological knowledge in rangeland management. *Ecological Applications*. 10: 1318-1326.

Fernandez-Gimenez, M. 2006. Land use and land tenure in Mongolia: a brief history and current issues. *USDA Forest Service Proceedings RMRS-P-39*. pp 30-36.

Fernandez-Gimenez, M., Allen-Diaz, B. 1999. Testing a non-equilibrium model of rangeland vegetation dynamics in Mongolia. *Journal of Applied Ecology*. 36: 871-885.

Fernandez-Gimenez, M., Allen-Diaz, B. 2000. Vegetation change along gradients from water sources in three grazed Mongolian ecosystems. *Plant Ecology*. 157: 101–118.

Fernandez-Gimenez, M., Swift, D. 2003. Strategies for sustainable grazing management in the developing world. In: Allsopp, N., Palmer, A., Milton, S., Kirkman, K., Kerley, G., Hurt, C., Brown, C. (eds), *Proceedings of the VIIth International Rangelands Congress*. 26 July –1 August 2003, Durban, South Africa, pp. 821–831.

Fewster, R., Laake, J, Buckland, S. 2005. Line transect sampling in small and large regions. *Biometrics*. 61: 856-859.

Field, A. 2005. *Discovering Statistics using SPSS*. Sage Publications, London.

Flores-Flores, J., Santha, S., Thomas, D., Safriel, U., Eswaran, H., Solh, M., Davies, J., Kowsar, Bissonnette, J. 2008. Experts address the question: "Are poverty and land degradation inevitable in desert-prone areas?" *Natural Resources Forum*. 32: 77-80

Folke, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*. 16: 253-267.

Folke, *C.* 2007. Social-ecological systems and adaptive governance of the commons. *Ecological Research* 22: 14-15.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C., Walker, B., Bengtsson, J., Berkes, F., Colding, J., Danell, K. 2002. *Scientific background paper prepared for the Environmental Advisory Council to the Swedish Government (International Council for Science Series for Sustainable Development), No. 3*. www.resalliance.org/ev.php?URL_ID1498&URL_DO=DO_TOPIC&URL_Section=201&reload=105281034.

Franklin, S. Downing, T. 2004. Vulnerability, *Global Environmental Change and Food Systems Briefing Paper*, Stockholm Environment Institute, Stockholm.

Fratkin, E., Mearns, R. 2003. Sustainability and pastoral livelihoods: lessons from East Africa and Mongolia. *Human Organization*. 62: 112-124

Gallopin, G. 2006. Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*. 16:293-303.

Gallopín, G., Funtowicz, S., O'Connor, M., Ravetz, J. 2001. Science for the 21st century: from social contract to the scientific core, *International Social Science Journal* 168: 219–229.

Gardner, A. 2005. The new calculus of Bedouin pastoralism in the Kingdom of Saudi Arabia. In: Paulson, S., Gezon, L., (eds), *Political Ecology across Spaces, Scales, and Social Groups*. Rutgers University Press, New Brunswick, pp. 76-93.

Geist, H. 2005. *The Causes and Progression of Desertification*. Ashgate, Burlington.

Geographical Atlas of Mongolia. 2004. Administration of Land Affairs, Geodesy and Cartography. Ulaan Bataar.

Gezon, L., Paulson, S. 2005. Place, Power, Difference Multiscale Research at the Dawn of the Twenty-first Century. In: Paulson, S., Gezon, L., (eds), *Political Ecology Across Spaces, Scales, and Social Groups*. Rutgers University Press, New Brunswick.

Gong, D., Wang, S. 2000. Severe summer rainfall in China associated with enhanced global warming. *Climatic Research*. 16: 51-59.

Goudie, A. 1990. Desert Degradation. In: Goudie, A. (ed), *Techniques for Desert Reclamation*. John Wiley & Sons, Chichester.

Gunderson, L., Hollings, C. 2002. *Panarchy*. Island Press, Washington.

Gunin, P. Vostokova, E., Dorofeyuk, P., Tarasov, P., Black, C. 1999. *Vegetation Dynamics in Mongolia*. Kluwer Academic Publishers, Boston.

Guttman, N. 1999. Accepting the Standardized Precipitation Index: a calculation algorithm. *Journal of American Water Resources Association*. 35: 311-322.

Hallack-Alegria, M., Watkins Jr., D. 2007. Annual ånd warm season drought intensity–duration–frequency analysis for Sonora, Mexico. *Journal of Climate*. 20: 1897-1909

Havstad, K., Herrick, J., Enkh-Amgalan, T. 2008. Mongolia's rangelands: is livestock production the key to the future? *Frontiers in Ecology and the Environment*. 7: 386-391.

Hayes, M., Svoboda, M., Wilhite, D., Vanyarkho, O. 1999. Monitoring the 1996 drought using the Standardized Precipitation Index. *Bulletin of the American Meteorology Society*. 80: 429-438.

Hedin, S. 1925. *My Life as an Explorer.* Kodansha International, N.Y.

Hein, L. 2006. Impacts of grazing and rainfall variability on the dynamics of a Sahelian rangeland. *Journal of Arid Environments.* 64: 488-504.

Hiernaux, P. 1996. The crisis of Sahelian pastoralism: ecological or economic? *Overseas Development Institute, Set 39*, London.

Herrmann S., Hutchinson C. 2005. The changing contexts of the desertification debate. *Journal of Arid Environments*, 63: 538-555.

Hilbig, W. 1995. *The Vegetation of Mongolia.* SPB Academic Publishing, Amsterdam.

Himmelsbach, R. 2008. Collaborative pasture management, a solution for grassland degradation in Mongolia. *Conference proceedings: Contemporary Mongolia – Transitions, Development and Social Transformations.* Vancouver, Canada November 15-17, 2008. pp. 1- 23.

Holling, C. 1973. Resilience and stability of ecological systems. *Annual Review of of Ecology and Systematics.* 4: 1-23.

Huang S., Siegert F. 2006. Land cover classification optimized to detect areas at risk of desertification in North China based on SPOT VEGETATION imagery. *Journal of Arid Environments*, 67: 308-327.

IFRC (International Federation of the Red Cross). 2001. Mongolia: snowfalls. *Emergency Appeal No. 07/2001.* www.ifrc.org/docs/appeals/01/070101.pdf

Independent Commission on International Humanitarian Issues (ICIHI). 1986. *The Encroaching Desert: the consequences of human failure.* Zed Books, London.

Ishiyama, T., Tanaka, S., Uchida K., Fujikawa S.; Yamashita, Y., Kato, M. 2001. Relationship among vegetation variables and vegetation features of arid lands derived from satellite data. *Advances in Space Research.* 28: 183-188.

Iwasaki, H. 2004. Impact of interannual variability of meteorological parameters on vegetation activity and predict possibility of vegetation activity over Mongolia. *Proceedings of the 3rd International Workshop on Terrestrial Change in Mongolia.* Tsukuba, Japan, pp. 31-34.

James, C., Landsberg, J., Morton, S. 1997. Provision of watering points in Australian rangelands: a literature review of effects on biota. *Journal of Arid Environments.* 41: 87-121.

Jamsran, T., Oyuntsetseg, B. 2000. *Botanical Dictionary.* Ulaanbaatar.

Janzen, J., Bazargur, D. 2003. The transformation process in mobile livestock keeping and changing patterns of mobility in Mongolia – with special attention to western Mongolia and Ulaanbaatar. In: Ishikawa, Y., Montari, A., (eds), *The New Geography of Human Mobility – Inequality Trends?* Societa Geografica Italiana, Rome.

Javzandulam, T., Tateishi, R., Sanjaa, T. 2005. Analysis of vegetation indices for monitoring vegetation degradation in semi-arid and arid areas of Mongolia. *International Journal of Environmental Studies.* 62: 215-225.

Jiang, H. 2004. Cooperation, land use, and the environment in Uxin Ju: the changing landscape of a Mongolian-Chinese borderland in China. *Annals of the Association of American Geographers.* 94: 117-139.

Jigjidsuren, S., Johnson, D. 2003. *Forage Plants in Mongolia.* Admon, Ulaan Baatar.

Johnson, D., Sheehy, D., Miller, D., Damiran, D. 2006. Mongolian *Rangelands* in transition. *Secheresse.* 17: 133-141.

Jones, D. 2007. Vegetation Measurement Methods Comparison. www.cemml. colostate.edu/methods/methods.pdf.

Jun Li, W., Ali, S., Zhang, Q. 2007. Property rights and grassland degradation: A study of the Xilingol Pasture, Inner Mongolia, China. *Journal* of *Environmental Management.* 85: 461-470.

Kawamura, K., Akiyama, T., Yokota, H., Tsutsumi, M., Yasuda, T., Watanabe, O., Wang, G., Wang, S. 2005. Monitoring of forage conditions with MODIS imagery in the Xilingol steppe, Inner Mongolia. *International Journal of Remote Sensing.* 26: 1423 – 1436.

Kelly, P., Adger, N. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change.* 47: 325-352.

Kerr, J., Ostrovsky, M. 2003. From space to species: ecological applications for remote sensing. *Trends in Ecology and Evolution.* 18: 299-305.

Kerven, C. 2003. Agrarian reform and privatisation in the wider Asian region: comparison with Central Asia. In; Kerven, C. (ed), *Prospects for Pastoralism in Kazakstan and Turkmenistan: from State Farms to Private Flocks.* RoutledgeCurzon, London. pp. 10-26.

Keyantash, J. and Dracup, J. 2002. The quantification of drought: an evaluation of drought indices. *Bulletin of the American Meteorological Society.* 83: 1167-1180

Khudulmur, S., and Erdenetuya, M. 2002. Remote Sensing in Mongolia. *ISPRS.* 7: 29-32.

King, C., Bigas, H., Adeel, Z. 2007. *Desertification and the International Policy Imperative.* UNU, Hamilton.

Klein Tank, A, Peterson, T., Quadir, D., Dorji, S., Zou, X., Tang, H., Santhosh, K., Joshi, U., Jaswal, A., Kolli, R., Sikder, A., Deshpande, N., Revedekar, J., Yeleuova, K., Vandasheve, S., Faleyeva, M., Gomboluudev, P., Budhathoki, K., Hussain, A., Afzaal, M., Chandrapala, L., Anvar, H., Amanmurad, D., Asanova, V., Jones, P., New, M., Spektorman, T. 2006. Changes in daily temperature and precipitation extremes in central and south Asia. *Journal of Geophysical Research.* 111: 1-8.

Kogan, F., Stark, R., Gitelson, A., Jargalsaikhan, L., Dugrajav, C., Tsooj, S. 2004. Derivation of pasture biomass in Mongolia from AVHRR-based vegetation health indices. *International Journal of Remote Sensing.* 25: 2889–2896.

Krader, L. 1955. Ecology of Central Asian pastoralism. *Southwestern Journal of Anthropology.* 11: 301-325.

Kürschner, H. 2004. Phytosociological studies in the Alashan Gobi - A contribution to the flora and vegetation of Inner Mongolia (NW China). *Phytocoenologia.* 34: 169-224.

Labedzki, L. 2007. Estimation of local drought frequency in central Poland using the standardized precipitation index SPI. *Irrigation and Drainage.* 56: 67 – 77.

Lambin, E. F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E. F., Rindfuss, R. R., Sato, Y., Skole, D., Turner II, B. L. and Vogel, C. 1999. Land-Use and Land-Cover Change (LUCC): Implementation Strategy. *IGBP Report No. 48, IHDP Report No. 10.* IGBP and IHDP; Stockholm and Bonn.

Lambin, E. 2005. Conditions for sustainability of human-environment systems: information, motivation and capacity. *Global Environmental Change* 15, 177-180.

Lamprey, H. 1975. Report on the desert encroachment reconnaissance in northern Sudan. *UNESCO/UNEP* p.16.

Landsberg, J., James, C., Morton, R., Muller, W. 2003. Abundance and composition of plant species along grazing gradients in Australian *Rangelands. Journal of Applied Ecology.* 40 (6): 1008-1024.

Lane, C., Moorehead, R. 1994. *Who should own the range? New thinking on pastoral resource tenure in drylands Africa.* IIED, London.

Leatherman, T., Thomas, R. 2001. Political ecology and constructions of environment in biological anthropology. In Crumley, C. (ed), *New directions in anthropology and environment: intersections.* Altimira Press, Lanham. pp. 113-132.

Lee, H., Zhang, D. 2005. Perceiving land-degrading activities from the lay perspective in northern China. *Environmental Management.* 36: 711-725.

Lepers, E., Lambin, E., Janetos, A., Defries, R., Achard, F., Ramankutty, N., Scholes, R. 2005. A Synthesis of Information on Rapid Land-cover Change for the Period 1981–2000. *BioScience.* 55: 115–124.

Lesorogol, C. 2006. Privatizing pastoral lands: economic normative outcomes in Kenya. *World Development.* 33: 1959-1978.

Li, J., Chen, F., Cook, E., Gou, X., Zhang, Y. 2007. Drought reconstruction for north central China from tree rings: The value of the Palmer drought severity index. *International Journal of Climatology.* 27: 903-909

Li, X., Jia, X., Dong, G. 2006. Influence of desertification on vegetation patter variations in the cold semi-arid grasslands of Qinghai-Tibet plateau, north-west China. *Journal of Arid Environments* 64, 505-522.

Lioubimtseva, E., Cole, R., Adams, J., Kapustin, G. 2005. Impacts of climate and land-cover changes in arid lands of Central Asia. *Journal of Arid Environments* 62: 285–308.

Lise W., Hess S., Purev B. 2006. Pastureland degradation and poverty among herders in Mongolia: Data analysis and game estimation. *Ecological Economics.* 58: 350-364.

Liu, Y., Wang, D., Gao, J., Deng, W. 2005*a*. Land use/cover changes, the environment and water resources in northeast China. *Environmental Management.* 36. 5: 691-701.

Liu, H., Cai, X., Geng, L., Zhong, H. 2005*b*. Restoration of pastureland ecosystems: case study of western Inner Mongolia. *Journal of Water Resources Planning and Management.* 131: 420-430.

Liu, M., Osborne, P. 2008. Leaf cold acclimation and freezing injury in C3 and C4 grasses of the Mongolian Plateau. *Journal of Experimental Botany.* 59: 4161–4170.

Liu, J., Li, S., Ouyang, Z., Tam, C., Chen, X. 2008. Ecological and socioeconomic effects of China's poicies for ecosystem services. *Proceedings of the National Academy of Scienc.* 105: 9477-9482.

Liverman, D., Yarnal, B., Turner II, B. 2005. The human dimension of global change. In Gaile, G. and Wilmott, C. (eds), *Geography in America at the Dawn of the 21st Century.* Oxford University Press, Oxford.

Lloyd-Hughes, B., Saunders, M. 2002. A drought climatology for Europe. *International Journal of Climatology.* 22: 1571-1592.

Ludwig, J., Eager, R., Williams, R., Lowe, L. 1999. Declines in vegetation patches, plant diversity, and grasshopper diversity near cattle watering-points in the Victoria River District, Northern Australia. *Rangelands Journal.* 21: 135-149.

Luers, A., Lobell, D., Sklar, L., Addams, C. 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley. *Global Environmental Change.* 13: 255-267.

Lund, C. 2000. African land tenure: questioning basic assumptions. *IIED Drylands Issue Paper 100.* London.

Ma, Y., Fan, S., Zhou, L., Dong, Z., Zhang, K., Feng, J. 2007. The temporal change of driving factors during the course of land desertification in arid region of North China: the case of Minqin County. *Environmental Geology.* 51: 999-1008.

Mainguet, M. 1991. *Desertification: Natural Background and Human Mismanagement.* Springer-Verlag, Berlin.

Mandzy-Herring, L. 2008. D.Phil Thesis. *Vegetation dynamics and environmental change in Mongolia.* Oxford University, Oxford.

McKee, T. Doeskan, N., Kleist, J. 1993. The relationship of drought frequency and duration to time scales. *Eighth Conference on Applied Climatology, Anaheim, Ca.* American Meteorological Association, 179-184.

Mearns, R. 1993. Territoriality and land tenure among Mongolian pastoralists: variation, continuity and change. *Nomadic Peoples.* 33: 73-103.

Mearns, R. 2004. Sustaining Livelihoods on Mongolia's Pastoral Commons: Insights from a Participatory Poverty Assessment. *Development and Change.* 35: 107-139.

Meier, P., Bond, D., Bond, J. 2007. Environmental influences on pastoral conflict in the Horn of Africa. *Political Geography.* 26: 716-735.

Middleton, N. 1991. Dust storms in the Mongolian People's Republic. *Journal of Arid Environments*. 20: 287–297.

Middleton, N. 1992. *Last Disco in Outer Mongolia*. Sinclair-Stevenson, London.

Middleton, N., Thomas, D. 1997. *World Atlas of Desertification, 2nd Ed.* Arnold, London.

Mihajlovic, D. 2006. Monitoring the 2003-2004 meteorological drought over Pannonian part of Croatia. *International Journal of Climatology*. 26: 2213-2225.

Miller, R. 1952. A selective survey of literature on Mongolia. *The American Political Science Review*, 46: 849-866.

Min, S., Kwon, W., Park, E., Choi, Y. 2003 Spatial and temporal comparisons of droughts over Korea with East Asia. *International Journal of Climatology*. 23: 223-233

MNE (Ministry of Nature and Environment). *Implementation of the UN Convention to Combat Desertification in Mongolia, Second National Report*. 2002. Ministry of Nature and the Environment. Ulaan Bataar.

Mongolian Statistical Yearbook 1989-2002. 2004. National Statistical Office of Mongolia. Ulaan Baatar.

Mongolian Statistical Yearbook, 2004. 2005. National Statistical Office of Mongolia. Ulaan Baatar.

Mongolian Statistical Yearbook, 2005. 2006. National Statistical Office of Mongolia. Ulaan Baatar.

Mongolian Statistical Yearbook, 2006. 2007. National Statistical Office of Mongolia. Ulaan Bataar.

Morid, S., Smakhtin, V., Moghaddasi, M. 2006. Comparison of seven meteorological indices for drought monitoring in Iran. *International Journal of Climatology*. 26: 971-985.

Mortimore, M. 2005. Dryland development: success stories from West Africa. *Environment*. 47: 8-21.

Moses, L., Halkovic, S. 1985. *Introduction to Mongolian History and Culture*. Research Institute for Inner Asian Studies, Bloomington.

Mpelasoka F., Hennessy, K., Jones R., Bates, B. 2008. Comparison of suitable drought indices for climate change impacts assessment over Australia towards resource management. *International Journal of Climatology*. 28: 1283-1292.

Munkhtsetseg, E., Kimura, R., Wang, J., Shinoda, M. 2007. Pasture yield response to precipitation and high temperature in Mongolia. *Journal of Arid Environments*. 70: 94-110.

Murayama, T., Sugimoto, N., Uno, I., Kinoshita, K., Aoki, K., Hagiwara, N., Liu, Z., Matsui, I., Sakai, T., Shibata, T., Arao, K., Sohn, B., Won, J., Yoon, S., Li, T., Zhou, J., Hu, H., Abo, M., Iokibe, K., Koga, R., Iwasaka, Y. 2001. Ground-based network observation of Asian dust events of April 1998 in East Asia. *Journal of Geophysical Research*. 106: 18,345–18,359.

Nandintsetseg, B., Greene, J., Goulden, C. 2007. Trends in extreme daily precipitation and temperature near Lake Hovsgol, Mongolia. *International Journal of Climatology*. 27: 341-347.

Nangula, S., Oba, G. 2004. Effects of artifical water points on the Oshana ecosystem in Namibia. *Environmental Conservation*. 31: 47-54.

NASA (National Aeronautics and Space Administration). 1999. Measuring vegetation (NDVI & EVI). www.earthobservatory.nasa.gov/Library/Measuring Vegetation/printall.php

Nasri, M., Modarres, R., Moradi, Y. 2006. The analysis of drought indicators and related impacts in Ardestan region, Iran. *International Symposium on Water and Land Management for Sustainable Irrigated Agriculture*. Adana, Turkey. symp.cu.edu.tr

Nicholson, S., Tucker, C., Ba, M. 1998. Desertification, drought, and surface vegetation: an example from the West African Sahêl. *Bulletin of the American Meteorological Society*. 79: 815-829.

Nori, M., Taylor, M., Sensi, A. 2008. Browsing on fences: pastoral land rights, livelihoods and adaptation to climate change. *IIED Issue paper no. 148*. London.

Normile, D. 2007. Getting at the Roots of Killer Dust Storms. *Science*. 317: 314-316.

Ntale, H. and Gan, T. 2003. Drought indices and their application to East Africa. *International Journal of Climatology*. 23: 1335-1357.

O'Brien, K., Eriksen, S., Schjolden, A., Nygaard, L. 2004. What is in a word? Conflicting interpretations of vulnerability in climate change research. *CICERO Working Paper 4*. Center for International Climate and Environmental Research, Oslo.

O'Brien, M., Holland, T. 1992. The role of adaptation in archaeological explanation. *American Antiquity*. 57: 36-69.

Ojima, D., Chuluun, T. 2008. Policy changes in Mongolia: implications for land use and landscapes. In: Galvin. K., Reid, R., Behnke, R., Hobbs, N. (eds), *Fragmentation in semi-arid and arid landscapes: consequences for human and natural systems.* Springer Publishing, N.Y., pp. 179-191.

Okayasu, T., Muto, M., Jamsran, U., Takeuchi, K. 2007. Spatially heterogeneous impacts on rangeland after social system change in Mongolia. *Land Degradation & Development*. 18: 555 – 566.

Okoruwa, V., Jabbar,M., Akinwumi, J. 1996. Crop-livestock competition in the West African derived savanna: Application of a multi-objective programming model. *Agricultural Systems*. 52:439-453.

Olson, J., Misana, S., Campbell, D., Mbonile, M., and Mugisha, S. 2004. A research framework to identify the root causes of land use change leading to land degradation and changing biodiversity. *Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 48*. International Livestock Research Institute, Nairobi.

PALD (Policy Alternatives for Livestock Development in Mongolia). 1993. Options for the Reform of Grazing Land Tenure in Mongolia. *Policy Option Paper No. 1.* Institute of Development Studies, Univeristy of Sussex, Brighton.

Pearce, R. 2006. Decentralization and sustainable resource management in West Africa: a line of action for revisiting national action programmes. In Johnson, P, Mayrand, K., Paquin, M. (eds), *Governing Global Desertification.* Ashgate, Aldershot.

Pelling, M. 2003. *The vulnerability of cities: natural disasters and social resielience*. Earthscan, London.

Perkins, J. 1996. Botswana: fencing out the equity issue. Cattleposts and cattle ranching in the Kalahari Desert. *Journal of Arid Environments*. 33: 503-517.

Perkins, J., Thomas, D. 1993. Spreading deserts or spatially confined environmental impacts? Land degradation and cattle ranching in the Kalahari Desert of Botswana. *Land Degradation and Rehabilitation.* 4: 179–194.

Pettorelli N., Vik J., Mysterud, A., Gaillard J., Compton J., Stenseth N. 2005. Using the satellite-derived NDVI to assess ecological responses to environmental change. *Trends in Ecology and Evolution.* 20:503-510.

Plummer, R., Armitage, D. 2007. A resilience-based framework for evaluating adaptive co-management: Linking ecology, economics and society in a complex world. *Ecological Economics.* 61: 62-74

Prasad, A., Khan, S. 2002. Murray-Darling Basin dialogue on water and climate. *River Symposium Report.* Brisbane, Australia. www.wac.ihe.nl/dialogue/Basin/ Murray-Darling/documents/Murray-Darling%20Report.pd

Pratt. D., Macmillan, D., Gordon, I. 2004. Local community attitudes to wildlife utilisation in the changing economic and social context of Mongolia. *Biodiversity and Conservation.* 13: 591–613

Propastin, P., Kappas, M. 2008. Spatio-temporal drifts in AVHRR/NDVI-precipitation relationships and their linkage to land use change in central Kazakhstan. *EARSeL eProceedings.* 7: 30-45.

Purevdorj, T., Tateishi, R., Ishiyama, T. Honda, Y. 1998. Relationships between percent vegetation cover and vegetation indices. *International Journal of Remote Sensing.* 19 (18): 3519-3535.

Rammel, C., Stagl, S., Wilfang, H. 2007. Managing complex adaptive systems – A co-evolutionary perspective on natural resource management. *Ecological Economics.* 63:9-21.

Reading, R., Bedunah, D., Amgalanbaatar, S. 2006. 'Conserving biodiversity on Mongolian Rangelands: implications for protected area development and pastoral uses. *USDA Forest Service Proceedings RMRS-P-39.*

Reed, M., Dougill, A. 2002. Participatory selection process for indicators of rangeland condition in the Kalahari. *The Geographical Journal.* 168: 224–234.

Retzer, V. and Reudenbach, C. 2005. Modelling the carrying capacity and coexistence of pika and livestock in the mountain steppe of the south Gobi, Mongolia. *Ecological Modelling.* 189, 89-104.

Reyes-Gómez V., Núñez López, D. 2006. Implementation of the Drought Monitoring System in Northwest Mexico. *North American Drought Monitor Workshop.* www.ncdc.noaa.gov/oa/climate/research/2006/nadm-workshop/20061019/1161271200-abstract.pdf

Reynolds, J., Stafford Smith, D. (eds), 2002. *Global Desertification: Do Humans Cause Deserts?* Dahlem University Press, Berlin.

Reynolds, J., Stafford Smith, D., Lambin, E., Turner II, B., Mortimore, M., Batterbury, S., Downing, T., Dowlatabadi, H., Fernandez, R., Herrick, J., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T. Maestre, F. Ayarza, M., Walker, B. 2007. Global desertification: building a science for dryland development. *Science.* 316: 847-851.

Richard, Y., Poccard, I. 1998. A statistical study of NDVI sensitivity to seasonal and interannual rainfall rainfall variations in Southern Africa. *International Journal of Remote Sensing.* 19 (15): 2907-2920.

Rindfuss, R., Stern, P. 1998. Linking remote sensing and social science: the need and the challenges. In Liverman, D., Moran, E., Rindfuss, R. and Stern, P. (eds), *People and Pixels: linking remote sensing and social science.* National Academy Press. Washington D.C., 1-27.

Robinson, J. 2008. Being undisciplined: transgressions and intersections in academia and beyond. *Futures.* 40: 70-86.

Robson, C. 2002. *Real World Research: a resource for social scientists and practioner-researchers.* 2nd edition. Blackwell, Oxford.

Rossabi, M. 2005. *Modern Mongolia: from khans to commisars to capitalists.* University of California Press, Berkeley.

Rouault, M., Richard, Y. 2003. Intensity and spatial extension of drought in South Africa at different time scales. *Water South Africa.* 29 (4): 489-500.

Rudaya, N., Tarasov, P., Dorofeyuk, N., Kalugin, I., Andreev, A. 2008. Holocene vegetation and environments in the Mongolian Altai derived from the Hoton-Nur pollen and diatom records. *Geophysical Research Abstracts.* 10: 1-2.

Sallu, S. 2008. D. Phil Thesis. *Biodiversity dynamics, livelihoods, and knowledge in Kalahari dryland biomes.* Oxford University, Oxford.

Sasaki, T., Okayasu, T., Takeuchi, K., Jamsran, U., Jadambaa, S. 2005. Patterns of floristic composition under different grazing intensities in Bulgan, South Gobi, Mongolia. *Grassland Science*. 51: 235–242.

Sasaki, T., Okayasu, T., Jamsran, U., Takeuchi, K. 2008. Threshold changes in vegetation along a grazing gradient in Mongolian rangelands. *Journal of Ecology*. 96: 145-154.

Sayre, N., Fernandez-Gimenez, M. 2003. The genesis of range science, with implications for current development policies. In: Also N., Palmer, A., Milton, S., Kirkman, K., Kerry, G., Hurt, C., Brown, C. (eds), *Proceedings of the VIIth International Rangelands Congress, 26th July – 1st August 2003*. Durban, South Africa. pp. 1976-1985.

Scoones, I., Graham, G. 1994. New directions for pastoral development in Africa. *Development in Practice*. 4:188-198.

Seiler, R., Hayes, M., Bressani, L. 2002. Using the standardized precipitation index for flood risk monitoring. *International Journal of Climatology*. 22: 1365-1376.

Shaoliang, Y., Ning, W., Peng, L., Qian, W., Fusun, S., Geng, S., Jianzhong, M. 2007. Changes in Livestock Migration Patterns in a Tibetan-style Agropastoral System. *Mountain Research and Development*. 27: 138–145.

Shinoda, M., Morinaga, Y. 2005: Developing a combined drought-dzud early warning system in Mongolia. *Geographical Review of Japan*. 78: 928-950.

Shinoda, M., Ito, S., Nachinshonhor, G., Erdenetsetseg, D. 2007. Phenology of Mongolian grasslands and moisture conditions. *Journal of the Meteorological Society of Japan*. 85: 359-367.

Smakhtin, V., Hughes, D. 2007. Automated estimation and analyses of meteorological drought characteristics from monthly rainfall data *Environmental Modelling & Software*. 22: 880-890.

Smit, B., Wandel, J. 2006. Adaptation, adaptive capacity, and vulnerability. *Global Environmental Change* 16: 282-292.

Sneath, D. 1998. State Policy and Pasture Degradation in Inner Asia. *Science*. 281: 1147- 1148.

Sneath, D. 2003. Land use, the environment and development in post-socialist Mongolia. *Oxford Development Studies*. 31: 441-459.

Sonmez, K., Komuscu, A., Erkhan, A. Turgu, E. 2005. An analysis of spatial and temporal dimension of drought vulnerability in Turkey using the Standard Precipitation Index. *Natural Hazards*. 35: 243-264.

Sorbo, G. 2003. Pastoral ecosystems and the issue of scale. *Ambio*. 32: 113-117.

"Southern province infested by locust plague" (2004). *Onoodor/Ulaan Bataar Post*. 29 July, 2004. p. 1, section 1.

Sporton, D., Thomas, D.S.G. 2002. Sustainable livelihoods in Kalahari environments: a contribution to global debates. In: Sporton, D., Thomas, D.S.G. (eds), *Sustainable Livelihoods in the Kalahari Environments*. Oxford University Press, Oxford.

Steiner-Khamsi, G., Stolpe, I. 2004. Decentralization and recentralization reform in Mongolia: tracing the swing of the pendulum. *Comparative Education*. 40: 29-53.

Sternberg, T. 2008. Environmental challenges in Mongolia's dryland pastoral landscape. *Journal of Arid Environments*. 72: 1294-1304.

Sternberg, T., Tsolmon, R., Middleton, N., Thomas, D. *in review*. Tracking desertification on the Mongolian steppe through NDVI and field-survey data. *International Journal of Digital Earth*.

Stringer, L. 2008. Reviewing the International Year of Deserts and Desertification 2006: what contribution towards combating global desertification and implementing the united nations convention to combat desertification? *Journal of Arid Environments*. 72: 2065-2074.

Stumpp, M., Wesche, K., Retzer, V., Miehe, G. 2005. Impact of grazing livestock and distance from water source on soil fertility in southern Mongolia. *Mountain Research and Development*. 25: 244-251.

Sugita, M., Asanuma, J., Tsujimura, M., Mariko, S., Lu, M., Kimura, F., Azzaya, D., Adyasuren, T. 2007. An overview of the Rangelands atmosphere-hydrosphere-biosphere interaction study experiment in northeastern Asia (RAISE). *Journal of Hydrology*. 333: 3-20.

Suttie, J. 2005. Grazing management in Mongolia. in: Suttie, J., Reynolds, S., Batello, C., (eds) Grasslands of the world. *FAO Plant Production and Protection Series No. 34*. Rome.

Swift, J., and Mearns, R. 1993. Mongolian pastoralism on the threshold of the twenty-first century. *Nomadic Peoples*. 33: 3-7.

Tanaka, T., Abe, Y., Tsujimira, M. 2005. Groundwater recharge process in the Kherlen River basin. *Journal of Groundwater Hydrology.* 47: 1-4.

Tebaldi, C., Hayhoe, K., Arblaster, J.,.Meehl, G. 2006. Going to the extremes: An intercomparison of model-simulated historical and future changes in extreme events. *Climatic Change.* 79: 185-211.

Thebaud, B. 1995. Land tenure, environmental degradation and desertification in Africa: some thoughts based on the Sahelian example. *IIED Drylands Programme 57*, London.

Thomas, D. 1997. Science and the desertification debate. *Journal of Arid Environments.* 37: 599-608

Thomas, D., Leason, H. 2005. Dunefield activity response to climate variability in the southwest Kalahari. *Geomorphology.* 64: 117-132.

Thomas, D., Middleton, N. 1992. *World Atlas of Desertification.* United Nations Environmental Programme. Edward Arnold, London.

Thomas, D., Middleton, N. 1994. *Desertification: Exploding the Myth.* John Wiley & Sons, Chichester.

Thomas, D., Sporton, D., Perkins, J. 2000. The environmental impact of livestock ranches in the Kalahari, Botswana: Natural resource use, ecological change and human response in a dynamic dryland system. *Land Degradation & Development.* 11: 327-341.

Todd, S. 2006. Gradients in vegetation cover, structure and species richness of Nama-Karoo shrublands in relation to distance from livestock watering points. *Journal of Applied Ecology.* 43: 293–304.

Tsolmon, R., Ochirkhuyag, L., Sternberg, T. 2008. Monitoring the source of trans-national dust storms in northeast Asia. *International Journal of Digital Earth.* 1: 119–129.

Tumurjav, M. 2003. Traditional animal husbandry techniques practiced by Mongolian nomadic people. In: Badarch, D, Zilinskas, R., Balint, P. (eds), *Mongolia Today.* RoutledgeCurzon. London.

Turner, M. 1999. Merging local and regional analyses of land-use change: the case of livestock in the Sahel. *Annals of the Association of American Geographers.* 89: 191-199.

Turner II, B. 2002. Contested identities: human-environment geography and disciplinary implication in a restructuring academy. *Annals of the Association of American Geographers.* 92: 52-74.

Turner II, B., Lambin, E., Reenberg, A. 2007. The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Science.* 104: 20666–20671.

Turner II, B., Kasperson, R., Matson, P., McCarthy, J., Corell, R., Christensen, L., Eckley, N., Kasperson, J., Luers, A., Martello, M., Polsky, C., Pulsipher, A., Schiller, A. 2003. A framework for vulnerability analysis in sustainability science." *Proceedings of the National Academy of Sciences 100.* 14: 8074-8079

Turner II, B. L., Skole, D., Sanderson, S., Fischer, G., Fresco, L. O. and Leemans, R. 1995. Land-Use and Land-Cover Change, Science/Research Plan. *IGBP Report No. 35, HDP Report No. 7.* IGBP of the ICSU and HDP of the ISSC, Stockholm and Geneva.

U.S. National Drought Mitigation Center. 2006. Standard Precipitation Index program files. www.drought.unl.edu/monitor/spi/program/spi_program.htm.

U.S. State Department. 2007. "MCC Approves $285 million Compact with Mongolia." www.mcc.gov/countries/mongolia/index.php

UN (United Nations). 2000. Mongolia – multiple '*dzud*' and drought. *OCHA (United Nations Office for the Coordination of Humanitarian Affairs) Situation Report No. 10.* New York.

UN (United Nations). 2001. Mongolia – winter disaster (*dzud*). *OCHA (United Nations Office for the Coordination of Humanitarian Affairs) Situation Report No. 4.* New York.

UNCCD (United Nations Commission to Combat Desertification). 2002. Second report on the implementation of the UN Convention to Combat Desertification. www.unccd.int/cop/reports/asia/national/2002/mongolia-eng.pdf

UNCCD (United Nations Commission to Combat Desertification). 2006. Mongolia National Report. www.unccd.int/cop/reports/asia/national/2006/mongolia-eng.pdf

UNCED (United Nations Conference on Environment and Development). 1992. UNCED Declaration. United Nations, New York. http://www.ciesin.org/TG/PI/TREATY/unced.html

UNDP (United Nations Development Programme). 2007. *Country Programme Action Plan between the Government of Mongolia and United Nations Development Program 2007-2011*. Ulaan Baatar.

UNDPI (United Nations Department of Public Information). 2000. Press conference by Minister for External Relations of Mongolia. UN Department of Public Information. New York.

UNEP (United Nations Environmental Programme). 2002. *Mongolia: State of the Environment 2002*. United Nations Environmental Program, Ulaan Bataar.

University of Texas 1996. Political map of Mongolia. Perry-Casteneda Library Map Collection. www.lib.utexas.edu/maps/ mongolia.html

UNU (United Nations University). 2007. Desertification: experts prescribe global policy overhaul to avoid looming mass migrations. www.unu.edu/media /archives/2007/files/mre29-a-07.pdf

van Leeuwen, W. 2006. Spectral vegetation indices and uncertainty: insights from a user's perspective. *IEEE Transactions on Geoscience and Remote Sensing*. 44:1931-1933.

Van Staalduinen, M., During, H., Werger, M. 2007. Impact of grazing regime on a Mongolian forest steppe. *Applied Vegetation Science*. 10: 299-306.

Vayda, A., Walters, B. 1999. Against Political Ecology. *Human Ecology*. 27: 167-179.

Veron, S., Paruelo J, Oesterheld M. 2006. Assessing desertification. *Journal of Arid Environments*. 66: 751-763.

Vetter S. 2005. Rangelands at equilibrium and non-equilibrium: recent developments in the debate. *Journal of Arid Environments*. 62: 321–341.

Vicente-Serrano, S., Cuadrat-Prats, J. 2006. Trends in drought intensity and variability in the middle Ebro valley (NE of the Iberian peninsula) during the second half of the twentieth century. *Theoretical and Applied Climatology*. 88: 247-258.

von Wehrden, H., Hilbig, W., Wesche, K. 2006. Plant communities of the Mongolian Transaltay Gobi. *Feddes Repertorium*. 117: 526-570.

Walker, B. 2005. A resilience approach to integrated assessment. *The Integrated Assessment Journal*. 5: 77-97.

Walker, B., Holling,C., Carpenter, S., Kinzig, A. 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society.* 9:5. www.ecology andsociety.org/vol9/iss2/art5/.

Walker, B., Abel, N. 2002. Resilient rangelands. In: Gunderson, L, Hollings, C. (eds), *Panarchy.* Island Press, Washington.

Walker, B., Salt, D. 2006. *Resilience Thinking.* Island Press, London.

Wang, S. 2005. Monitoring of forage conditions with MODIS imagery in the Xilingol steppe, Inner Mongolia. *International Journal of Remote Sensing.* 26: 1423 – 1436.

Wang, X., Chen, F., Hasi, E., Li., J. 2008. Desertification in China: an assessment. *Earth-Science Reviews.* 88: 188-206.

Warren, A. 2002. Land degradation is contextual. *Land Degradation & Development.* 13: 449–459.

Washington-Allen, R., Ramsey, R., West, N., Norton, B. 2008. Quantification of the. ecological resilience of drylands using digital remote sensing. *Ecology and Society.* 13:1-18.

Watts, M. 2000. Political ecology. In Sheppard, E. & Barnes, T. (eds), *A companion to economic geography.* Blackwell Publishers, Massahcussets.

Wesche, K., Retzer, V. 2005. Is degradation a major problem in semi-desert environments of the Gobi region in southern Mongolia? *Erforsch. biol. Ress. Mongolei.* 9: 133-146.

Wessels, K., Prince, S., van Zyl, D. 2004. Assessing the effects of human-induced land degradation in the former homelands of northern South Africa with a 1 km AVHRR NDVI time-series. *Remote Sensing of Environment.* 91: 47-67.

White, K. 2007. Monitoring oasis degradation using coarse resolution remotely sensed vegetation index data. In Mills, J. and Williams, M. (eds), *Challenges for Earth Observation: Scientific, Technical and Commercial; Proceedings of the 2007 Annual Conference of the Remote Sensing & Photogrammetry Society.* Newcastle upon Tyne. pp. 11-14.

White, R., Nackoney, J. 2003. *Drylands, people, and ecosystem goods and services: A web-based geospatial analysis.* World Resource Institute. Washington, D.C.

WHO (World Health Organization). 2007. *Guidelines for drinking-water quality, 3rd ed.* www.who.int/ water_ sanitation_health/dwq/guidelines/en/index.html

Wilhite, D. 2000. Drought as a natural hazard: concepts and definitions. In Wilhite, D. (ed), *Drought: A Global Assessment, Volume 1.* Routledge, London

Williams, D. 2002. *Beyond Great Walls.* Stanford University Press, Stanford.

Williams, M., Balling, R. 1996. *Interactions of Desertification and Climate.* Arnold, London.

WMO (World Meteorological Organization). 1986. Report on drought and countries affected by drought during 1974-1985. *WCP-118, WMO/TD.No. 133.*

World Bank. 2002. *Mongolia Environmental Monitor.* Ulaan Baatar.

World Bank. 2004. *Mongolia Environmental Monitor.* Ulaan Baatar.

Wu, H., Hayes, M., Weiss, A., Hu, Q. 2001. An evaluation of the Standardized Precipitation Index, the China-Z Index, and the Statistical Z-Score. *International Journal of Climatology.* 21: 745-758.

Wu, H., Hayes, M., Wilhite, D., Svoboda, M. 2005. The effect of the length of record on the Standardized Precipitation Index calculation. *International Journal of Climatology.* 25: 505-525.

Wu, H., Svoboda, M., Hayes, M., Wilhite, D., Wen, F. 2007. Appropriate application of the Standardized Precipitation Index in arid locations and dry seasons. *International Journal of Climatology.* 27: 65-79.

Xuan, J., Sokolik, I., Hao, J., Guo, F., Mao, H., Yang, G. 2004. Identification and characterization of sources of atmospheric mineral dust in East Asia. *Atmospheric Environment.* 38: 6239-6252.

Xue, Y. 1996. The impact of desertification in the Mongolian and the Inner Mongolia grassland on the regional climate. *Journal of Climate.* 9: 2173-2189.

Yang, X., Rost, K., Lehmkuhl, F., Zhenda, Z., Dodson, J. 2004. The evolution of dry lands in northern China and in the Republic of Mongolia since the last Glacial Maximum. *Quaternary International.* 118: 69-85.

Yang, X., Zhang, K, Jia, B., Ci, L. 2005. Desertification assessment in China: An overview. *Journal of Arid Environments.* 63: 517-531.

Ykhanbai, H., Bulgan, E., Beket, U., Vernooy, R., Graham, J. 2004. Reversing grassland degradation and improving herder's livelihoods in the Altai Mountains of Mongolia. *Mountain Research and Development.* 24: 96-100.

Yu, F., Price, K., Lee, R., Ellis, J. 1999. Monitoring the interannual variations of the grasslands bordering the eastern edge of the Gobi desert in central Asia with time-series NOAA/AVHRR data. *Proceedings of PECORA 14th & Land Satellite Information III.* Denver, Colorado, 7–9 December 1999 (Bethesda: American Society for Photogrammetry and Remote Sensing). 172–181.

Yu, F., Price, K., Ellis, J., Feddema, J., Shi, P. 2004. Interannual variations of the grassland boundaries bordering the eastern edges of the Gobi Desert in central Asia. *International Journal of Remote Sensing.* 25: 327 – 346.

Zha, Y., Gao, J. 1997. Characteristics of desertification and its rehabilitation in China. *Journal of Arid Environments.* 37: 419-432.

Zhang, M., Borjigin, E., Zhang, H. 2007. Mongolian nomadic culture and ecological culture: On the ecological reconstruction in the agro-pastoral mosaic zone in Northern China. *Ecological Economics.* 62: 19-26.

Zhao, H., Zhao, X., Zhou, R., Zhang, T., Drake, S. 2005. Desertification processes due to heavy grazing in sandy rangeland, Inner Mongolia. *Journal of Arid Environments.* 62: 309-319.

APPENDIX A: Thesis Article in Mongolian

Мал аж ахуйн хэлбэр, арга ажиллагаа : Малчдын амьжиргаа, нүүдэл шилжилт, ялгаа Төв Азийн тал хээр дахь байгаль орчны талаархи үйл ажиллагаа

Troy Sternberg

(Pastoral mosaic: livelihood, mobility, differentiation, and environmental engagement on the Inner Asian steppe)

Article to be published in the Mongolian Journal ***Geographical Issues,*** Spring, 2009.

Мал аж ахуйн хэлбэр, арга ажиллагаа :
Малчдын амьжиргаа, нүүдэл шилжилт, ялгаа
Төв Азийн тал хээр дахь байгаль орчны талаархи үйл ажиллагаа

Хураангуй

Төв азийн нүүдэлчдийн аливаа зүйлд зохицож чаддаг амьдралын хэв маяг нь түүхийн бүхий л хугацаанд өөрийн оршин тогтнох чадварыг батлан харуулсаар иржээ. Өнөөдрийн эдийн засаг, байгаль орчны өөрчлөлт, малчдын мал маллах сонирхол зэрэг нь монголын уламжлалт мал аж ахуйг сорьж байгаа хүчин зүйлс юм.

Малчдын амьдралын хэв маяг, зан төрхийг ойлгоход хөдөөгийн тухай мэдлэг, сүүлийн үеийн арга ажиллагаа чухал юм. Бид өргөн хүрээний асуулгын аргаар явуулсан энэхүү судалгаагаар малчдын амьжиргааны хэлбэр, байгалийн харилцан хамааралыг олохыг зорилт болгосон. Судалгааны үр дүнгээс харахад малчдын амьдралд нүүдлийн тоо болон хоорондын зай аль аль нь чухал ач холбогдолтой байгаа нь харагдаж байна. Нэгдэлжих үеэс ялгаатай нь малчид одоо бие даан малаа хариулж, амьжиргааны олон янзын хэлбэрийг ашиглаж байгаа бөгөөд эдийн засгийн хүчин зүйл малчдын мал маллахад нөлөөлж, малчид мал маллах нь хүүхдүүийн хувьд ажил мэргэжил биш гэдгийг ойлгодог болжээ. Одоо ч гэсэн билчээрийн газрыг дундаа ашигладаг уламжлалт арга, бие даан шийдэр гаргах, нүүдэл хийх зэрэг асуудлууд малчдын дунд байсаар байна. Хөдөөгийн ялгарал нас, боловсрол, малын тоо, төрөл, байрлал зэргээр илэрч байна. Усны нөөцийн хомсдол, бэлчээрийн талхлалт, хур тунадас багасах зэрэг байгалийн хүчин зүйлс, амьжиргааны зардал, малчдын мал маллах сонирхол өөрчлөгдөх, засгийн газрын дэмжлэг дутагдах зэрэг нийгэм эдийн засгийн хүчин зүйлс ч оршсоор байна. Малчдын оролцоог дэмжих, орчин үеийн нийгмийн хөгжилтэй хөл нийлүүлэх, боловсрол, технологи, тээврийн хэрэгслийг ашигласнаар 21-р зуунд хөдөөд амьдралд тогтвортой байх болно. Мал маллах бодот шаардлагыг хүлээн зөвшөөрөх, шийдэхэд өнөөгийн болон цаашдын бодлого, менежмент, хөгжил дэвшил үр дүнтэй гэж тодорхойлсон.

Түлхүүр үг: мал аж ахуй, нүүдэл, амьжиргаа, ялгарал, байгаль орчин, монгол, хээр тал

Оршил

6500 жилийн малчдын хичээл зүтгэлийг харуулсан мал аж ахуй монголын тэгш өндөрлөг талд мянган жилийн турш хөгжсөөр ирсэн бөгөөд сүүлийн үед мал аж ахуйн хөгжилд дэвшил гарсан. /мандзу2008/ Түүхийн бүхий л хугацаанд амьжиргааны уламжлалт хэлбэр нь улс төр, эдийн засгийн үндсэн өөрчлөлтөөс хамааралтай байсан байна. Өнгөрсөн зуунд уламжлалт мал маллах арга ажиллагаа нь феодализмаас социализмын хамтралын систем рүү шилжин өөрчлөгджээ. 1990 онд коммунизм нурснаар зах зээлийн эдийн засагт аажмаар шилжих нөхцөл бүрдсэн. /Фернандз 2008/

Зөвлөлтийн хамтрал устсаны дараа монголын мал аж ахуйд томоохон өөрчлөлт гарч, малчдын мал маллах дур сонирхол ч өөрчлөгдсөн. Зах зээлд суурилсан эдийн засагт шилжсэний дараа хөдөөгийн амьдралд засгийн газар үйл

ажиллагаагаа төвлөрүүлсэн бөгөөд мал аж ахуйн өнөөгийн ерөнхий нөхцөл байдлыг харуулан тавьсан нь судалгааны ажлын эхний үр дүн юм./Swift and Means 1998, PALD 1993/ Үүний дараа үндсэн сэдэв экологи, нийгмийн бодот байдал, эдийн засаг хөгжил дэвшлийн өөрчилсөн асуудлуудад чиглэгдсэн. Хөдөөд бэрхшээлтэй асуудал олноор бий болсноор мал аж ахуйн дотоодын хөгжил цэцэглэлт, нийгмийн асуудалд эзэлдэг тэргүүлэгч байр суурь алдагдсан юм. Засгийн газар малчдыг зөнд нь орхиж, хөдөөд бүх зүйл маш сайн байгаа, наад зах нь бүгд хэвийн байгаа гэсэн ойлголттой байсан нь мал аж ахуй харьцангуй хөгжиж байгаагийн илрэл юм. Хамтралаас хувийн өмчид шилжсэн шилжилт нийгмийг хамарсан ямар нэгэн замбараагүй байдал гарсангүйрээр явагдсан юм./Suttie 2005/

1990 оноос хойш малчин айл өрхийн тоо 75000-168000 хүртэл буюу 225 хувиар өссөн нь хээр талын малчдын амьдрах чадварыг харуулж байгаа хэдий ч засгийн газрын дэмжлэг хязгаарлагдмал байна. /Mongolin statistical yearbook 2005/

1990 оноос хойш дотоодын болон олон улсын үйл ажиллагаанд байсан асуудлууд нь мал хувьчлал, хоол тэжээлийн хүртээмж, бүтээгдэхүүний зах зээлийг бий болгох, хөдөөгийн засаг захиргааны бүтцийг байгуулах, орон нутгийн үйлчилгээ үзүүлэх зэрэг иргэний нийгмийн тухай ойлголтод чиглэгдэж, орлогын бусад эх үүсвэр жендер, уул уурхайн нөлөөлөл зэрэг өдөр тутмын бэрхшээлийг мал аж ахуйн асуудлаас тусгаарласан бйана. 1990 онд хөдөөгийн амьжиргааны асуудлыг шийдэж чадсан ч, усны хүртээмж, бэлчээрийн чанар зэрэг байгалийн бэрхшээлүүд байсаар байна. Ноос ноолуурын зах зээл, тээврийн хөлс, суурьшмал амьдрал, цаг агаарын өөрчлөлтөөс хамааралтай нүүдэл, бэлчээрийн талхлалт, уул уурхайн нөлөө зэрэг шинэ хүчин зүйлс бий болжээ. Бодит ашигтай эдийн засаг, засгийн газрын бодлогод хамааралтай байгаа хөдөөгийн амьжиргааны цаашид оршин тогтнох чадвар, хөдөөгийн өнөөгийн бодит байдлын тухай асуудлууд чухал. юм Малчдыг нэгэн төрлийн бүлэг анги давхарга гэж үзсээр ирсэн ч малчдын нийгмийн ерөнхий сонгомол төлөөлөлөөс сонгон авсан. Мал аж ахуйн үндсэн бүрэлдэхүүн болох мал, нүүдэл, экологийн шууд нөлөөлөл, бие даасан амьжиргааны хэлбэр өөрчлөгдсөөр байна. Бэлчээрийн нээлттэй системд шилжсэнээр тэдний хувийн үүрэг нэмэгдэж, засгийн газрын оролцоо буурч, газар эзэмших эрх, малын тоо өссөн бөгөөд экосистемийн өөрчлөлт, малын тоо, хөрөнгө, боловсрол, нас зэрэг дээр үндэслэсэн ялгарал бий болсон байна. Өнөөгийн мал аж ахуйн арга ажиллагааны тухай мэдлэг, тэгш бус байдалтай холбоотой бодлого, менежментийн арга замыг тодорхойлох чиглэлийг ойлгох асуудлууд нь үндсэн шийдвэрлэгч хүчин зүйлс болж байна. Энэ судалгаагаар малчдын өнөөгийн байдал, амьдралын туршлага, өнөөгийн арга ажиллагааны цаашдын үр дагаварыг судлахыг оролдлоо. Барууны орнуудын судалгааны байгууллагуудтай хамтарсан сүүлийн үеийн судалгаанууд нүүдэл, уул уурхайн нөлөө, эдийн засаг, боловсрол зэрэг нийгмийн хүчин зүйлс, экологийн мэдлэг, бэлчээрийн талхлалт, ус хөрсний онцлог шинж, алслагдмал байдал, ган зэрэг байгалийн хүчин зүйлсд чиглэгдсэн цогц асуудлыг бүхэлд нь багтаасан байдаг. /Fernandez-Gimenez 2000, Steiner-Khamsi and Stolpe 2004, Farrington 2005, Lise et al 2006, Sasaki et l 2007, Tsolmon et al 2008, Sternberg 2008/

Эдгээр нь илүү их мэдээллийг өгч байгаа хэдий ч мал аж ахуй, нийгэм, байгаль орчны талаарх өөрсдийн санал, үйл ажиллагаа зэрэг үндсэн асуудлуудыг зарим

талаар орхигдуулж байна. /Fernandez-Gimenez 2000/. Өнөөдрийн арга ажиллагаатай харьцуулахад нэгдэл нь 1990 оны бүдгэрсэн дурсамж, хээр талд түүх болон үлджээ. Өнөөдөр малчид нэг ижил бүлгийн хүмүүс биш, харин өнөө үеийн нүүдэлчдийн янз бүрийн арга ажиллагаа, дур сонирхолыг төлөөлж байгаа хүмүүс гэдэг таамаглал дэвшүүлсэн.

Энэ өгүүлэл нь өнөөдөр мал аж ахуй юу юунаас бүрдэж байгааг олж мэдэх, малчдын орон гэрийн асуудлыг авч үзсэн байна. Асуулгад малчид, хүрээлэн буй орчин, нүүдлийн хэлбэр, нийгэм эдийн засгийн хүчин зүйлс, цаашдын зөвлөмж зэрэг асуудлыг оруулсан болно.

2. Судалгааны хүрээ, арга зүй

2.1 Судалгааны хүрээ

Энэхүү судалгаагаар Монголын орны Төвийн болон өмнөд хэсгийн Өвөрхангай, Өмнөговь аймгуудын мал аж ахуйг байдлыг судалсан. болно Хагас тал хээр, говь цөлийг хамарч монголын төв хэсэгт оршдог судалгааны хүрээ / 46"N 103"E/ болох Өвөрхангай аймгийн хойд хэсэг Хангайн уулсаар хүрээлэгдсэн юм. Гурван сайхан уулаар хүрээлэгдсэн цөл хээрин бүсэд оршдог, судалгааны хоёр дахь бүс болох / 44" N 104"E/ Өмнөговь аймгийн зүүн өмнөд хэсгийг хамруулсан юм. Энэ судалгаанд хамрагдсан бүс нутаг далайн түвшнээс дээш 1000-200 метр өндөрт, хайрга чулуун гадаргуутай тэгш өндөрлөг газар оршдог./Hibig 1995/

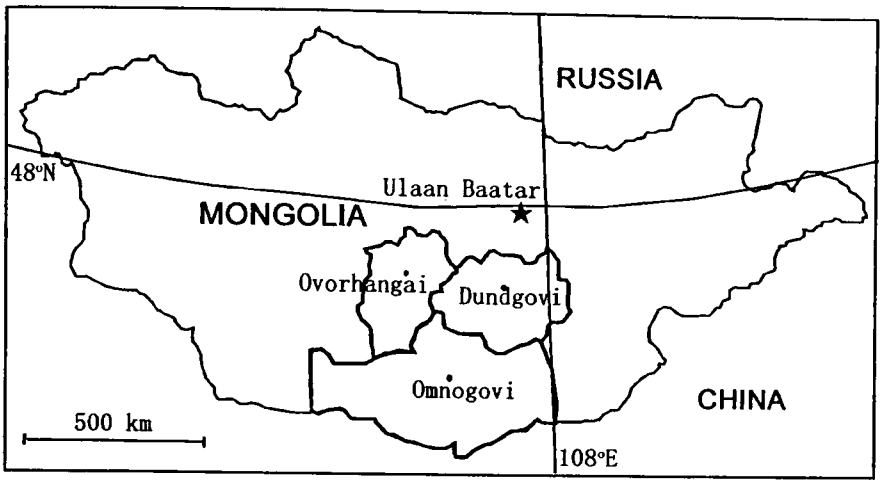
Судалгаанд тухайн нутгийн газрын гадаргын 50 хувийг хамруулж байгаа билээ. /Geographical Atlas of Mongolia 2004/ Монгол орон хуурай уур амьсгалтай бөгөөд богино халуун зун, урт хүйтэн өвөлтэй, зун нь гол хур тундас нь ордог. /Yu et.al 1999/

Эдгээр аймгийн хур тунадасны дундаж хэмжээ тус бүр ойролцоогоор 234- 121 мм байдаг. Монголд хур тундасны хэмжээ тогтворгүй байгаа нь эдапик /edaphic/, абиотик/abiotic/ хүчин зүйлээр ургамалын ургалтыг хязгаарлаж, тал хээрийн бэлчээрийн хөрсний үржил шим муудаж байгаа тэнцвэргүй байдлыг харуулж байна. / Fernandez –Gimenez and Allen –Diaz 20028 Begzsuren et l 20048 Retzer and Reudenbachi 2005, Munktsetseg et al 2000/

Жилд орох хур тундасны хэмжээ болон хур тундас орох хугацааны зөрүү нь мал, ургамалын төрөл зүйлд ихээхэн нөлөөлж, өвс ургамалын тархалтыг нилээд хэлбэлзэлтэй болгосон байна. Малын бүтцэд хонь, ямаа зонхилж байгаа эдгээр аймгуудад мал аж ахуйн уламжлалт хэлбэр байсаар байна.

Бүдүүвч судалгааны бүс нутгийн бүдүүвч зураг

Хүснэгт 1



Өвөрхангай, Өмнөговь аймгуудын байгаль, нийгмийн онцлог

Аймаг	**Өвөрхангай**	**Өмноговь**
Талбай	56	56
Газар	тал хээр –говь	говь
GPS	/ 46”N 103”E/	/ 44” N 104”E/
Өндөрлөг		
Метр дундаж	1707	1484
Жилийн дундаж мм	235	121
хур тунадас мин-мах	119-378	51-235
Дундаж температур		
нэгдүгээр сар/долдугаар сар	-14.4/-16.3	13.9/21.9
Усны цэг худаг/гадаргын ус	40-16	50-6
Малчид хүн ам %	57	49
Мал төрөл	хонь, ямаа, адуу, үхэр	ямаа, хонь, үхэр адуу
Малын тоо 2002/2006	2,623,300	909,000/1,555,700

2.2 Судалгаа

2006 оны 10 сараас 7 сар, 2007оны 5 сараас 2 сар хүртэл судалгааг судалгааны - 2 талбайд малчид удирдан явуулсан бөгөөд өмнөд зүгийн цөл хээрийн бүсээс хойд хэсгийн тал хээрийн бүсийг хамарсан өндөрлөг бус газрыг сонгон авсан. Аймгийн төвөөс сонгосон газар хүртэл үргэлжилсэн шороон замаар аялж явахдаа судалгааны ажлаа эхлүүлж, зам дагуу байрласан айл өрхөөс асуулга авсан юм. Энэ судалгааг аймаг тус бүрт 1 градусын өргөрөгөөс 2 градусын уртрагийн хооронд явуулсан. Энэ аргаар малчдыг өөр өөр газраас нийгмийн шалгууруас илүү газарзүйн байрлалаар нь сонгон авсан билээ. /аймаг бүрт n=112,56/

Тухайн бүс нутгийн малчдын мал аж ахуйн тухай ойлголтыг тодруулах зорилгоор үнэлгээ хийгдсэн юм. Энэ судалгааг 1990 оноос хойш малчдын

амьжиргаа, байгаль орчны харилцан хамаарал хэрхэн өөрчлөгдсөнийг тодорхойлохын тулд малчдын санал, асуулгын аргад тулгуурлан хийсэн. Судалгаа нь:

1/ малчдын бүтэц, онцлог

2/ байгаль орчны харилцан нөлөөлөл ялангуяа одоогийн болон өнгөрсөн үеийн усны нөөц, бэлчээр ашиглалт

3/ нүүдлийн хэлбэр

4/ нийгэм эдийн засгийн зэрэг хүчин зүйлүүдэд чиглэгдсэн юм. Мал аж ахуйн туршлагын талаарх цогц асуулга нь малчдад хувийн үзэл бодлоо илэрхийлэх боломжийг олгосон билээ. Асуулгад оролцогчид бүх асуултад хариулаагүй байна. Монголын малчдын өнөөгийн өдөр тутмын амьдралтай холбоотой ерөнхий асуудал энэхүү асуулгаас урган гарсан. Ургамалын нормалчилсан дифференциал индексийн /Normalized Difference Vegetation Index (NDVI)/ баримтын хоёрдахь эх сурвалжийг олохын тулд 1998-2006 оны хиймэл дагуулын мэдээг ашигласан юм. Өмнөх судалгааны бүс нутгийн ургамалын нормалчилсан дифференциал индекс (NDVI) баримтыг газар дээрх судалгаагаар гаргаж ирсэн. /Sternberg et al . *in review* /

30 өдрийн тоон үнэлгээг 2006 оны 4-10 сарын турш газар бүрт тооцож хийсэн билээ. Жил бүрийн ургамалын нормалчилсан дифференциал индексийг (NDVI) олохын тулд үр дүнг нь дунджилсан. Ургамлын нормалчилсан дифференциал индексийг (NDVI) хязгаарлахдаа түүнийг өвс ургамал, хур тунадасны тухай малчдын ойлголттой холбож үзэн газрын тархац, өвс ургамалын тооцоо хийхэд ашигласан байна. /Richard and Poccard 1998/

Мал аж ахуйн арга ажиллагааг малчдын онцлог, байгаль орчны харилцан хамаарал, нүүдэл, нийгэм эдийн засгийн хүчин зүйл гэсэн сэдвүүдээр бүлэг болгон ангиллаа.

80 өгөгдөхүүн доторх ач холбогдолтой харилцан хамаарлыг олохын тулд SPSS-14.0 –ийг ашиглаж баримтыг задлан шинжилсэн. /Chicago Il / Ангилал дотор байгаа хувилбаруудад нөлөөлж байгаа нөлөөлөлийг үнэлэх зорилгоор зонхилох хүчин зүйлсийг дахин судалж, өгөгдөхүүн бүрээр гол тодорхойлогчийг олохын тулд шугаман буцаалтын аргыг хэрэглэлээ.

Үндсэн бүрэлдэхүүний анализ

Анхны мэдээлэлийг илүү их боломжтой хэмжээгээр нь хадгалахын тулд үндсэн бүрэлдэхүүний анализыг илүү их хянаж болох хэмжээгээр баримтыг багасгахад мэдээлэлийг хялбарчлах аргыг ашиглалаа. Тэдгээрийг ангилахад үндсэн бүрэлдэхүүний анализ /Principal Component Analysis (PCA)/ нь харилцааны бүтцийг тодорхойлж, хамгийн их зөрүүг олсон (Field 2005). Энэ судалгаанд малын тоо, хонины эквивалент нэгжийг /Sheep Equivalency Units (SEU)/ малын төрлийг тодорхойлоход хэрэглэсэн. Бод мал бог малаас илүү их жин эзэлж байсан нь

/ тэмээ 7, адуу 6, сарлаг 5/, /хонь 1, ямаа 0,9/ сүргийн бүтцийг сайн харуулж байна. / Geographical Atlas of Mongolia-2004/

Малчдын үндсэн хөрөнгө болох мал нь орлогын эх үүсвэр. Малын тоо өсөж багаа явдал нь эдийн засгийн хөгжлийн гол үзүүлэлт болж байна. /Johnson et al/

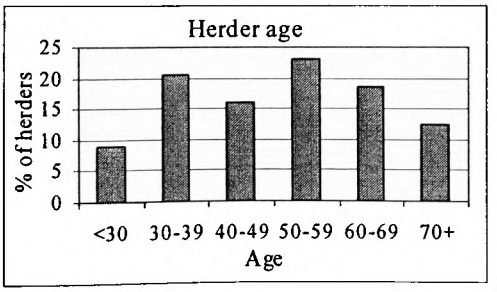
3. Үр дүн

Мал маллах хувь хүний онцлог, туршлага малчдын дунд олон янз байдаг. Нас, туршлага, малын тоо, нүүдэл, нүүдэл хийсэн зай, боловсрол, зэрэг малдчын дунд байдаг ялгааг харуулж байна. Хувьчлалын талаарх бодол, ус хэрэглэх боломж, нүүдлийн хяналт, засгийн газрын хяналт зэрэг асуудлыг нэгтгэсэн. Асуулгад оролцогчдын үзэл бодол тогтворгүй байгаа явдал нь малчдын туршлага, хөрөнгө, ойлголтын ялгааг харуулж байна. Мал, нүүдэл болон шилжилт, нүүдлэх зай, боловсрол, тээврийн хэрэгслийн эзэмшил зэрэг үндсэн хүчин зүйлс болж байгаа гэж дүгнэлээ. Амьжиргааны түвшин, мал малласан жил, насны үүргийн оронд бие даасан хөрөнгийн хэмжээ болдог.

3.1 Малчдын онцлог шинж

Монголын насанд хүрсэн хүн амын бүдүүвчээс харахад малчид настай голдуу байна. Малчдын 14% нь 70 аас дээш, энэ насны бүлэг нийт хүн амын 2,5 хувиас бүрдэж байна.

Хүснэгт 2 малчдын тэн хагас буюу 48 хувь нь 5-8 жилийн боловсролтойг харуулж байна. Малчид социализмын үед бүрэн дунд боловсролыг эзэмшдэг байжээ. Нас, болон боловсролын хооронд сөрөг харилцан хамаарал / p-0,001/ байгааг харуулж байна. Мал малласан жил нь 1990 онд социализмаас капитализмд шилжсэний дараа асуулгад оролцогчдын хагас буюу 58 хувиас илүү олон хүн малчин болсныг харуулж байна. Мал малласан жил нь нас болон өвөлжөө эзэмших газрын гэрээтэй холбоотой. Малчдыг газар эзэмших эрхтэй болгосон ч мал малласан жил нас, боловсрол, тээврийн хэрэгслийн эзэмшилд сөргөөр нөлөөлж байна. *Малчид өмнө нь машин, мотоциклтэй байсангүй*, харин одоо малчин айл өрхийн 73 хувь нь хувийн машинтай болсон байна. Малчид жижиг машин болон ачааны машинаас /29%/ илүүтэйгээр мотоциклийг /44%/ түгээмэл хэрэглэж байна. Бага өртөгтэй хятад мотоцикль хэрэглэх үзэгдэл түгээмэл болжээ. Зарим талаар говьд тэмээг уналга тээвэрт хэрэглэх болжээ. Малчдын 52% нь газар эзэмшдэг бөгөөд 700 м2 (Fernandez- Gimenez and Batbuyan 2004) өвөлжөөг гэрээгээр эзэмших явдал хөдөөд нийтлэг үзэгдэл болсон байна. Газар эзэмших гэрээ нь хэдийгээр мал маллах хугацааг нэмэгдүүлсэн /p-0,005/ боловч, малын эквивалент нэгж (SEU), боловсролтой (P=0,001) сөрөг хамааралтай байна



Бүдүүвч 2. Малчдын нас

Хүснэгт 2. Малчдын боловсрол

Боловсрол (жилээр)	%
үгүй	7
1 - 4	17
5 - 8	48
9 - 10	13
Коллежын боловсрол техникийн	9
Дээд боловсрол	5

Хүснэгт 3. Мал малласан жил

Малласан жил	%
10 хүртэл	16
10 - 19	42
20 - 29	14
30 - 39	8
40 - 49	12
50-с дээш	8

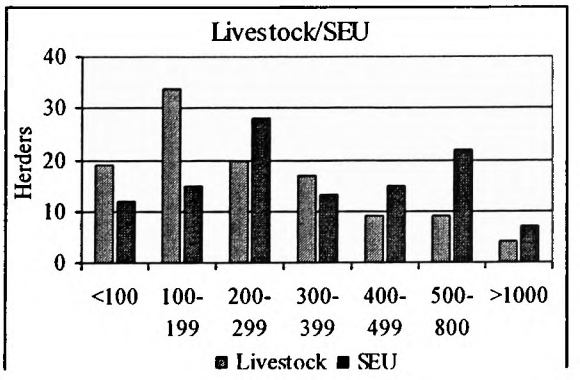
Малын тоо баримтаас харахад судалгаанд оролцсон малчдын 47% нь 200-аас дээш малтай, малын тоо нь амьжиргааны түвшин доогуур байгааг харуулж байна. /Johnson et al 2006/ (Хүснэгт 3)

Асуулгад оролцогчдын 33 хувь нь 200-400 малтай байна. 20% нь 400-с дээш малтай байгаа нь амьдрал сайжирсныг харуулж байна (Janzen and Barzagur 2003). Хонины эквивалент нэгжээр /SEU/ судалгаа хийхэд малчдын тоо 24 % хүртэл буурсан байна. Малын бүтцийн хувьд Өвөрхангайд хонь, Өмнөговьд ямаа зонхилдог. /бүдүүвч 4/

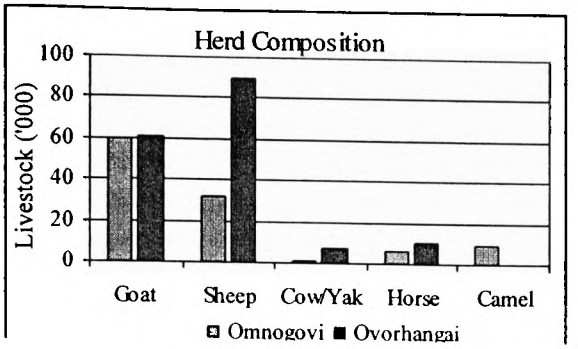
Нас нь малын тоо, хонины эквивалент нэгжтэй сөрөг харилцан хамааралтай (P = 0.01) ба хонины эквивалент нэгж /Sheep Equivalency Units (SEU)/ (P = 0.05) байна. Иймд малын тоо нэмэгдэхэд орлого буурч байгаа нь харагдсан. Хэдийгээр хөрөнгийн хэмжээ бага байсан ч настай малчид амьдралынхаа ихэнх үеийг мал маллахад зориулж өөрсдийн хувь нэмрээ оруулжээ. /p-0,005/

" *Малчны амьдрал сайхан. Бидэнд хэцүү үе, сайхан үе ч байсан. Би дуртай газар руугаа нүүж чаддаг*" . " (нэргүй судалгаанаас 2007).

Бүдүүвч 3: Малын тоо ба Хонины эквивалент нэгж /sheep equivalency unit/



Бүдүүвч 4: Сүргийн бүтэц



3.2 *Байгаль орчны харилцан хамаарал*

Энэ судалгааны материал нь тарчиг өвстэй газрын хүрээнд хязгаарлагдмал нөөцийг хангаж тал хээрийн газрын хүрээлэн буй орчны онцлогийг нэгтгэн харуулсан болно. Бэлчээрийн чанарын талаарх малчдын бодлыг өөрчилснөөр тэдний 1/3 нь чанар нь сайн, малчдын хагас хувь нь муу, маш муу гэж хариулсан бөгөөд ихэнх малчид хур тунадас тэдний хувьд муу зүйл гэж хариулжээ.
Сүүлийн 10 жилд өвсний бүтэц муудсан гэж малчдын 84% нь тодорхойлсон бол 7 % нь бэлчээр сайжирч байгаа гэж хэлсэн.

Хүснэгт: Бэлчээрийн чанар, хур тунадас

Хүснэгт 4. **Бэлчээрийн чанар ба хур тунадас** (тухайн жилд)

	Бэлчээр - %	*Хур тунадас - %*
Маш сайн	1	0
Сайн	31	6
Боломжийн	20	11
Муу	40	73
Маш муу	8	10

" Сант суманд би усыг мөрөөдөж байлаа. Харин одоо энд Сантын усыг мөрөөдөж байна"
Ус хөдөөгийн малчдын үндсэн хэрэгцээ бөгөөд нүүдэл хийх гол шалтгаан болдог. Худаг болон ус байгаа газрын ойролцоо малчдын бөөгнөрөлийг харж болно. Малчдын бараг тэн хагас нь буюу /47%/ нь худгаас нэг километраас ойр зайд амьдардаг бол 70 % усны эх үүсвэрээс 2 километрын дотор амьдардаг. /хүснэгт5/
Ихэнх малчид усаа худгаас авдаг. /хүнэгт6/ Энэ нь уснаас үүдэлтэй малчдын бөөгнөрөл, мал, айл өрхийн хоорондын зөрчил тэмцлийг харуулж байна. Хувийн усны эх үүсвэрийг ашиглаж малаа усалж байгаа дундаж тоо нь 1435. Энэхүү бөөгнөрөлийн үр дүнд NDVI судалгаагаар, өвс ургамалтай газрын

гадаргын усны нөөц их болон /p=0,001/ өндөрлөг газраа илүү их байгааг харуулсан. /p=0,001/

Малчдын 80 % нь энэ газар усны нөөц ширгэж байгааг харуулсан. Газрын гадаргын ус болох гол, горхи, булаг худгаас илүү их алга болж байна /хүснэгт5/. *" Намайг хүүхэд байхад маш их устай олон гол байсан харин одоо ус нь багассан бөгөөд жижиг голууд нь ширгэчихсэн гэсэн"* малчдын хэлснээс үзвэл худагнуудаас илүү газрын гадаргын ус болох гол, горхи, булаг ширгэсэн байна. Эвдэрсэн худагнууд, хур тунадасны хэмжээ бага байгаа асуудал, гол, горхи, булаг ширгэж байгаа асуудал, дэлхийн дулаарал, уул уурхайн үйл ажиллагааны нөлөө зэрэг нь усны цэгүүд багасаж байгаагийн шалтгаан болсныг харуулж байна. 1990 оноос хойш усны нөөцин эх үүсвэр ширгэж байгаа явдал, инженерийн худаг/80%/, гар худаг /40%/-ийн тоо багасаж байгаа асуудлууд нь бэлчээр, малын бөөгнөрөл, бэлчээрийн талхлалт нэмэгдэж байгаа, бэлчээрийн даац буурч байгаагийн шалтгаан юм. /Tanaka et.al 2005/

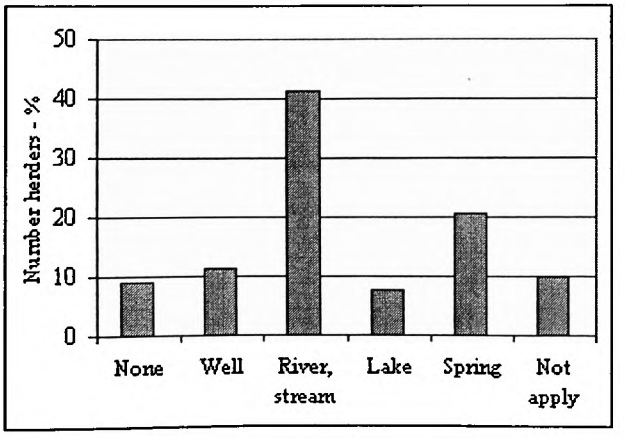
Бүдүүвч 5 Усны эх үүсвэр ширгэж байгаа талаарх малчдын ойлголт

Хүснэгт 5.

Km	Усанд хүрэх зай %
< 0.5	37
0.5-1	10
1 to 2	24
2 to 3	11
3 to 4	13
5+	6

Хүснэгт 6. Усны нөөц

Төрөл	Бүгд %	Өмнөговь %	Өвөрхангай %
Худаг	80	89	71
Гадаргын ус	20	11	29



Хүснэгт 5 Уёны нөөц багасаж байгаа талаархи малчдын хандлага

Хүснэгт 7. Усны ойролцоо байх айл болон малын тоо

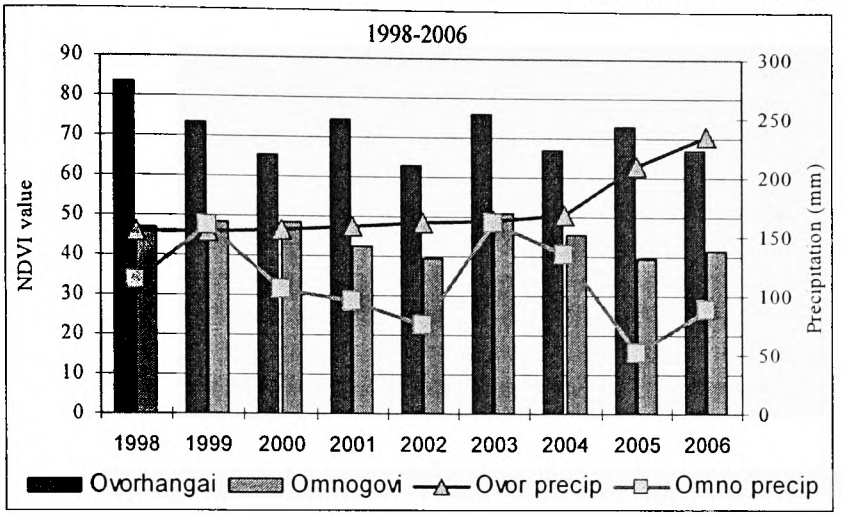
1 усны нөөцийн хажууд байх айл	Усны нөөц болон худгийн тоо	L1 усны нөөцийн хажууд байх мал	1 өрхийн талын тоо
1	16	285	277
2	18	462	228
3	16	880	294
4	7	1207	248
5	16	1715	334
6	10	2167	311
7	4	2500	405
8	3	1967	150
10+	8	2536	247
20+	7	6000	217

Засгийн газар хөдөөгийн усны хангамжийн асуудалд хязгаарлагдмал үүрэгтэйгээр оролцдог. Нэг малчин " *Би хэзээ ч Засгийн газар хаа нэгтээ худаг барисан гэж сонсож байгаагүй.* " гэж хэлсэн бол харин зөвхөн хоёр малчин л "*...Засгийн газар худаг засаж байгаа*" гэж хэлжээ. Үлдсэн нь худгийн мотор солих зэрэг засварыг Засгийн газрын үүрэг гэж боддог гэсэн саналаа хэлсэн. Үүнтэй холбоотойгоор Засгийн газар усыг зохицуулах үүрэг хүлээдэггүй гэсэн дүгнэлтэнд хүрсэн билээ.

Одоогоор малчид бэлчээрээ хамгаалах ажлыг өөрсдөө хийдэг. Үүнд хувираа худаг барих, тухайн газар руу нүүж ирэх малчдын тоог хязгаарлах, бэлчээрийн ойролцоо байдаг жуулчны баазуудад гүний худаг барих, хэрэглэх боломжийг хориглох зэрэг асуудлууд багтана. Усны үнийг засгийн газраас тогтоодоггүй боловч инженерийн худгийн хөдөлгүүрийн түлшний төлбөрийг авдаг. Энэ нь усыг хүргэж өгсний төлбөр бөгөөд усыг үнэгүй бараа гэж үздэг.
Ус нөөцөөс хол байгаа явдал нь мал маллахад илүү том талбай хэрэгтэй гэсэн санал дэвшүүлсэн. Үр дүнд хонины эквивалент нэгж SEU /p=0,05/ илүү өндөр байсан. Энэ нь малыг онцлон харуулж байгаа ч илүү том бэлчээр шаардлагатай болдог. NDVI –р тодорхойлсноор аймгийн төвүүдийн хур тунадас болон байгалийн орчны байдал нь малчны хэтийн төлөвийн харьцууллыг гаргасан байна. Газрын гадаргын үнэлгээ нь сүүлийн 9 жилийн турш харьцангуй тогтвортой байгаа бөгөөд 2002 онд хамгийн доогуур үзүүлэлттэй байсан байна. Өвс ургамалын ургацын түвшин нь хязгаарлагдмал ба байнгын өөрчлөлт байгааг харуулсан. Гэсэн хэдий ч өвс тарчиг байгаа явдал нь зөвхөн өвс ургамлын талаарх малчдын ойлголтыг бус харин өвсний бүтэц, төрөл, үржил шим зэргийг харуулсан. Харин 2 аймагт хур тунадасны хэмжээ ялгаатай байна. Ялангуяа Өвөрхангай илүү чийглэг уур амьсгалтай байсан харин хур тунадасны хэмжээ адилхан байсан. Хоёр аймгийн малчид " *хур тунадас муу, маш муу байна* " гэжээ. Судалгааны үед Өвөрхангайд хур тунадасны хэмжээ бага зэрэг их байсан бол Өмнөговьд хэвийн хэмжээнээс доогуур байсан.

Бүдүүвч 6

Хур тунадас ба ургамалын нормалчилсан дифференциал индексийн тоо баримт 1998-2006/Normalized differentiation vegetation index/



Бэлчээр муудаж байгаа үзүүлэлтэд малын бөөгнөрөлийн талаарх малчдын бодол, малд нөлөөлж байгаа байдал, бэлчээр, ажлын нөхцөл, ялангуяа хаврын элсэн шуурга ордог(Okayasu *et al.* 2007). Асуулгад оролцогчдын 70 хувь нь элс бол санаа зовоож байгаа асуудал, элсний тархалт, хэмжээ нэмэгдэж байгаа нь малд нөлөөлөх байдал, бэлчээрт үзүүлж буй сөрөг нөлөөлөл, элсэн шуурга ихсэж байгааг харуулж байна. 4 малчин ".. *элсний үр уршиг ямар ч улиралд адилхан. 26 %- нь элс асуудал биш* гэсэн боловч хэн нь ч элсний нөлөөлөл нэмэгдэж байгаа тухай дурдаагүй. Элсний асуудал хүндэрсээр байгаа гэсэн үзэл газрын гэрээтэй малчдын дунд элбэг байдаг. Малдчын 39 хувь нь газрын гэрээгүй. Газрын гэрээтэй малчдын тоо 3 дахин нэмэгдсэн. Элс бол асуудал биш гэж боддог малчид нүүдэл бага хийдэг байсан ч цаашид бусад малчдаас илүү олон нүүдэл хийдэг болсон байна.

Хүснэгт 8. Элсний асуудал – Хариулагчдын %

	бүгд	Өмнөговь	Өвөрхангай	Бэлчээр эзэмших	Бэлчээр эзэмших	Хэдэн удаа нүүдэллэдэг	Нүүх газрын зай (km)
Асуудал биш	26	23	29	13	39	3	51
Арай гайгүй	0	0	0	0	0	~	~
Адилхан байна	4	6	2	6	2	7	32
Улам мууд	70	71	69	81	59	4	39

3.3 Нүүдэл,шилжилт

"Монголчууд нүүдэлчин ард түмэн тиймээс хур тунадас ихтэй, бэлчээр сайтай нутаг руу нүүдэл хийдэг. Нүүдэл хийх нь мал аж ахуйн системийг тогтвортой байлгах нөхцөл болдог. /Fernandez-Gimenez and Sayre 2003/ Бид нүүдэллэх зай, давтамж, тээврийн хэрэгсэл, өнгөрсөн үеийн амьжиргааны хэлбэр, нүүдлийг зохицуулах засгийн газрын хяналт, малчдын дунд байгаа бодит тэмцэл, зөрчил, газар эзэмших эрх зэрэг нүүдэл хийхэд нөлөөлдөг хэд хэдэн хүчин зүйлийг судалсан. Малчдын хувьд хамгийн чухал харилцан хамаарал нь орлого нэмэгдэх, малын өсөлт зэрэг нүүдлийн ач холбогдлыг харуулдаг зүйлс байдаг. Дээд боловсролын түвшин, өнөөгийн амьжиргааны нөхцлийн талаарх ойлголтыг илүү их тусгах, нүүдэл хийхэд түлхэц болдог тээврийн хэрэгслийн эзэмшил, ихэвчлэн хол нүүдэл хийдэг малчдыг оруулсан.Ургамалын нормалчилсан дифференциал индекс /Normalized differentiation vegetation index NDVI /, усны эх үүсвэр, өндөрлөг газар зэрэг асуудлууд нь мөн нүүдэл хийх шалтгаан болдог. Ургамалын нормалчилсан дифференциал индексээр судлахад бэлчээр багатай, худгаас хамааралтай малчид нүүдэл хийх нь илүү их ажиглагджээ.

Хүснэгт 9. Нүүдэллэх тоо болон мал маллах ялгавартай байдлын ач холбогдол

Ач холбогдол (P=)	Мал /SEU	Зай	Тээврийн хэрэгсэл	Боловсрол	Усны нөөц	NDVI	Өндөр
Нүүдэллэсэн тоо	0.01	0.01	0.01	0.01	0.05	0.05	0.05

"*Олон удаа нүүдэл хийдэг байсан ч би тоог нь тоолж байгаагүй*". Ихэнх малчид нүүдэл хийдэг өнгөрсөн үеийн хэлбэр, арга ажиллагаанд эргэлздэг байна. Арван жилийн өмнөх нүүдэллэх хэлбэр, арга ажиллагааг мэддэг малчдын жил бүрийн нүүдэллэсэн тоо 58%-иар өссөн. Суурьшмал амьдрал өмнөх үеэсээ буурсаар байна. /хүснэгт 10/

Хүснэгт 10. Нүүдэллэсэн тооны өөрчлөлт

Өнөөдөр / 10 жилийн өмнө	%
Өссөн	58
Хэмжээндээ	21
Буурсан	21

Хүснэгт 11. Нүүдэллэсэн тоо

Нүүдэл	Өнөөдөр %	10 жилийн өмнө %
0	16	19
1 - 2	26	21
3 -5	36	48
6 - 8	10	12
10 - 12	10	0
14 +	3	0

Нүүдлэлэх дундаж тоо нь 4 байсан үед малчдын 42 % нь хоёр удаа, түүнээс олон нүүдэл хийдэг бөгөөд 1/6 нь огт нүүдэл хийдэггүй байсан. Энэ бүлгийн хувьд нүүдэл хийх нь мал өсгөх, малын чанарыг нь дээшлүүлэх хүчин зүйл болдог байна. Нүүдэллэх замын зай нь малын тоо, тээврийн эзэмшлийн хувьд чухал үзүүлэлт бөгөөд усны эх үүсвэрээс хол байгаа асуудал, боловсролтой харилцан хамааралтай. Малчид усны нөөцөөс хол амьдардаг ба дээд боловсролтой малчид магадгүй илүү олон нүүдэл хийдэг.Асуулгад оролцогчдын хагас нь жил бүр 20-аас олон нүүдэг бөгөөд бараг жилд 3 удаа 50 километрээс хол зайд нүүдэл хийдэг. Нүүдлийн хэлбэр (P = 0.05), тээврийн хэрэгслийн эзэмшил хоорондоо харилцан хамааралгүй байгаа боловч малчдын 1/3 нь тээврийн хэрэгсэлтэй, үүнтэй адил тооны малчид нүүдэл хийхийн тулд тээврийн хэрэгсэл хөлсөлдөг байна. /хүснэгт13/

Машин хөлсөлж нүүх үзэгдэл хөдөөд хамгийн түгээмэл байдаг. Нүүдэл хийхийн тулд нүүх зайнаасаа хамаарч малчин айл өрх нэг буюу түүнээс дээш малаар бензин солилцож нүүдэг. Монголчууд бэлчээрийг дундын өмч гэж үздэг. Малчдад бэлчээр чөлөөтэй гэсэн үзэл малчдын дунд элбэг тохиолддог. Ялангуяа ган, хүйтэн өвлийн улиралд. Нүүдлийг хянах асуудлыг малчид ихээхэн эсэргүүцдэг бөгөөд нүүдлийн талаар төрөөс ямар нэг хяналт тогтоож, зохицуулах арга хэмжээ авдаггүй гэж асуулгад оролцогчдын 91% хариулсан. Цөөн хэсэг нь өөр газар руу нүүхэд тухайн орон нутгийн удирдлагад татвар төлж зөвшөөрөл авдаг гэж хариулсан. 2% нь малчид өөрсдөө нүүдэл, шилжитийг зохицуулдаг байна. Зарим малчид өөрсдийнх нь газар нүүн ирж байгаа малчдын тоог хязгаарлах арга хэмжээ авдаг ч, энэ ховор тохиолддог. *"Надад тэдэнд энэ газрыг орхиод яв гэж хэлэх зориг байдаггүй. Учир нь бидэнд ч гэсэн бэлчээргүй болвол ийм зүйл тохиолдох болно".*

Хүснэгт 12. Нүүлэллэх зай

km	%
0	16
1 - 5	16
6 - 9	4
10 - 19	14
20 - 49	19
50 - 99	17
100 +	14

Хүснэгт 13. Нүүдэллэх тээврийн хэрэгсэл - %

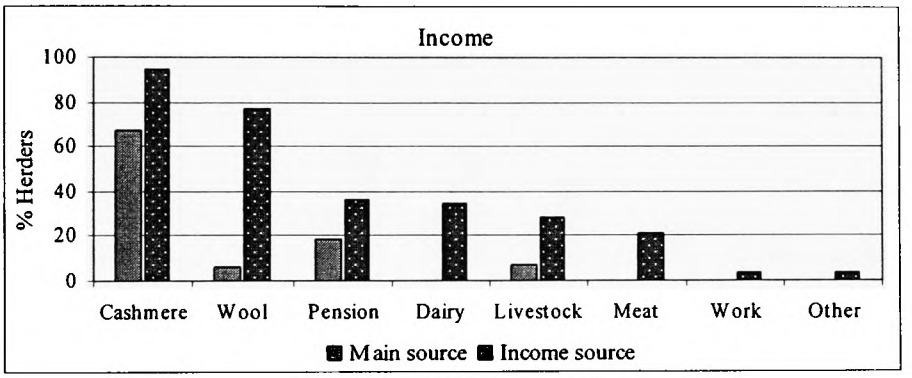
Хувийн эзэмшлийн тээврээр	12
Мотоциклээр	1
Үхэр, тэмээ болон морин тэргээр	9
Түрээсэлсэн тээврийн хэрэгсэлээр	73
Трактороор	4

3.4 Нийгэм-эдийн засгийн хүчин зүйл

Малчдын амьжиргааг тодорхойлох үндсэн хүчин зүйл нь нийгэм- эдийн засгийн үндсэн үзүүлэлт юм. Энэ бол бүтээгдэхүүний өртөг, орлогын хоорондын тэнцвэр юм. Малчдаас авсан асуулгаас харахад малчдын орлогын үндсэн эх үүсвэр нь ноолуур байна. /бүдүүвч 7/

Малчдын 95% нь ноолууraас орлого олдог. 2/3 –ын хувьд ноолуур орлогын гол эх үүсвэр болдог. Хонь, тэмээний ноос хоёр дахь хамгийн түгээмэл орлогын эх үүсвэр боловч өндөр үнэд хүрдэггүй ч хааяа орлогын үндсэн эх үүсвэр болдог. Тэтгэвэр, тэтгэмж бас үндсэн орлого болдог. Малчдын 19% нь тэтгэвэрээс хамааралтай байдаг. Гурван айл өрхийн нэгд нь тэтгэвэрийн хүн байдаг. Мал малчдын хувьд хамгийн үнэтэй хөрөнгө хэдий ч цөөн хэсэг нь /7%/ малыг орлогын үндсэн эх үүсвэр гэж үздэг. Малчдын гол амь зуулга болох мах, цагаан идээ малчдын орлогод зонхилох нөлөө үзүүлдэггүй. Малчдын амьдралд гадны дэмжлэг тусламж хэрэгтэй гэсэн саналыг малчид гаргаж ирсэн.

Бүдүүвч 7 Малчдын орлогын эх үүсвэр



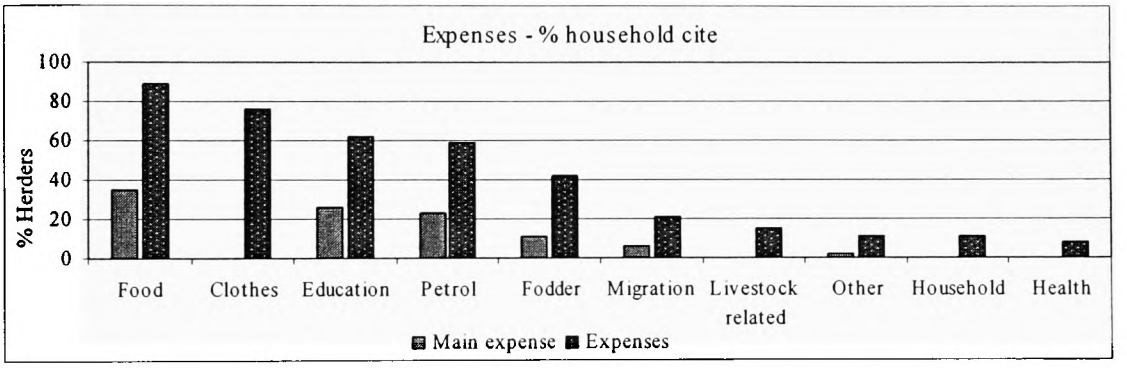
Хүснэгт 14. Орлогын талаархи ойлголт - %

Маш сайн	1
Сайн	13
Зүгээр дээ сайн	55
Муу	27
Маш муу	1

Хоол хүнс, хувцас, хүүхдийн боловсрол, түлш зэрэг нь малчдын амьжиргааны үндсэн зардал юм. /Бүдүүвч 8/ Үүний дараа малын тэжээл, нүүдэлтэй холбоотой зардал, вакцин, малын эмчийн хөлс гэсэн зардлууд ордог. Хамгийн нийтлэг амьжиргааны зардлыг ерөнхийд нь ангилвал хоол хүнс/ 35%/, боловсрол/26%/, түлш/23%/ тус бүр байна. Эндээс харахад амьжиргааны хамгийн гол зардал нь хоол хүнс байгаа хэдий ч сүүлийн жилүүдэд хөдөөд болсон өөрчлөлт, шинэчлэл нь боловсрол, түлшийг амьжиргааны үндсэн зардал болсныг харуулсан. Сүүлийн арван жилд хоёр аймагт аль алинд нь анхан шатны болон дунд

сургуульд элсэгчдийн тоо өссөн/ 33%/, их сургуульд элсэгчдийн тоо ч гэсэн мөн адил өссөн байна. Хөдөөний оюутнууд сургалтын төлбөр төлөх шаардлага гардаг./Mongolian Statistical Yearbook 1989-20028 ibid.2007/ Хотын хүүхдүүдийн хувьд боловсролыг цаашдын ажил мэргэжлийн үндэс суурь гэж үздэг ба мал маллахаас дээр гэсэн бодолтой байдаг. Сургуульд элсэгчдийн тоо нэмэгдэж байгаа нь бод мал маллаж байгаатай харилцан хамааралтай. Бензин түлшний хэрэгцээний хувьд малдчын 60% тээврийн хэрэгсэл өргөнөөр хэрэглэж байгаа явдал нь мал аж ахуйн хэлбэр, арга ажиллагаанд гарсан өөрчлөлтийг харуулсан. Нэг малчны хэлснээр өмнө нь малчид малаа мориор хариулдаг байсан бол харин одоо мотоциклоор хариулж байна. Үндсэн зардал болох тээврийн хэрэгслийг хэрэглэх явдлаас үүдэлтэй. Зургаан жилд гурав дахин өссөн бөгөөд энэ хэсэгт үйл ажиллагааны зардлыг харуулсан. Судалгааны ажлын үед монголд нэг литр бензиний үнэ америкаас илүү өндөр байсан. Тээврийн хэрэгсэл эзэмшлийг /p=0,05/бог мал маллаж байгаатай холбож үздэг. Амьжиргааны хоёрдогч үндсэн зардалд малын тэжээл, нүүдэл хийхэд гарсан зардал, айл өрхийн зардал орно.

Бүдүүвч 8 Малчдын зардлууд



" Хэн танд тусалдаг вэ? Ерөнхийлөгч Н.Энхбаяр танд туслдаг уу? Үгүй, юунд ч тусладаггүй" /инээлээ/

Тэнд энэ талаар юу ч дурдаагүй нь засгийн газрын үүрэг, үйл ажиллагааны асуудлыг ойлгоход хэцүү байгааг харуулсан. Асуулгад оролцогчид засгийн газар мал аж ахуйд оролцогчийн үүрэгтэй байдаггүй гэж боддог, социализмын үед засгийн газар бүх зүйлд оролцдог байсан. Үүнтэй харьцуулахад өнөөгийн засгийн газар тун бага зохицуулалт хийн, хураасан татварыг багасгасан. Хөдөөгийн малчдын амьдралд зориулсан засгийн газрын дэмжлэг хөтөлбөр байхгүй учир энэ нөхцөл байдлыг өдөр тутмын амьдралд бага ч гэсэн хамааралгүй байгааг харуулж байна. Харин засгийн газрын үүргийн талаар " *Засгийн газар юу хийх хэрэгтэй вэ?"* гэсэн асуулт тавихад засгийн газар юу ч хийдэггүй гэсэн уламжлалт хариулт хэлж, засгийн газар юу хийх хэрэгтэй талаар хэд хэдэн санал дэвшүүлсэн байна. /хүснэгт15/

Малчдын хувьд гол санаа зовоож байгаа зүйл нь худаг барих, засварлах гэх мэт усны эх үүсвэртэй холбоотой асуудал. Иймд засгийн газрын үндсэн үйл ажиллагаа үүнд чиглэгдэх ёстой гэж хэлсэн. / Sternberg 2008/

Хоёр дахь санаа зовоосон асуудал бол малын тэжээл. Амьжиргаагаа дээшлүүлэхэд нь зориулж малчдад тусламж, итгэлийн мөнгө өгдөг. Энэ нь тэтгэвэр болон хүүхдэд сар бүр өгдөг итгэлийн мөнгө. /сард 3 доллар/

Сард 20 доллар өгөх нь боломжийн дэмжлэг байдаг гэж малчид хэлсэн. Зарим хэсэг нь мал маллахад засгийн газрын оролцоо байхгүй байгаа нь сайн зүйл гэж хэлсэн. Тэдний амьжиргаанд зориулсан бодлого, зохицуулалт байдаггүй, авахыг ч хүсэхгүй байгаагаа хэлсэн. " *Бид хөдөөний хүмүүс, засгийн газраас дэмжлэг авах шаардлагагүй* " гэсэн байна.

Бэлчээр гэх мэт байгалийн хүчин зүйлийг хамгаалах асуудал мал аж ахуйд зайлшгүй шаардлагатай. Учир нь хүний гараар байгаль орчны өөрчлөлт бий болдог. Хөрш улс болох хятадын туршлагыг судлах талаар саналаа хэлж, засгийн газраас бороо оруулах зорилгоор тэнгэр буудаж өгөхийг хүссэн. Асуулгад оролцогчдын цөөн хэсэг түлш, бензиний зардалд тусламж, дэмжлэг хэрэгтэй гэж хариулжээ.

Хүснэгт 15. Засгийн газрын үүрэг - %
(Доорхи зүйлээр хангах хэрэгтэй гэж хариулсан...)

Юугаар ч тусладаггүй	77
Ус	69
Тэжээл	28
Тусламж	17
Юу ч хүсдэггүй	12
Байгаль орчноо хамгаалах	12
Бороо оруулахын тулд үүл буудах	9
Бензин, түлш	6

Нүүдэл, бэлчээрийн өөрчлөлтийг зохицуулах ажлыг засгийн газар авч хэрэгжүүлдэггүй. Бэлчээр,усны төлөөх тэмцэл малчдын дунд тулгамдсан асуудал болсон. /Oyuntsetseg 2006/

Бидний хийсэн судалгаа энэхүү маргаан, зөрчил малчдын хамгийн их санаа зовоож байгаа асуудал биш гэдгийг харуулсан. 112 асуулгад оролцогчдын найм нь энэ маргаан тэмцэл нь бодит байдал дээр байдаг гэж хариулсан. Бэлчээртэй холбоотой маргааны тухай /4/, усны нөөцөд нөлөөлж байгаа уул уурхайн нөлөөлөл, нинжа гэж нэрлэгддэг жижиг талбайд олборлолт хийгчидтэй хийсэн тэмцлийн тухай /2/, жуулчны баазууд байдаг газарт гүний худгийн хэрэгцээг хязгаарласан маргааны тухай /2/ гэж тус тус хариулсан. Малчдын 93% маргаан тэмцэл хийсэн ч тэдний амьдралд нөлөөлөхгүй байгаа гэж хариулсан. Газрын хувьчлал малчдыг зөрчил тэмцэлд хүргэж байна гэдгийг ойлгодог болсон байна.

3.5 Статистик аналаиз -Үндсэн бүрэлдэхүүний анализ (Principal Component Analysis) /буцаалт/

Үндсэн бүрэлдэхүүний анализыг /PCA/ илүү бодит тоонд тохируулж олон баримтыг багасгахад хэрэглэдэг. Үндсэн бүрэлдэхүүний анализ тусдаа тэнхлэгийн тоогоор үндсэн бүлэг рүү өгөгдлийн дотоод бүтцийг цэгцлэн оруулдаг. Дүгнэлтийн зөрүүг тайлбарлах дараалалыг багасгадаг. Энэ

судалгаагаар үндсэн бүрэлдэхүүн өгөгдлийн зөрүүний 31%-ийг эзэлж байхад 3 үндсэн бүрэлдэхүүн хэсэг нь хамтдаа судалгааны 72%-ийг эзэлж байна. /Хүснэгт 16/

Хүснэгт 16 Үндсэн бүрэлдэхүүний анализ

Тайлбарласан нийт ялгавар

Бүрэлдхүүн	Эхлэлийн Eigenvalues		
	Нийт	Ялгаврын %	
1	2.51	31.373	31.373
2	2.22	27.751	59.124
3	1.05	13.154	72.278
4	0.76	9.436	81.714
5	0.59	7.405	89.119
6	0.49	6.103	95.222
7	0.26	3.279	98.501
8	0.12	1.499	100

Бүрэлдхүүний матрикс

Component Matrix

	Бүтэц		
	1	2	3
аймгууд	-0.63	0.57	0.08
Хонины эквивалент нэгж /SEU/	0.38	0.81	-0.30
нүүдэл	0.66	0.25	0.32
ургамалын нормалчилсан дифференциал индекс/NDVI/	-0.70	0.50	0.29
Боловсрол	0.39	0.23	0.78
Тээврийн хэрэгсэл	0.59	0.24	0.14
Өндөр /altitude/	-0.68	0.34	0.19
Мал	0.28	0.84	-0.35

Гэсэн хэдий ч судалгааны 1/3-ийг гурван үндсэн прадигмаар авж үзлээ.Зонхилох хүчин зүйлийн бүрэлдэхүүний эерэг бүлэг болох нүүдэл, хонины эквивалент нэгж, тээврийн хэрэгсэл, сөрөг бүлэг болох ургамалын нормалчилсан дифференциал индекс, өндөрлөг газар, аймаг харилцан хамааралтай. Эдгээр нь судалгааны материалын бараг 1/3-ийн эзэлж байна. Хоёрдахь бүрэлдэхүүн болох хонины эквивалент нэгж, мал нь боловсрол , нүүдэл, тээврийн хэрэгсэлтэй бага зэрэг эерэг харилцан хамааралтай. Гуравдахь бүрэлдэхүүнд боловсрол дараа нь нүүдэл, нормалчилсан зөрүүний өвсний индекс ордог. Хонины эквивалент нэгж, мал сөрөг хамааралтай.

Хүснэгт 16 Үндсэн бүрэлдэхүүний анализ

Малчдын хариулт өгсөн зонхилох хүчин зүйлээр хир үр дүнтэй байгааг тодорхойлох зорилгоор өгөгдлүүдэд анализ хийлээ. Өгөгдөхүүн бүрээр харилцан хамааралтай хүчин зүйлийг судалсан. Гол онцлогийг нь тодорхойлсон эдгээр баримтыг сайн ойлгохын тулд шугаман буцаалт /linear regression/ хийсэн. /хүснэгт17/

r^2 – нь судалгааны баримт тусдаа өгөгдсөн хүчин зүйлийг хэрхэн тодорхойлж байгааг харуулна.Малын тоо ($r^2 = 0.94$) ,Хонины эквивалент нэгж ($r^2 = 0.80$) нь r^2 үнэлгээ их байсан нь жагсаалтад багтсан бүрэлдэхүүн хэсгүүдийн гол өөрчлөлтийн шалтгааныг харуулж байна. Үүний зэрэгцээ эдгээр хоёрын харилцан хамаарал адил өгөгдөхүүний ялгаатай хэмжигдхүүн болж байгаа нь мал аж ахуйд бий болсон чухал асуудлууд болох усны эх үүсвэр ширгэх /0,00/, усны цэгийн ойролцоох малын бөөгнөрөл /0,00/, нүүдлийн тоо /0,05/ зэрэг нь чухал болохыг харуулж байна. Хонины эквивалент нэгжийн хувьд малын тоог тодорхойлдог тээврийн хэрэгсэл /0,002/, газрын гэрээ хийгээгүй байдал /0,005/, усанд явах зай /0,07/ зэрэг нэмэлт үндсэн хүчин зүйлс болно. Аймгуудын хоорондын ялгаа ($r^2 = 0.83$) ($r^2 = 0.61$) , адилхан өгөгдөхүүнээр тодорхойлсон ч ганц бүрэлдэхүүн ялгаагүй зонхилж байгаагүй. Ургамалын нормалчилсан дифференциал индекс /Normalized Differential Vegetation Index- 0,07/ хамгийн чухал үзүүлэлт байсан ч өндөр хэмжээнд байгаагүй.

Өндөрлөг газрын ($r^2 = 0.61$) хувьд гол хүчин зүйлс болох гадаргын усны хомсдол(0.02), цөөн тооны нүүдэл (0.05), элстэй хамааралгүй асуудлууд /0,02/ болон ургамалын нормалчилсан дифференциал индекс NDVI үзүүлэлт илүү өндөр байсан. Ургамалын нормалчилсан дифференциал индекс NDVI ($r^2 = 0.51$) өндөрлөгтэй (0.02) зонхилж байна. Тээврийн хэрэгслийн эзэмшил($r^2 = 0.51$) нь мал малласан жилтэй /0,05/ сөрөг харилцан хамааралтай байсан нь өндөр настай малчид тээврийн хэрэгсэл эзмших явдал бага байгаа бөгөөд хүмүүс яаж нүүдэг байсныг /0,01/ харуулж байна. Иймд машинтай малчид тээврийн хэрэгслээ хөлслүүлдэг явдал бага, машингүй малчид тээврийн хэрэгсэл хөлсөлдөг үзэгдэл их байна Боловсрол ($r^2 = 0.43$) , нүүдлийн тоо /0,00/ болон мал малласан жилтэй (0.00) илүү их харилцан хамааралтай. Малын нас арай бага хамааралтай /0,00/. Нүүдлийн тоо ($r^2 = 0.41$) нь боловсролын байдал болон нүүдэллэх зайтай нилээд их харилцан хамааралтайг үзүүлж байна.

Шугаман буцаалтын хүснэгт дахь r^2 –н хэмжээ өндөр байгаа нь судалгааны өгөгдөхүүн нь малын тоо, хонины эквивалент нэгж, аймгийн үр нөлөө зэргийг тайлбарлах нь чухал болохыг харуулсан байна. Энэ судалгаа нь үндсэн хүчин

зүйлийг гаргаж ирсэн ч бусад зүйлүүд нь цугларсан өгөгдлөөр сайн тодорхойлогдоогүй болно. Тиймээс боловсрол болон малын тоо зэрэг r^2 бага тоо хэмжээг сайн тодорхойлоход илүү их судалгаа шаардлагатай байна.

Хүснэгт 17 Мал аж ахуйн үндсэн хүчин зүйлсийн шугаман буцаалт /Linear regression/

Мал
/Livestock

$r^2 = 0.94$	Beta	Ач холбогдол Significance
Нас	-0.01	0.836
Н??дэллэх зай /distance moved	0.206	0.148
Хуурайшиж байгаа н??ц??д /drying sources	0.642	0
Усны нэгж н??цийн дэргэдэх айл ?рх??д /families at water pt	-0.054	0.26
Н??дэллэх км /km moved	-0.153	0.275
Газрын эрс тэс байдал /land contract	0	1
Усны нэгж н??цийн дэргэдэх мал /livestock at water pt	0.2	0
Н??дэл /move	0 085	0.051
Хувьчлал /privatization	-0.029	0.423
Хонины эквивалент нэгж /SEU	0.236	0
Тээврийн хэрэгсэл /vehicle	-0.047	0.248

Хонины эквивалент нэгж
/SHEEP EQUIVALENCY UNIT

$r^2 = 0.80$	Beta	Ач хол Signifi
Н??дэллэх зай /distance moved	0.063	0.8
Усанд х?рэх зай /distance to water	0.151	0.0
Хуурайшиж байгаа н?? /drying sources	-0.042	0.8
Н??дэллэх км /km moved	-0.096	0.7
Газрын эрс тэс байдал /land contract	-0.187	0.0
Мал /livestock	0.753	0.0
Н??дэл /move	-0.049	0.6
Хувийн тээвэр /private	-0.007	0.9
Тээврийн хэрэгсэл /vehicle	0.232	0.

Айгууд
Province

$r^2 = 0.83$	Beta	Ач холбогдол Significance
Х??хд??дийн ирээд?й /children's future	-0.056	0.86
Хуурайшиж буй уёны н??ц??д /drying sources	-0.615	0.386
Усны нэгж н??цийн дэргэдэх айл ?рх??д /families at water pt	-0.297	0.579
Малчдын амьдрал /herder life	-0.067	0.803
Н??дэллэх км /km moved	-0.449	0.105
Мал /livestock	0.489	0.485
Усны нэгж н??цийн дэргэдэх мал /livestock at water pt	0.285	0.565
Н??дэл /move	-0.061	0.837
Ургамалын нормалчилсан дифференциал индекс /NDVI	0.7	0.068
Хонь /sheep	0.808	0.266
Газар нутаг /territory	-0.091	0.674
Усны н??ц /water source	-0.443	0.349
Сарлаг-?нээ /yak-cow	-0.197	0.605

?нд?рл?г
/ALTITUDE

$r^2 = 0.61$	Beta	Ач хо Signif
Усны н??ц Water source	-0.229	0.
/families at water pt	0.225	0.
Усны нэгж н??цийн дэр /livestock at water pt	0.199	0.
Н??дэл /move	-0.167	0.
Ургамалын нормалчил	0.403	
Элс /sand	-0.18	0.
Газар нутаг /territory	-0.153	0.
Тээврийн хэрэгсэл /vehicle	0.001	0.

Ургамалын нормалчилсан дифференциал индекс /NDVI

$r^2 = 0.51$	Beta	Ач холбогдол Significance
?нд?рл?г /altitude	0.289	0.016
Х??хд??дийн ирээд?й /children's future	0.156	0.139
Усны нэгж н??цийн дэргэдэх айл ?рх??д /families at water pt	0.199	0 219
Усны нэгж н??цийн дэргэдэх мал		

Тээврийн хэрэгсэл
/VEHICLE

$r^2 = 0.44$	Beta	Ач хо Signi
?нд?рл?г altitude	-0.204	0
Н??дэллэх зай /distance moved	-0.201	0
Хуурайшиж буй н??ц?? /drying sources	0.498	0
Боловсрол /education	0.072	0
Яаж н??х/ how move	-0.27	(
Н??сэн км /km moved	0.142	0
Мал /livestock	-0.379	
Н??дэл /move	0.196	(
NDVI	-0.143	(
NDVI 2006	-0.1	(
Элс /sand	-0.138	(

4.6 Ялгаварал

Энд дурдсан өгөгдлийн гол санаа нь тал хээрийн малчдын ерөнхий дүр зургийг харуулах юм. Эдгээр бүлгийн хоорондын ялгааг олохын тулд энэхүү өгөгдлийг ангилсан. Ижил төрлийн хүмүүсийн дунд гаднаас юу бий болох нь амьжиргааны үндсэн хүчин зүйлийн ялгааг харуулдаг. Мал аж ахуын арга ажиллагааг илүү сайн мэдэхийн тулд хонины эквивалент нэгж, нас, боловсрол, аймаг, эдийн засаг, газарзүйн демограф гэсэн сэдвүүдийг судаллаа. Сонгосон ангилалын өгөгдөхүүнийг судалгаанд оролцогчдын 20% дээд, дунд, доод гэсэн гурван бүлэгт хуваасан юм. Асуулгад оролцогчид бүх асуултад хариулаагүй учраас асуулгад оролцогчдын хариултын хувийг ашигласан болно.

Хонины эквивалент нэгж /SEU

"Баян малчид тээврийн хэрэгсэлтэй, хөрөнгө мөнгөтэй учраас нүүж чаддаг. Харин ядуу хүмүүст маш олон бэрхшээл байдаг ".

Хонины эквивалент нэгжийн амьжиргааны шийдвэрлэх өгөгдөхүүн гурван бүлгийн тодорхой ялгааг харуулсан. Доод бүлгийн 20% нь дунд бүлгийн 1/3 аас багагүй, дээд бүлгийн 1/10-тай тэнцдэг. Энэ бүлгийн дундаж нас бусад бүлгээс илүү өндөр байng. Нүүдэл, боловсролын түвшин, тээврийн хэрэгслийн түвшин доогуур байна. Тэд малчдын амьжиргааны гол зардлыг хоол, хүнс гэж тодрхойлсон байна. Өгөгдөдхүүнийг дээрээс доош нь жагсааж үүнд нүүдлийн тоо, нүүдлийн зай, боловсрол, тээврийн хэрэгслийн эзэмшил, насны урвуу хамаарал, газрын гэрээ, тэтгэвэр, үндсэн зардал гэж үздэг хоол, хүнс орно. Дээд бүлгийн малчид илүү их нүүдэл хийсэн, хол нүүдэл хийсэн, боловсролын түвшин өндөр байсан бөгөөд илүү олон тээврийн хэрэгсэлтэй байсан. Одоо малын чанар эерэг үзүүлэлттэй байгаа.

Хонины эквивалент нэгж, амьжиргааны хэлбэр, нүүдэл, эдийн засгийн хүчин зүйлтэй холбоотой гэсэн таамаглал дэвшүүлж байна.

Нас

"Бид үүнээс илүү олон мал хариулж чадахгүй. Учир нь энэ нь бидний насанд хүнд ажил".

Мал аж ахуйд насны нөлөөг судалснаар залуу малчид мал маллахад хамгийн их амжилт гаргадаг. Хүснэгт 18 / Энэ бүлэг ноолуурын орлогоос нилээд хамааралтай, үндсэн амьжиргааны зардал нь хоол хүнс, бензин бөгөөд хамгийн олон тээврийн хэрэгсэлтэй хүмүүс. Залуу малчидтай харицуулахад дунд насны малчид жилд олон удаа нүүдэл хийдэг, харьцангуй боловсролтой хүмүүс байдаг. 1/3 тээврийн хэрэгсэлтэй. Ноолуур амьжиргааны үндсэн орлогын эх үүсвэр болдог. Хамгийн настай малчид цөөн малтай, арай ойрхон зайд цөөн нүүдэл хийдэг бөгөөд дунджаар дөрвөн жилийн боловсролтой хүмүүс байдаг. Малын тухай мэдлэг харьцангуй ихтэй. Мал маллахдаа сэтгэл хангалуун байдаг бөгөөд хүүхдээ, ач нараа малчин болгохыг маш их хүсдэг. Тэтгэвэр тэдний хувьд орлогын үндсэн эх үүсвэр болдог бөгөөд хагас нь тээврийн хэрэгсэлтэй. Залуу малчид мал маллахыг өөрсдийн үндсэн ажил гэж ойлгодог ба үүнээс өөр ажил хийж чадахгүй гэж хэлдэг.Насаар нь ангилснаар мал аж ахуйд хандах хандлагыг тодорхойллоо.Сонголт багатай байсан коммунизмын үед мал маллаж эхэлсэн настай хүмүүсийн амьжиргааны талаарх бодол нь илүү эерэг байсан.

Харин залуу малчдын хувьд эдийн засгийн асуудалд илүү анхаарал хандуулж байсан.

Боловсрол

" Хүүхэд боловсрол эзэмших хэрэгтэй. Говь цөл болж байна".
Дээд боловсролтой малчид харьцангуй олон малтай, жилд илүү их нүүдэл хийдэг, нүүдлийн зай хол, тээврийн хэрэгсэл/86%/ их эзэмшдэг, газар эзэмших /72%/ явдал ч өндөр байсан.
Энэ бүлгийнхний хувьд цөөн жил мал маллаж байгаа, боловсролын түвшин доогуур байгаа нь бага зэргийн сөрөг үзүүлэлт боловч амьжиргааны үндсэн зардал нь боловсрол бус харин хоол хүнс, малын тэжээл гэж тодорхойлсон байна. Хамгийн доогуур боловсролтой бүлгийн 1/3 нь сургуулийн боловсролгүй, бусдаасаа настай, мал маллахдаа хамгийн их сэтгэл хангалуун байгаа харагдсан. Энэ бүлгийн хувьд боловсрол эзэмших боломж өөрсдийнх нь сонирхолооос хамааралтай байна. Коммунизмын үед ерөнхий боловсрол эзэмшсэн байхыг чухалчлан үздэг байсан бол ардчилсан нийгэмд шилжсэнээс хойш дээд боловсрол эзэмшигчдийн тоо эрс нэмэгдсэн. Боловсролын түвшин хамгийн доогуур үзүүлэлттэй байсан бүлэгт тэтгэвэр орлогын гол эх үүсвэр байсан бол нөгөө талд ноолуур үндсэн орлого бол ж байна. Дээд боловсролтой малчдын 1/3 болох дунд насны хүмүүсийн амьжиргааны үндсэн зардал нь боловсролд чиглэгджээ. Үүний дараа хоол хүнс, тэжээл амьжиргааны үндсэн зардалд багтсан.

Аймаг

Мачлдын амьжиргааны хэлбэр хоёр аймагт өөр өөр байна. Өвөрхангайд дунджаар малчдын 35% олон бог малтай, 14% нь хур тунадас их, ургамалын нормалчилсан дифференциал индексийн түвшингээс шалтгаалж хонины эквивалент нэгж SEU өндөр үзүүлэлттэй гарсан. /Хүснэгт19/
Хамгийн өндөр давтамжтай зардлыг бензин, хоол хүнс гэж ангилсан. Өвөрхангайд малдын амьжиргааны үндсэн зардал боловсрол, хоол хүнс байхад Өмнөговийн малдчын хувьд бензин, хоол хүнс байна. Тэд хол зайд, илүү олон нүүдэл хийдэг нь тус аймгийн хуурай уур амьсгал, хязгаарлагдмал усны нөөц ялангуяа гадаргын усны нөөц багассан явдал юм. Газар эзэмших түвшин, малчдын мал маллаж байгаадаа сэтгэл хангалуун байдал Өмнөговь аймагт илүү өндөр үзүүлэлттэй байлаа. Говь хээрийн бүсийн өрѓөрөгийн градусаар үр дүнг тодорхойлсон.

4.7 Мал аж ахуйн цаашдын хогжил

Мал аж ахуй хааш нь явж байна вэ? Энэхүү дүгнэлтийн хэсэг мал аж ахуйн өнөөгийн хандлага, арга ажиллагааны бодит үр дагавар, цаашдын хөгжлийг тодорхойлоход чиглэгдсэн. Үндсэн асуудлууд нь эдийн засаг, байгаль орчны тогтвортой байдал, насны демографик, амьжиргааны хэлбэр, хандлага байлаа. Малчид эдгээр асуудлыг хэрхэн шийдсэнээр монголын мал аж ахуйн цаашдын хөгжлийг тодорхойлох болно.
Орлогын түвшин бага, амьдралын хэв маягтаа сэтгэл хангалуун байдаг настай малчид мал аж ахуйд орчин үеийн арга ажиллагааг ашиглахыг дэмждэг, зах

зээлийн үеийн залуу малчдаар мал маллуулах сонирхолтой байдаг. Коммунизмын үеийн эдгээр малчдын мал маллхад нөлөөлдөг зүйл нь эдийн засгийн хүчин зүйл болох ноолуур юм. Хэрвээ мал малласнаар тухайн айл өрхийн амьжиргааны чухал хэрэгцээг /боловсрол, тээврийн хэрэгсэл/ хангах орлогыг олж чаддаг бол энэ нь мал аж ахуй тогтвортой хөгжих үндэс болно. Өөрөөр хэлбэл амьжиргааны түвшин доогуур байгаа асуудал малчдыг хотод суурьших, жижиг хэмжээний олборлолт хийхэд хүргэдэг үндсэн хүчин зүйл болдог. Малчдын орлогын үндсэн эх үүсвэр болох малын бүтээгдэхүүнийг өндөр үнээр борлуулах зах зээлийг бий болгох нь мал аж ахуй цаашид хөгжих үндэс болно. Усны нөөцийн хомсдол, бэлчээрийн чанараас үүдэлтэй зөрчил маргаан гарсаар байгаа үзэгдэл нь бэлчээрийн тогтвортой байдал цаашид малчдын аьжиргаанд хэрхэн нөлөөлөхийг харуулж байна. Мал аж ахуйг эрчимжүүлэх асуудал малын төвлөрөл их байгаа усны цэгийг хязгаарлах, бэлчээрийн талхлалт, нүүдлийг багасгахад чиглэгдсэн. Малын бүтцийн өөрчлөлт, цаг агаарын өөрчлөлтийн бодот нөлөө, температурын өсөлт /Batima et.al 2005/ нь цаашид орлого багасах, эдийн засгийн хувьд малчдад бодитоор нөлөөлсөн байдал, мал аж ахуйн ашиг тусд нөлөөлөх урт хугацааны тогтвортой байдлын ойрын үеийн шаардлагаас үүдэлтэй.Эвдэрсэн худаг засах, усны эх үүсвэр ширгэж байгаатай холбоотой асуудал, газар эзэмших эрхийн хэлбэр, шинэ параметрийг нэгтгэх, улирлын чанартай малын бэлчээр, нүүдлийн хэлбэрийг тогтвортой байлгахад байгалийн хүчин зүйл чухал юм. Хүн ам зүйн бодлого малчдын цаашдын амьдралд нөлөөлнө. Улсын хэмжээнд малчдын дундаж нас 12 /насанд хүрсэн малчдын дундаж нас 51 байгаа нь насанд хүрсэн хүн амын 39%-тай тэнцэнэ./

60-аас дээш настай малчдын тоо насанд хүрсэн хүн амын хувиас 5,5 дахин их байна. Мал аж ахуйд гарч байгаа шинэ хандлага нь малд маллах явдал хүмүүсийн тэтгэвэрт гарсны дараах ажил болсныг, хөдөөний залуус мал маллагаанаас хөндийрч байгааг харуулж байна. Суурин газар малчдад илүү их орлого олох, эрүүл байх, боловсрол эзэмших боломж олгодог. Ялангуяа залуу хүмүүсийн хувьд дэлхийг хамарсан сүүлийн үеийн хандлага, соёлын хэм хэмжээнд татагдах болсон. Үүнд цахилгаан, гар утас, интернэт, машин орно. Малчин айл өрх мал аж ахуйг цаашид хөгжүүлэхэд чухал үүрэг гүйцэтгэж байна. Малчдын 92% суруулийн насны хүүхэдтэй/ 62 гэрбүл/ бөгөөд хүүхдээ малчин болгох дургуй байдаг. *"Миний хүүхэд боловсрол эзэмших хэрэгтэй, тэд малчин болохгүй"* гэж хэлж байна. Эцэг эхчүүд ерөнхий боловсрол эзэмших явдлыг ихэд дэмжиж, энэ нь ажил олох боломжийг нэмэгдүүлнэ гэж үздэг. Хотод ажил хийх нь мал маллаж олдог орлогын эх үүсвэрээс илүү найдвартай, ажлын хугацаа бага, эрсдэл багатай гэсэн бодол малчдын дунд элбэг. Харин зарим эцэг эхчүүд тэдний хүүхэд малчин болно гэдэгт итгэдэг. Энэ нь сайхан амьдрах арга бөгөөд эцэг эхчүүд хөгшрөөрөө малаа хүүхддээ шилжүүлнэ гэж боддог. Сүүлийн үед эцэг эхчүүд эдгээр нь зөвхөн хүүхдийн өөрсдийнх нь сонголт гэдгийг ойлгодог болжээ. Зарим малчид *"Мал маллах хамгийн сайхан ажил, үүнээс илүү амьдрах арга зам байгааг төсөөлж чаддаггүй"* гэж өөрсдийн үзэл бодлоо илэрхийлсэн байна . /Хүснэгт20/

Энэ сэтгэл хангалуун байдал, нас, мал малласан жилтэй нилээд харилцан хамааралтай. /p=0.05/ боловч малын тоо, нүүдэл, бэлчээрийн чанар, тээврийн хэрэгсэлийн эзэмшил гэх мэт хүчин зүйлтэй шууд хамааралгүй. Энэ нь залуу, настай малчдын хоорондох ойлголтын зөрүүг харуулсан. Залуу малчдад

туслахгүй байгаа явдал, мал маллахыг ажил гэж үздэг уламжлалт амьдралын хэв маяг илүү бодитой дүгнэлт гаргахад нөлөөлнө.

Хүснэгт 20. Малчдын амьдарлын чанарын талаархи ойлголт perception of quality of herding life

	%
Үнэхээр сайхан	25
Сайхан	58
Боломжийн	8
Хүнд хүчир	9

		Хонины эквивалент нэгж *SHEEP EQUIVALENCY UNITS*				Нас *AGE*	
Ялгавар *Variable (average)*	Б?х малчид All herders	Доод 20 Bottom 20	Дунд 20 Middle 20	Хамгийн дээд 20 Top 20	Хамгийн залуу 20 Youngest 20	Дунд 20 Middle 20	Дээд 20 Oldest 20
Хонины эквивален SEU	410	92	316	948	452	398	366
Мал livestock	271	86	201	584	296	293	181
Нас age	50.8	59	46	45	29.6	50.6	73
Н??дл??д moves	4	2	4	6	4	4.9	2.4
Н??сэн км km moved	42	10	27	66	34	45	23
Боловсрол /анги/ education (grade)	6	3	5	6	6	6	4
Мал малласан жил year herd	22	26	22	22	11	21	42
Тээврийн хэрэгсэл vehicle (%)	70	50	68	90	86	73	50
Газрын гэрээ land contract (%)	50	70	50	32	54	54	45
Малчдын амьдрал herding life	Сайн good	Маш сайн very good	Сайн good	Сайн – З?гээр good-OK	Сайн good	Сайн good+	good++
Х??хэд мал маллад child herd - yes (%)	10	18	0	15	6	7	33
Гол орлого main income (%)	68 – ноолуур cashmere	59 - ноолуур cashmere	59 - ноолуур cashmere	68 - ноолуур cashmere	95 - ноолуур cashmere	80 - ноолуур cashmere	59 – тэтгэвэр
Орлого income	19 – тэтгэвэр pension	27 - тэтгэвэр	23 - тэтгэвэр	14 – мал livestock	5 – ноос wool	10 – мал livestock	32 - ноолуур
Орлого income	7 – мал livestock	9 – мал livestock	14 –ноос wool	9 – ноос wool	~	10 - Бусад other	9 - other
Гол зардал main expense (%)	34 – хоол х?нс food	63 - хоол х?нс food	41 - хоол х?нс food	32 - Бензин petrol	47 - хоол х?нс food	33 - Боловсроле food	45 - хоол х?нс
зардал expense	26 – Боловсрол education	16 - Тэжээл fodder	14 - Боловсро	23 – Боловсрол education	42 - Бензин petrol	33 - хоол х?нс food	25 - petrol
зардал expense	23 – Бензин petrol	21 - Боловсро	14 – Н??дэл migrate	23 - хоол х?нс food	11 – Тэжээл fodder	24 - Бензин petrol	10 - education

		Боловсрол *EDUCATION*			*Аймгууд PROVINCE*	
Variable (average)	Б?х малчид All herders	Доод 20 Bottom 20	Дунд 20 Middle 20	Дээд 20 Top 20	?мн?говь Omnogov	?в?рхангай Ovorhangai
Хонины эквивалент н SEU	410	412	421	440	383	437
Мал livestock	271	221	284	323	230	311
Нас age	50.8	66	43.3	49	51.3	50.3
Н??дэл moves	4	3	2.8	5.8	5	3
Н??сэн км km moved	42	38	29	60	51	33
Боловсрол -анги education (grade)	6	2	6	Коллеж some college	6	5
Мал маллам\сан жил year herd	22	40	18	11	21	24
Тээврийн хэрэгсэл vehicle (%)	70	55	77	86	73	73
Газрын гэрээ land contract (%)	50	41	32	72	60	43
Малчдын амьдрал herding life	Сайн good	Маш сайн good++	Сайн good+	Сайн good	Сайн good+	good-OK
child herd - yes (%)	10	22	6	6	9	13
Гол орлого main income (%)	68 - ноолуур cashmere	45 - ноолуур cashmere	86 - ноолуур cashmere	55 - ноолуур cashmere	68 - ноолуур cashmere	67 - ноолуур cashmere
орлого income	19 – тэтгэвэр pension	45 - тэтгэвэр pe	14 - Бусад other	27 – тэтгэвэр pension	16 – тэтгэвэр pension	22 - pension
орлого income	7 - livestock	9 - wool	~	19 - livestock	11 - wool	9 - livestock
Гол зардал main expense (%)	34 - хоол х?нс food	41 - хоол х?нс food	43 – Боловсрол education	35 - хоол х?нс food	34 – Бензин petrol	45 - food
Зардал expense	26 – Боловсрол education	32 – Бензин petrol	43 - хоол х?нс food	24 - Тэжээл fodder	28 - хоол х?нс food	23 - education
Зардал expense	23 - Бензин	14 - Тэжээл fodder	14 – Бензин petrol	18 – Боловсрол education	17 – Боловсрол education	13 - fodder

Мал маллаж байгаа хүн амын насны нэгдсэн хүчин зүйл, мал маллахыг санал болгож байгаа амьдралын хэв маягаас холдсон хандлага, залуу малчдын мал маллахад сэтгэл дундуур байгаа явдлыг /p=0.05/ мал аж ахуйн цаашдын заавар зөвлөмжинд тусгах хэрэгтэй. Мал аж ахуйг хөгжүүлэх хэд хэдэн боломж байгаа бөгөөд үүнд мал маллах шинэ арга ажиллагаа, газар эзэмших эрхийг нэмэгдүүлэх. /Хэлэлцүүлэгийн хэсгээс харна уу/

Малчдын өнөөгийн нээлттэй байдлыг " *одоо амьдрал социализмын үеэс илүү дээр байна. Бид юу хийхээ бие даан шийдэж чаддаг болсон. Ардчилсан нийгэмд шилжсэнээс хойш мал маллагаа сайжирсан*" гэж дүгнэсэн. Зарим нь *социализмын үед төрийн дэмжлэг үгүйлэгддэг байсан* гэж хариулж байлаа.

Энэ судалгааны ажлын нөгөө тал нь хэрвээ малчид тухайн орныхоо нийгэм, эдийн засгийн хөгжилд хувь нэмэр оруулж байгаа, амьдрал дээшилсэн, боловсрол, технологийн дэвшлийг ашиглах болсныг ойлговол мал маллах нь тохиромжтой амьжиргааны хэлбэр юм. Мал аж ахуйг хөгжүүлэхийн тулд алслагдмал байдлыг багасагах, аймгуудын хоорондын нүүдэл хөдөлгөөнийг дэмжих, орлогын шинэ эх үүсвэрийг олох, мал аж ахуйг эрчимжүүлэхэд

анхаарах хэрэгтэй. Мал маллах явдал залуу хүмүүсийн дунд зонхилох болсон учраас уламжлалт амьдралын хэв маягаас илүү орчин үед тохирох боломжийг эрж, бодит орлого дээр тулгуурлан сонголт хийх болж байна .

Хэлэлцүүлэг

Өнөөдөр мал аж ахуй нэгдлийн үеийн нэг ижил төрлийн хэлбэртэй байхаа больсон байна. 1990 оноос хойш монголын малчид амьдралын шинэ хэлбэр, газрын харилцан хамаарлыг гаргаж ирсэн. Тэд бие даан малаа маллаж, эдийн засгийн хүчин зүйл мал маллахад нөлөөлөх болж, мал маллах нь малчдын хүүхдүүдийн хувьд ажил мэргэжил биш гэдгийг ойлгодог болсон. Мал аж ахуй одоо орлого дээр үндэслэсэн ажил болсон. Үндсэн хэрэгцээндээ нийцүүлж өмнөх үүргээ өөрчилсөн. Мал малчдын хувьд амьжиргааны үндсэн хэрэгцээгээ хангах, эдийн засгийн хувьд малын тоо, бүтцийг нэмэгдүүлэх хүчин зүйл болсон байна. Энэ судалгааны үр дүн нь урт хугацааны байнгын нүүдэл, хонины эквивалент нэгж, малын тоог нэмэгдүүлэх үндэс болсныг харуулж байгаа бөгөөд эдгээр нь эдийн засгийн хувьд чинээлэг амьдрахад нөлөөлөх хүчин зүйл юм. Хоёрдугаарт хонины эквивалент нэгж, нас, боловсрол, нүүдлийн тоо, аймаг, өндөрлөг газар зэрэг хэд хэдэн асуудлаар малчдын ялгааг олж тодорхойлсон. Мал маллах сонирхол амьжиргааг дэмжих, материаллаг шагнал урамшуулал авах, хүүхдүүдийн боловсролыг дэмжих, мал маллах нь ажил мэргэжил биш гэж үздэг үзэл орлогын нэмэлт эх үүсвэрийн дунд хэлбэлзэж байна. Настай малчид санхүүгийн хувьд чөлөөтэй байхын тулд малтай байхыг илүүд үздэг боловч энэ нь тэдний хувьд хэтэрхий хүнд ажил. Залуу малчид өнөөдрийн техник технологийн дэвшил болох тээврийн хэрэгсэл, гар утас хэрэглэхийг хүсэх болсон. Энэхүү тохиромжтой байдал мал маллаагааг өнөөдрийн ертөнцөд татан оролцуулж, малчид хотын оршин суугчдын хоорондын зөрчлийг бууруулж байна. Чинээлэг амьжиргаанд нөлөөлж байгаа амьжиргааны бүтэц, усны хүртээмж, тээврийн хэрэгсэл ашиглах боломж, малчид болон бүтээгдэхүүний зах зээлд нөлөөлж байгаа хамгийн чухал асуудлыг хөндсөн сэдэв юм. Ядуу малчдын хувьд нүүдэл хийхэд тээврийн хэрэгслийн зардал өндөр байдгийг гаргалаа. Бэлчээрийн талхлалт, малын өсөлт доогуур байгаа үзүүлэлт нүүдэл хийгээгүйн улмаас бий болдог. Энэхүү судалгаагаар бид хөрөнгөтэй, тээврийн хэрэгсэлтэй малчид бүр хүн хөлсөлж нүүдэл хийдэг бөгөөд санхүүгийн дарамт шахалтаас илүү бэлчээрийн хүчин зүйлийн улмаас нүүдэл хийдэг байна гэдгийг гаргалаа.

Бага орлоготой учраас нүүж чадаагүй малчдын 16 хувь нь хэдэн мянган малаа үржил шимтэй бэлчээрт бэлчээрлүүлсэн үү ?

"Засгийн газар ямар ч үүрэггүй. Хэрвээ би тэдэнд юу хийх хэрэгтэйг нь хэлсэн ч тэд юу ч хийхгүй. Тиймээс юу ч хэлэх шаардлагагүй. Тэд магадгүйөөрсдийн халаасандаа л мөнгө хийх байх" гэж малчид үздэг. Засгийн газрын үүргийн талаарх асуудал газар дээрх бодит байдал, ойлголтын хоорондзөрүү байгааг харуулж байна. Засгийн газар мал аж ахуйд бага үүрэгтэй оролцдог гэдэг нь тодорхой ч малчид илүү том асуудлыг шийдэхийн тулд үүнийг гаргаж ирсэн. Малчдын хувьд хамгийн чухал асуудал усны хангамж. Ихэнх худгийг малчид өөрсдийн хөрөнгөөр барьдаг. Засгийн газар инженерийн худаг барихад л оролцдог. /Sternberg 2008/ Мөн бороо оруулахын тулд тэнгэр буудах ажлыг засгийн газраас зохион байгуулдаг.Засгийн газрын үйл ажиллагааны талаар сөрөг ойлголттой байгаа хэдий ч энэ ньоршсоор байгаа шалтгаан нь социалист

арга, үзэл санааны нөлөө удаан хугацаанд ноёрхож байсныг харуулж байна /Ynkhanbai et.al 2008/

Энэ нь хөдөө зохион байгуулалт байхгүй байгаа, нэгдэл устасны үр дагавар. Гэвч илүү сайн хамтын ажиллагаа хэрэгтэй гэж үздэг. " *Хэрвээ малчид хамтдаа ажиллавал илүү үр дүнтэй. Яг л нэгдлийн үе шиг. Энэ бол хоёуланд нь ашигтай тустай зүйл"* гэж тодорхойлж байна. Нэгдэлийг устгасанаар хувь хүн, айл өрхүүдэд малаа өөрсдөө маллах боломж олгосон.Энд тодорхойлсноор энэ нь дэд бүтцийг хөгжүүлэх, бүтээгдэхүүний зах зээлийг бий болгох, малын чанарыг нэмэгдүүлэх арга, боломж бололцоог хязгаарладаг байна. *"Засгийн газар малчид мөн худгийн асуудалд анхаарч үздэггүй"* гэсэн бодол малчдын дунд байдаг. Энэ нь хөдөөд төрийн оролцооны талаарх асуудлыг хөндөж байгаа. Хэрвээ иргэдийн хэрэгцээ байхгүй болвол энэ нь засгийн газрын ажиллагаатай холбоотой юу. Асуудлын нөгөө тал нь мал аж ахуйн талаар цаашид авч хэрэгжүүлэх бодлого, менежмент. 2002 онд газрын тухай хуульд хийсэн нэмэлт өөрчлөлт нь өвөлжөө эзэмших эрхийг малчдад өөрсдөд нь өгсөн явдал хөдөөгийн амьдралд нөлөөлсөн. /Fernandez-Gimenez and Batbuyan 2004/

Орлого, татварын эх үүсвэр, донор байгууллагын тусламж, уул уурхайн ач холбогдол нэмэгдэж байгаагийн улмаас газар хувьчлал гэх мэт хөдөөд чиглэсэн төрийн бодлогыг өөрчлөх шаардлага гарч ирсэн. Малчдын 96% газар хувьчлал нь монголын нөхцөлд тохиромжгүй гэж үзэж байна. Учир нь тэнцвэртэй бус орчинд малчдын нүүдлийг хязгаарласны үр дагавар. Бодит үр дагаварын талаарх малчдын бодол" *баян хүмүүс маш их газар авдаг харин ядуу хүмүүс чаддаггүй"*. Асуулгын үр дүнд мал маллах бодпт хичээл зүтгэл, малчид монголын бусад иргэдтэй адил боломж эдлэхийг хүсдэг гэх мэт асуудлууд шинээр гарч ирг байна. Хэрвээ эдгээр нь боломжгүй болвол малчид өөрсдийн амьжиргааны гол хэрэгсэл болох мал маллах ажиллагаагаа орхиж чаддаг. Хөдөөд ядуурлын түвшин нэмэгдсэн явдал нь зах зээлийн эдийн засаг мал аж ахуйд нөлөөлснийг харуулж байна. /Sneath 2003/

Нийгмийн бусад талуудтай харьцуулбал мал аж ахуйн амьжиргааны түвшин нь мал маллахыг өөрийн харилцаагаар дүгнэдэг. Хэдэн жилийн туршийн таатай нөхцөл байдал, сайжрал малчдыг малын ашиг тусд анхаарлын хандуулхад нөлөөлж байна. Үүнд махны хангамж, тээврийн хэрэгсэл, хүүхдээ сургуульд оруулах, нээлттэй бэлчээрт чөлөөтэй нүүдэллэх зэрэг асуудлууд орно. Үүний дараа уламжлалт бэрхшээл болох цаг агаар, хүйтэн өвөл, ган, орно. Байгалийн үзэгдэлтэй тэмцэх нь малчдын хувьд хамгийн бэрхшээлтэй асуудал. Хүний гараар хийгдсэн өөрчлөлт, малын эрчимжүүлэлт, усны цэг дээрх бөөгнөрөл, ямааны бүтцийн өөрчлөлт зэрэг нь бэлчээрийн талхлалтын бодит шалтгаан болж байна./Perkins and Thomas 1993, Thomas et al 2000, Tumurjav 2003/

Энэ нь өнөөдрийн зах зээлийн эдийн засгийн асуудал мал аж ахуйд хэрхэн нөлөөлж байгаагийн жишээ юм. Мөн түүнчлэн өнөөдрийн хандлагад парадигмийн өөрчлөлт хийхгүй бол мал нь зөвхөн орлого нэмэгдүүлэх арга болж үлдэнэ. Үүнийг малыг үржүүлэх үйл ажиллагааг сайжруулснаар хийж болно. Үүнд сайн чанартай ноолуур, сүү, махны стандартыг сайжруулах, маркетинг боловсруулах /дэд бүтэц, нийлүүлэлт, зар сурталчилгаа/, нэмэгдсэн өртөгтэй бүтээгдэхүүн гаргах, /бяслаг, арьсан бүтээгдэхүүн/ болон шинэ зах зээл /Хятад, Япон, Солонгос/ хөгжүүлэх явдал юм. Засгийн газар, олон улсын байгууллагын оролцоогүйгээр мал аж ахуйд гайхалтай өөрчлөлт хийгдэхгүй юм. Урьдчилсан төлөвлөгөө байхгүйгээр малчдын нэн даруй хэрэгцээ болон тэдний

хүсэл нь малчид эдийн засаг болон байгаль орчны нөхцлийг өөрчлөлтийг цаашид ч хийх болно.
1990 оноос хойш мал аж ахуйд нилээд өөрчлөлт гарсан. Дэд бүтэц, тээвэр, малчдын тэтгэмж, бэлчээрийн хэрэглээний талаар хууль тогтоомж гарч, малын бүтээгдэхүүн, нүүдлийн тал дээр төрийн дэмжлэг алга болсон. Төрийн боловсрол, эрүүл мэндийн үйлчилгээнд чиглэсэн бодлого үргэжилсээр байгаа. Хувийн эзэмшил, малчны хариуцлага, зах зээлийн нөлөө, идэвхтэй мал аж ахуйн үүргээс засгийн газрыг чөлөөлж, өмнөх нэгдлийн болон социализмын үеийн мал маллах арга ажиллагааг өөрчилсөн болно.

Өнөөдрийн мал аж ахуй 5-10 жилийн дараа ямар байдалтай байх вэ?

Юуны өмнө ядуу малчид баян малчдын бүлэгт орж тэдний төлөө ажиллах ба илүү амьжиргаанд тулгуурлаж ойр ойрхон газар нүүдэл хийнэ.
Малчдын амьжиргаа ноолуураас илүү их хамааралтай байх болно. Магадгүй айл өрхийн гишүүд хэрэгцээгээ хангахын тулд ажил хийж, малаа өсгөх боломжгүй болно. Илүү олон нүүдэл хийдэг малчид бэлчээрээ нэмэгдүүлэх, ус хэрэглэх боломжийг нэмэгдүүлэхийн тулд хувийн худаг барина. Газар эзэмших эрх бий болсноор /улирлын чанартай хаваржаа, өвөлжөө, намаржаа, зуслан,/ суурин амьдрах боломжтой болж, малаа хашаалан үржүүлж, эзэнгүй газрыг хувийн эзэмшилд авч мал маллагаанд том хэмжээний бүтээмжийг бий болгоно. Засгийн газар хувь хүний тууштай ажиллах чадварыг багасгана. Эдгээр нь хязгаарлагдмал сонголттой учраас нийгэмд нөлөөлнө. "*...Хотын оршин суугчид махаа ханаас авах вэ. Нийлүүлэлт багасснаар үнэ өснө, дараа нь малчдын орлого нэмэгдэнэ. Шинэ түвшинд очтол мал маллагаа малчдыг илүү ихээр татах болно...*" гэж эдийн засагчид таамаглаж байна. Эсрэгээр мал маллагааны статус квот байсаар байх бөгөөд бусад төлөөлөлийн гибрид болно. Бүс нутаг, экосистемээр нь өөрчилнэ. Хэрвээ өнөөгийн эдийн засаг, байгаль орчны асуудлууд байсаар байх юм бол мал аж ахуйд үзүүлэх нөлөөлөл байсаар байх болно.
. Мал аж ахуйд цаашид хийх ажлын жишээ нь монголд АНУ-ын мянганы сорилтын хамтын ажиллагаанаас олгож байгаа 256 сая долларын тусламж юм. Энэ нь төмөр замын тээвэр, хөрөнгө эзэмших эрх, мэрэгжлийн боловсрол, эрүүл мэндийн халамж үйлчилгээнд чиглэгддэг. /US State Department 2007/
Энэ бүгд чухал салбарт чиглэгдсэн тусламж боловч мал аж ахуйн асуудлыг шийдэхэд зориулсан тусламж байхгүй байна. Үүнд ус, дэд бүтэц,хөдөөгийн эдийн засгийн хөгжил зэрэг асуудлууд багтана. Энэ нь хөдөөгийн асуудлыг чухалчлан авч үздэггүйг харуулсан. Бэлчээрийн талхлалт, усны нөөц, бэлчээрийн хэрэглээний хэлбэр, малчдын ялгарал, ядуурал, уул уурхайн нөлөө зэрэг асуудлууд цаашид ч мал аж ахуйн тулгамдсан асуудал болсоор байх бөгөөд айл өрхийн хэмжээнд авч шийдэх болно. Мал аж ахуйг эдийн засагтай холбож ойлгох асуудал, ажлыг бий болгох гэсэн оролдлого, түүний нийгмийн үүргийн талаарх эргэлзээтэй байдал оршсоор байна

Дүгнэлт

"*Хэрвээ цаг агаар муу байвал мал маллахад маш хэцүү байдаг. Хэрвээ бороотой, нартай сайхан байвал малчдын амьдрал сайжирна*".

1990 оны улс төр, нийгэм, эдийн засгийн өөрчлөлтийн дараа мал аж ахуй монголын малчдын амьжиргааны салшгүй хэсэг болсон. Энэ нь ямар нэгэн байгууллагын үйл ажиллагаагаар бус зөвхөн малчдын өөрсдийн хөдөлмөр, хичээл зүтгэлээр бий болсон байна. Өмнө нь цаг агаар мал, малчдын санаа зовоодог байжээ. Энэ нь одоо хэвээр байгаа хэдий ч /худаг, гол, горхи ширгэх/ усны нөөц, бэлчээрийн талхлалт, орлогын эх үүсвэр, амьжиргааны зардал /хоол хүнс, боловсрол, бензин/, зэрэг тулгамдсан асуудлууд гарч ирсэн.
Мал аж ахуй амьжиргааны хэлбэрээс илүү ажил болж байгаа үед настай хүмүүсээс илүү залуу малчид мал маллах болж байна. Малын тоо зах зээлийн бүтэц, малчид хэрхэн зохицож байгаатай хамааралтай. Засгийн газрын бодлого, менежмент цаашид ч гол үүрэг гүйцэтгэнэ.. Энэхүү уламжлал болсон туршлагыг дэмжих, боломжийг нь бүрдүүлэх, чармалт, бэрхшээл малын өсөлтөнд нөлөөлдөг.

"Одоо эрх чөлөөтэй болж байна.! Амьдрал бол хялбар", бөгөөд "20 жилийн өмнө малчны амьдрал сайнгүй аяцүү амьдрал байлаа. Ардчлалын дараа амьдрал сайхан болж байна."

APPENDIX B: Questions in semi-structured herder interviews

Questions

BACKGROUND Date _____
Altitude _____ GPS _____ _____

Name _____
Soum _____ Bag _____
Number family members _____
Adults, Males/Females _____ Kids _____
Years herder _____ Before, other work _____
Age, head of house _____ Education_____
Vehicle _____
Income sources, cashmere, dairy, pension, etc. _____
_____
Livestock – their own, (herd for others) _____
Number - Sheep _____ Goat _____ Horse _____ Cow ___ Camel ___
Fodder use_____
Number of workers (need more) _____
Livestock lost to weather _____

WATER
Source – now, 5 yr, 10 yr, 15 yr ago _____
Distance - now, 5 yr, 10 yr, 15 yr ago _____
location/time to water _____
Change in water source, use, practices _____
Water quality – good, ok, bad: improving, worsening, polluted _____
Humans and animals use same or different water source _____
Salinity of water _____
Wells – engineered or hand wells _____
Water level in wells – change _____
Use different wells for each season, or different locations, which important & when
_____
Precipitation – rain and snow. Now, 5 yr, 10 yr, 15 yr _____
Drying up spring/stream, diversion of water source _____
How much time to water animals/how often water animals _____
Number of families, number of livestock using water source _____
Water regulation/control/possession _____
Who fixes, builds wells _____
Water price, tax _____
Role of government _____
Mining impact on water _____
Water conflicts – other herders, government, mining _____

LAND
Pasture quality - now, 5 yr, 10 yr, 15 yr ago _____

a) very good b) good c) normal, OK d) bad e) very bad
Level/amount grass - now, 5 yr, 10 yr, 15 yr. More or less, thinning, timing

_____

What affects pasture _____
Weather and Climate _____
Insects _____
Composition - changing vegetation. How many types of grass? _____

_____

Possession/contract for land. If so, what season, years had, contract with whom

_____

How possession affects land use _____
Pasture capacity, quality affect number of animals - now, 5 yr, 10 yr, 15 yr

_____

Competition, intensification for pasture _____
Role of government - organize, emergency fodder, economic, $. What should govt. do? _____
Territory – their pasture area _____
Tax/Fees, price _____
Land conflicts – other herders, government, mining _____

MIGRATION

Number of moves per year – now, 5 yr, 10 yr, 15 yr ago _____
Winter _____ Summer _____ Spring _____ Fall _____
How far, where - now, 5 yr, 10 yr, 15 yr _____

_____

Time stay - now, 5 yr, 10 yr, 15 yr _____
Decision factors, why move _____
Otor move? _____
How move, cost (% income) _____
Regulation/control movement _____
Government, Soum role _____
Tax/Fees, price _____
Sand level over time – how changing, what season? _____
Mapping migration

OTHER

Family income (wealth) increasing/decreasing a) very good b) good c) normal, OK d) bad e) very bad _____
Main household expenses, in order (highest to low expenses)

_____

Wild animals – gazelle, etc. (increase/decrease over time); effect on herding (wolf, cat) _____
What do you think about land privatization? _____
Children's future – will they be herders? _____
What do you think of herding life? _____

QUOTES _____

_____ _____

APPENDIX C: Statement of Originality/Co-author statement

Statement of Originality

January 29, 2008

The work in this thesis is my own in terms of data collection, analysis, and interpretation. Co-authors on papers, as is the norm in science publications, reflects participation of others in terms of supervision, the development of ideas, and wider discussion. The work and ideas are substantially my own.



Troy Sternberg

Physics and Electronics School
National University of Mongolia

Statement for inclusion with Troy Sternberg's thesis

November 10, 2008

I declare that the manuscript presented in this thesis entitled "Tracking desertification on the Mongolian steppe through NDVI and field-survey data", is substantially the work of Troy Sternberg and that my contribution as co-author has been limited to remote sensing and supervisory input and comments on drafts. Troy was responsible for fieldwork, data analysis, and writing of the manuscript.

Dr Renchin Tsolmon

NUM-ITC-UNESCO Remote Sensing/GIS laboratory
School of Physics and Electronics
National University of Mongolia
Phone: +976-11-329993, 99776193
Fax: +976-11-329326
E-mail: tsolmon@num.edu.mn