Herd management and livestock productivity in the Altai region of Western Mongolia

Munkhnasan Tsevegmed

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Erste Gutachterin:	Prof. Dr. Eva Schlecht, Universität Kassel and Georg-August- Universität Göttingen
Zweite Gutachterin:	Prof. Dr. Togtokhbayar Norovsambuu, Mongolian University of Life Science
Prüfer:	Prof. Dr. Andreas Bürkert, Universität Kassel
Prüfer:	Dr. Christian Hülsebusch, DITSL GmbH Witzenhausen
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1st supervisor:	Prof. Dr. Eva Schlecht, University of Kassel and Georg-August- University of Göttingen
2nd supervisor:	Prof. Dr. Togtokhbayar Norovsambuu, Mongolian University of Life Science
Examiner:	Prof. Dr. Andreas Bürkert, University of Kassel
Examiner:	Dr. Christian Hülsebusch, DITSL GmbH Witzenhausen
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Table of contents

List of tables

List of figures

List of annexes

List of abbreviations

ADF	Acid detergent fiber
ADFI	Acid detergent fiber intake
AFP	Age at first parturition
ANOVA	Analysis of variance
a.m.	Morning
a.s.l	Above sea level
BIC	Bayesian information criterion
C	Carbon
°C	Celsius
Ca	Calcium
CaI	Calcium intake
CATPCA	Categorical principal component analysis
cC	Commercial field cropping
cL	Commercial livestock keeping
cLscC	Commercial livestock keeping plus semi-commercial field cropping
cm	Centimeter
CP	Crude protein
CPI	Crude protein intake
d	Day
DM	Dry matter
DMI	Dry matter intake
E	East
Eq	Equation
exp	Exponential function
FAOSTAT	Food and Agricultural Organization's statistics
FM	Fresh matter
g	Gramm
GDP	Gross domestic product
GIS	Global information system
GPS	Global positioning system
h	Hour
ha	Hectare
HH	Household
IC	Improved culling
IF	Improved feeding
IFAD	International Fund for Agricultural Development
kg	Kilogram
km	Kilometer
km^2	Kilometer square
LW	Live weight
$LW^{0.75}$	Metabolic body weight
ME	Metabolizable energy
MJ	Mega joule
m	Meter
mm	Millimeter
MNT	Mongolian National Tugrik

N	Nitrogen
N	North
n	Number
NDF	Neutral detergent fiber
NDFI	Neutral detergent fiber intake
n.s.	Non-significant
NIRS	Near Infrared Reflectance Spectroscopy
NRC	National Research Council
NSOM	National Statistical Office of Mongolia
OM	Organic matter
OMD	Organic matter digestibility
OMI	Organic matter intake
P	Phosphorus
PI	Phosphorus intake
p	Probability
PC	Personal computer
p.m.	Evening
R	A language and environment for statistical computing
R^2	Coefficient determination
scLsC	Semi-commercial livestock keeping plus subsistence field cropping
SD	Standard deviation
SEM	Standard error of mean
SPSS	Statistical Package for Social Sciences
SQ	Status quo
SU	Sheep unit
t	Tonne
USA	United States of America
USD	United States Dollar
UNFPA	United Nations Fund for Population Activities
UTM	Universal transverse Mercator (projection)
vs.	Versus
WGS	World Geodetic System
WMO	World Meteorological Organization
€	Euro

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Summary

It is well known that in Mongolia the livestock sector is a source of livelihood for nearly half of the national population, especially since the political and economic changes in the early 1990s strongly affected the lives of rural people. This thesis analyses, in a localized context, the current rural development, the economic settings and political measures that affect the traditional extensive livestock husbandry system and its importance for rural livelihoods. Possibilities to improve the current livestock management and thus herders' livelihoods in an environmentally, economically and socially sustainable manner are discussed at a regional scale. The study focusses on Bulgan county (*soum*) of Khovd province (*aimag*), the westernmost county of Mongolia with a very poor road network and thus very difficult access to regional and national markets. Even though the county borders China, the only recent regular opening of the common border post did not much improve the economic conditions of the county's inhabitants, since China follows a restrictive policy concerning imports of livestock products from Mongolia.

Through a household survey following an altitudinal gradient along the Bulgan River valley in the Mongolian Altai Mountain region, qualitative and quantitative information about rural livelihood strategies and livestock management was obtained. The collected data was subjected to cluster analysis and four main livelihood strategies were identified. The households practicing commercial livestock keeping (31%) proved to be the most active herders with on average 167 animals herded throughout the year. The households involved in semi-commercial livestock keeping plus semi-commercial field cropping (11%) were the most well-off households among all clusters, since in addition to selling animals they also sold crop products, even though transhumant herd management was still a mainstay of their income. The poorest and almost sedentary households were practising commercial field cropping (7%) and only owned a few animals for their subsistence needs. The households engaged in semi-commercial livestock keeping plus subsistence field cropping (51%) keep about 100 animals as their income source and cultivate common crops, such as potato, carrot, cabbage, plus the cereals wheat and rye, for family consumption. In summary, for most rural households in Bulgan *soum* the economic backbone is livestock husbandry. This activity still represents their traditional way of living and is practiced in the customary transhumant manner. The poor infrastructural development of the study area and the lack of nearby market possibilities as well as very the harsh environmental conditions prevent a wide diversification of household activities.

In order to better understand the livestock management and pasture utilization system in Bulgan *soum*, the grazing itineraries of small ruminants (sheep and goats) and the herbaceous biomass offer, in terms of quantity and quality, along the daily itineraries was studied. Additionally, the animals' grazing behaviour and their feed intake were determined during the spring and summer seasons of 2013 and 2014. Across the two years, the average daily distance walked by sheep and goats, respectively, was 13 ±1.3 km and 14 ±0.9 km ($p>0.05$), and the grazed area averaged 64 ±11.7 km^2 and 71 ±9.2 km^2 per day. Both variables slightly decreased from spring (June) to early and late summer (July and August) in each year. Varying the length of the daily grazing itinerary and adjusting it to the biomass on offer seems to be the only strategy to secure a requirement-covering feed intake of small ruminants. The herbage dry matter (DM) yield along the daily itinerary was a bit higher (837 kg DM/ha) in 2014 than in 2013 (711 kg DM/ha; $p>0.05$). The herbage yield declined from June to August 2013 while no difference between the months (that is, the seasonal pastures) was observed in 2014. The concentrations of DM and cell wall constituents (neutral and acid detergent fibre, NDF and ADF) in the pasture vegetation increased from June to August in both years, whereas the crude protein (CP) and phosphorus concentration declined ($p\leq0.05$). The intake of dry matter and proximate diet components of sheep and goats was similar across the two years ($p>0.05$) and 67% and 66% of ingested organic matter (OM) were digested ($p>0.05$). The intake of feed DM and nutrients from the natural pasture vegetation during the summer season apparently covered the requirements for maintenance plus growth of the local small ruminant breeds, with the exception of their phosphorus requirements. Therefore a source of macro- and micro-minerals should be offered to the small ruminant herds during the summer season. The behaviour of grazing sheep and goats was similar across the summer months, in which the animals spent 56%, 31%, 10% and 2% of their daily time on grazing, resting, walking and other activities. With regards to the diurnal rhythm of grazing, the afternoon seems the vital day time for small ruminants to securing their daily feed intake; which should be considered in the daily herding practices.

Finally, the reproductive performance and economic profitability of small ruminants under the present management was analyzed using progeny history data from 83 ewes and 173 does of 21 herder families, and feeding the resulting information into the bio-economic PRY Herd Life model. The average age at first parturition of ewes and does was about 27 months, and the parturition interval was close to 13 months long. This was due to the herders' breeding strategy which takes into account the local environmental constraints such as seasonal feed supply and harsh winter weather conditions. The parturition rates (50% - 96%) and abortion rates (6% - 47%) of both species varied year by year, reflecting feed supply on the natural pastures and weather conditions, especially during the spring and winter seasons. But these variables were also influenced by the herding knowledge of the livestock keepers. The simulation of present and alternative herd management strategies with the PRY Herd Life model showed that the current management of small ruminants is profitable with an average annual monetary output of 24 € and 26 € per unit of sheep and goat (female animal with offspring), respectively. Intensifying the culling (scenario IC) of unproductive (female) and surplus (male and female) animals has the potential to improve the economic benefit per sheep and goat, and stabilize herd size. However, successful implementation of such alternative management needs a well-functioning market that absorbs live animals and offers possibilities to transform carcasses into attractive meat products.

Summarizing the results, this study shows that the rural communities became more sedentary over the past 25 years, even though the livestock herding practices still follow the traditional transhumance, which is an efficient and very well adopted land use system in view of the country's environmental conditions. Herding practices and the quantity and quality of pasture vegetation have gradually declined, due to climatic and socio-economic impacts, and these trends together have lowered animal (re)productive performances, weakening thus the economic situation of rural households. The national government should therefore very carefully consider measures that sustain the transhumant livestock husbandry system, such as improving the rural infrastructure, developing regional markets and creating alternative employment possibilities. Such measures should also contribute to lowering the currently high grazing pressure on the seasonal pastures and by this slow pasture degradation.

Zusammenfassung

Bekanntermaßen stellt die Viehwirtschaft die Erwerbsquelle für annähernd 50% der mongolischen Bevölkerung dar, deren ländlicher Teil stark von den politischen und wirtschaftlichen Umwälzungen zu Beginn der 1990er Jahre betroffen war. Die vorliegende Arbeit analysiert an einem Fallbeispiel die aktuelle ländliche Entwicklung, die wirtschaftlichen Rahmenbedingungen sowie die politischen Entscheidungen, welche die traditionelle extensive mobile Nutztierhaltung beeinflussen, sowie deren Bedeutung als Lebensgrundlage der ländlichen Bevölkerung. Möglichkeiten die Nutzierhaltung und somit die Lebensgrundlage der Nutztierhalter auf ökologisch, ökonomisch und sozial nachhaltige Weise zu verbessern werden auf regionaler Ebene diskutiert. Die vorliegende Studie beschränkt sich auf den am weitesten westlich in der Mongolei befindlichen Landkreis Bulgan (Bulgan *soum*) in der Provinz Khovd, der von einem sehr schlechten Straßennetz und damit einem äußerst schwierigen Zugang zu regionalen und nationalen Märkten charakterisiert ist. Obwohl der Landkreis sich in direkter Nähe zu China befindet, hat die Öffnung des chinesisch-mongolischen Grenzübergangs vor wenigen Jahren die ökonomische Situation der Bevölkerung kaum verbessert. Der Grund hierfür liegt vor allem in der restriktiven chinesischen Importpolitik für Nutztierprodukte aus der Mongolei.

Mittels direkten, individuellen Befragungen wurden qualitative und quantitative Informationen bezüglich der Strategien der ländlichen Haushalte hinsichtlich der Bestreitung ihres Lebensunterhalts und der Nutztierhaltung erhoben. Die interviewten Haushalte wurden zufällig und entlang eines Höhengradienten längs des Flusstals des Bulgan im mongolischen Altaigebirge ausgewählt. Mittels einer Clusteranalyse wurden auf Grundlage der erhobenen Daten vier Hauptstrategien identifiziert. Die aktivsten Hirten waren Haushalte, die kommerziell Nutztierhaltung betrieben (31%). Sie besaßen im Durchschnitt 167 Tiere, die das ganze Jahr über gehütet wurden. Haushalte, die halbkommerziell Nutztiere hielten und halbkommerziellen Ackerbau betrieben (11%), gehörten zu den wohlhabendsten Familien innerhalb der vier Cluster. Neben dem Verkauf von pflanzlichen Erzeugnissen ist die transhumante Nutztierhaltung beziehungsweise der Verkauf von Nutztieren ein wichtiges Einkommensstandbein. Die Haushalte mit dem geringsten Einkommen gehörten zu den weitestgehend sesshaften Familien, die kommerziell Ackerbau betrieben und lediglich wenig Nutztiere für den

Eigenbedarf besaßen (7%). Haushalte, die eine halbkommerzielle Nutztierhaltung sowie Ackerbau zu Selbstversorgung betrieben (51%), hielten circa 100 Nutztiere und bauen Kartoffeln, Karotten, Kohl sowie die Getreidearten Weizen und Roggen an. Zusammenfassend betrachtet bildet die Nutztierhaltung das ökonomische Rückgrat für die meisten ländlichen Haushalte in Bulgan *soum*. Die Viehhaltung spiegelt immer noch ihre traditionelle Lebensweise wider und wird in einer typischen transhumanten Weise betrieben. Die schlechte Infrastruktur in der Untersuchungsregion, der Mangel an Marktzugang sowie extreme Umweltbedingungen (bergiges Gelände, arides Kontinentalklima) verhindern eine breite Diversifikation der Haushaltsaktivitäten.

Um die Nutztierhaltung und die Weidenutzungssysteme in Bulgan *soum* besser zu verstehen, wurden die Weiderouten von Kleinwiederkäuern (Schafe und Ziegen) und die Verfügbarkeit der krautigen Biomasse (Quantität und Qualität) entlang ihrer täglichen Weiderouten erfasst. Darüber hinaus wurde das Weideverhalten der Tiere und ihre Futteraufnahme während des Frühjahres und des Sommers 2013 und 2014 bestimmt. Während dieser zwei Jahre betrug die täglich zurückgelegte Wegstrecke von Schafen und Ziegen 13 ±1.3 km bzw. 14 ±0.9 km ($p>0.05$), dabei wurde eine Weidefläche von 64 ±11.7 km^2 und 71 ±9.2 km^2 pro Tag genutzt. Beide Variablen nahmen in jedem Jahr vom Frühjahr (Juni) zum frühen und späten Sommer (Juli und August) hin ab. Die einzige Strategie, um eine bedarfsgerechte Futteraufnahme der Kleinwiederkäuer zu sichern, ist es, die Länge der täglichen Weiderouten zu variieren und an die verfügbare Biomasse anzupassen. Der Grünfuttertrockenmasseertrag (TM) entlang der täglichen Weiderouten war in 2014 etwas höher (837 kg TM/ha) als in 2013 (711 kg TM/ha; $p>0.05$). Dieser Ertrag nahm von Juni zu August 2013 ab, wohingegen für 2014 kein Unterschied zwischen diesen beiden Monaten zu beobachten war. Die Konzentrationen der Weidevegetation an Trockenmasse und an Zellwandbestandteilen (neutrale und saure Detergentienfaser, NDF und ADF) stieg in beiden Jahren von Juni zu August an. Die Konzentrationen an Rohprotein- und Phosphornahmen dagegen ab ($p\leq0.05$). Die Trockenmasseaufnahme und ungefähre Futterzusammensetzung von Schafen und Ziegen war zwischen den beiden Jahren ähnlich ($p>0.05$), wobei 67% und 66% der aufgenommenen organischen Masse verdaut wurden ($p>0.05$). Während der Sommersaison deckt die Aufnahme an Futtertrockenmasse und Nährstoffen von der natürlichen Weidenvegetation offensichtlich den Erhaltungs- und Wachstumsbedarf der lokalen Ziegen- und Schafrassen ab. Eine Ausnahme bildet die Phosphorversorgung, folglich sollte während der Sommersaison eine Supplementierung der Kleinwiederkäuer mit Makro- und Mikronährstoffen vorgesehen werden. Das Weideverhalten von Schafen und Ziegen war über die Sommermonate ähnlich, wobei die Weidephasen, Ruhezeiten und Marschphasen sowie sonstige Aktivitäten 56%, 31%, 10% und 2% an der täglichen Zeit auf den Weideflächen ausmachten. Bezüglich der diurnalen Weiderhythmik scheint der Nachtmittag die entscheidende Tageszeit für die tägliche Nahrungsaufnahme der Kleinwiederkäuer zu sein, was im alltäglichen Hütemanagement berücksichtigt werden sollte.

Des Weiteren wurde auch die Reproduktionsleistung der Kleinwiederkäuer und ihre ökonomische Profitabilität unter Berücksichtigung des gegenwärtigen Managements analysiert. Hierzu wurde die Zuchtgeschichte von 83 Mutterschafen und 173 Zicken von 21 Hirtenfamilien erfasst und in das bioökonomische Herdenmodell PRY eingegeben. Das durchschnittliche Erstlammalter lag für Mutterschafe und Zicken bei ungefähr 27 Monaten, die Tragzeit lag in beiden Fällen bei rund 13 Monaten. Der Grund hierfür ist in der Zuchtstrategie der Hirten zu finden, die die lokalen Umweltbedingungen wie saisonale Futterversorgung und raues Winterwetter berücksichtigt. Die von Jahr zu Jahr variierende Wurf- (50% - 96%) und Fehlwurfrate (6% - 47%) spiegelt nicht nur das Futterangebot der natürlichen Weiden und die Wetterbedingungen (vor allem der Frühlings- und Wintersaison) wider, sondern wird auch von den Hütekenntnissen der Nutztierhalter beeinflusst. Die Simulation der gegenwärtigen und alternativen Herdenmanagementstrategien mittels des PRY Herdenmodells zeigt, dass das derzeitige Kleinwiederkäuermanagement mit einem durchschnittlichen monetären Ertrag von 24 € und 26 € pro Schaf- und Ziegeneinheit (weibliches Tier mit Nachwuchs) profitabel ist. Unter der Annahme einer konsequenten Merzung (d.h. Verkauf / Schlachtung; Szenario IC) von unproduktiven (weiblichen) und überschüssigen (weiblichen und männlichen) Tieren, wäre eine Verbesserung des ökonomischen Nutzens pro Schaf und Ziege möglich, zugleich würde die Herdegröße konstant gehalten. Eine erfolgreiche Implementierung einer solchen Managementalternative setzt jedoch einen gut funktionierenden Markt voraus, der in der Lage ist, Lebendtiere aufzunehmen und Möglichkeiten bietet, geschlachtete Tiere in attraktive Fleischprodukte umzuwandeln.

Die Ergebnisse zusammenfassend zeigt die vorliegende Studie, dass die ländliche Bevölkerung im Landkreis Bulgan während der letzten 25 Jahre sesshafter wurde. Jedoch ist die Hütepraktik für Nutztiere immer noch die traditionelle Transhumanz, die in Anbetracht der örtlichen Umweltbedingungen ein effizientes und gut angepasstes Landnutzungssystem darstellt. Aufgrund von klimatischen und sozioökonomischen Beeinflussungen nimmt jedoch das aktive Hüten sowie die Qualität und Quantität der Weidevegetation allmählich ab, was sich in Kombination negativ auf die Tier(re)produktionsleistung und folglich die ökonomische Situation der ländlichen Haushalte auswirkt. Folglich sollte die nationale Regierung sich intensiv mit Maßnahmen zur Verbesserung der ländlichen Infrastruktur, Entwicklung regionaler Märkte und alternativen Beschäftigungsmöglichkeiten befassen, und die transhumanten Nutztierhaltungssysteme durch unterstützende Politikentscheidungen erhalten. Maßnahmen sollten ebenfalls dazu beitragen, den gegenwärtigen hohen Beweidungsdruck auf die saisonalen Nutztierweiden und somit die Degradation dieser Weiden zu reduzieren.

List of publications related this thesis

1 Munkhnasan, T., Wiehle, M., Schlecht, E., 2014. Characterisation of Agro-Pastoralist Households Along the Bulgan River in the Altay Region of Western Mongolia. In: Bridging the Gap between Increasing Knowledge and Decreasing Resources. Proceedings of the Tropentag 2014 conference, Prague, Czech Republic.

Available from: *http://www.tropentag.de/2014/abstracts/links/Schlecht_zfVV1B9D.php*

2 Sabir, A., Munkhnasan, T., Schlecht, E., 2015. Reproductive Performance of Small Ruminants in the Transhumant Grazing Systems of the Chinese-Mongolian Altay Mountains. In: Management of land use systems for enhanced food security-conflicts, controversies and resolutions. Proceedings of the Tropentag 2015 conference, Berlin, Germany.

Available from: *http://www.tropentag.de/2015/abstracts/links/Schlecht_L1PncTpF.php*

3 Jordan, G., Goenster, S., Munkhnasan, T., Shabier, A., Buerkert, A., Schlecht, E., 2016. Spatio-temporal patterns of herbage availability and livestock movements: a cross-border analysis in the Chinese-Mongolian Altay. Pastoralism 6(1), 1-17. DOI: 10.1186/s13570-016-0060-2.

4 Jordan, G., Shabier, A., Munkhnasan, T., Goenster, S., Buerkert, A., Schlecht, E., 2016. Cross-border analysis of biomass availability and stocking densities on seasonal pastures in the Chinese-Mongolian Altay-Dzungarian region. In: The future management of grazing and wild land in a high-tech world. Proceedings of the International Rangeland Congress, Saskatoon, Saskatchewan, Canada.

Chapter 1

General introduction and research objectives

1 General introduction and research objectives

Livestock husbandry is well known as essential source of food, income and other functions (providing manure, power and financial instruments) worldwide (Li et al., 2007). Nowadays the development direction of livestock systems are being shifted to more sustainable ways where the domestic livestock can behave naturally (Frewer et al., 2005), in order to produce healthier and safe organic food for the rapidly raising world population (The World Bank, 2008). The present study was carried out in the transhumant livestock husbandry system in Mongolia where the above mentioned development principles exist together with site-specific advantages and restrictions. Mongolia is a landlocked country in Central Asia covering 150 million hectares of area and hosting 3 million people; 99.5% of the country's total territory is used for pasture with a carrying capacity of approximately 75 million sheep units of livestock per year (FAOSTAT, 2014). Consequently, the livestock husbandry is the most significant subsector that produces 88% of total agricultural products (20% of GDP), around 10% of the country's export income, directly employs 35% of total work force and contributes to alternative income generation of half of the country's population (NSOM, 2014). Therefore this study deals with current livestock husbandry and pasture management and their contribution to livelihoods of pastoralists at herder households' level.

1.1 The present livestock management

Most of the global livestock population is kept in developing countries (Upton, 2004), where it serves as an important source of especially rural populations' economic activities and subsistence by supplying income and livelihoods (Herrero et al., 2013). The majority of the respective herbivorous animals are kept under different forms of (agro-) pastoralism (Blench, 2001). Mongolia is one of most livestock-dependent developing countries in the world (Suttie et al., 2005), with almost half of its population directly depending on transhumant livestock husbandry (NSOM, 2014). The livestock husbandry itself relies on native pasture vegetation as the basic source of feed for all types of herbivores throughout the year. Across the country, livestock owners or (hired) herders move their animals between four main seasonal pastures that are used for spring, summer, autumn and winter grazing. Additionally, some pastures are reserved for *otor,* that is fattening of a subgroup of animals (Murphy, 2011), or as a forage reserve in case of sudden extreme weather events. Among the seasons, winter and spring are the most difficult in terms of feed shortages; to this adds an increased feed requirement of females in the spring lambing/calving season. Mearns (1993) and Fernandez-Gimenez (2006) reviewed historical (1200-1990) regulations of Mongolian transhumant livestock systems and pasture use rights and found a closer relationship between the pastoral land use pattern and the political and economic changes of the country. Indeed the livestock husbandry and pasture use right regulators were granted by nobles, powerful Buddhist lamas, Khoshuun princes (i.e., provincial leaders) and lastly by the national socialist central government. During the socialist period (1950 – 1992) all livestock belonged to the state, all herders were state-employed and received regular monthly salaries, and the government supported the transportation of herds, paid for additional labour, provided emergency feed, veterinary services and water points (wells) at pastures in order to maintain livestock numbers (Johnson et al., 2006) and also control livestock numbers and movements (Fernandez-Gimenez, 1999b).

This highly subsidized and strongly regulated socialist livestock husbandry system ended when Mongolia entered into democracy and open market economy in the early 1990s. During the transition period all subsidies stopped and livestock was privatized to individual herders whereas pasture property remained with the newly established government (Fernandez-Gimenez and Batbuyan, 2004). Since the local herders' livelihoods strongly depended on their livestock, and they now had to face all socio-economic and environmental production risks by themselves, they searched to increase the number of economically productive livestock to ensure their revenues (monetary, and non-monetary) under the new political and economic situation (Johnson et al., 2006; Lkhagvadorj et al., 2013a; Undargaa and McCarthy, 2016). Consequently, the total number of all types of livestock increased sharply (Figure 1.1 A), and the share of individual animal species within the national herd changed. From 1990 to 2009, the total number of livestock in Mongolia increased (Lkhagvadorj et al., 2013b; NSOM, 2014) by a factor of 1.7, whereby the highest increase occurred in goats (factor 3.8) followed by sheep (factor 1.3), whereas the increase in large animals (cattle, horse and camel) ranged from 0.5 to 0.9 times. The respective changes were primarily related to the economic importance of certain animal species for household total cash income (Lkhagvadorj et al., 2013b). For example, cashmere fibre from goats has accounted for more than 70% of a household's total annual cash income after the introduction of open market economy

(Lkhagvadorj et al., 2013a). The increase in total livestock numbers was also supported by the dissolution of many state-owned small enterprises in urban areas such tailoring, shoe making and constructional enterprises, which resulted in a high level of unemployment. Many of these unemployed people started to keep livestock which was seen as one of the few ways to survive during the transition period (Asian Development Bank, 2013). Yet, livestock numbers did not constantly increase, there were some pointed decreases reported for small ruminants (sheep and goats) and slight declines for large animals in 2002 and 2009/10, which were due to the occurrence of drought and *dzud* (harsh winter). As a consequence of the 2009/10 *dzud* the highest mortality ever was recorded for goats (loss of 29.4% of the national goat herd), but headcounts recovered rapidly since 2010 (Figure 1.1 A). Despite this, the majority of current herd sizes in Mongolia do not fully sustain their owners' needs for income and food security (Begzsuren et al., 2004; Addison and Brown, 2014).

Paralleling the nationwide trend, the total number of livestock in Bulgan county of Khovd province, where this study was carried out, increased from 1990 to 2009, mostly due to a sharp increase in the number of goats (Figure 1.1 B). Surprisingly, the numbers of sheep, horse and camel in Bulgan county had declined by 33%, 8.7% and 43% in 2009 as compared to 1990, which was not matching the nationwide dynamics. Given the remoteness of this region, its lack of infrastructure and in consequence difficult access to regional and national markets, the storable cashmere fibre seems to be the only commodity that is worth producing at larger scale in this region. Moreover, the ecological conditions of Bulgan county, which is located in the transition area of the Mongolian Altai Mountains to the Gobi-Altai sub-region, are apparently more suitable for small ruminants, and especially goats (Barzagur, 2002).

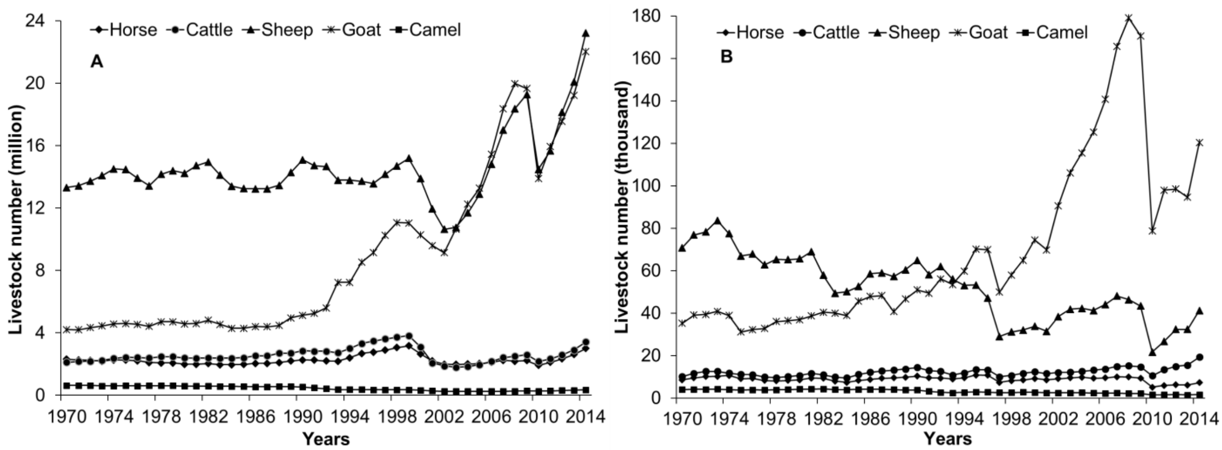

Figure 1.1. Development of livestock numbers in Mongolia (A) and in Bulgan county of Khovd province (B) during 1970 to 2014 (data provided by National Statistical Office of Mongolia). Please note that y-axes are scaled differently in figure A and B.

1.2 Environmental challenges

Depending on their agro-ecological settings, different regions of the world are dominated by either nomadic or transhumant pastoralist systems, transhumant or sedentary agro-pastoralist systems or sedentary mixed systems (Alexandre and Mandonnet, 2005) – mainly depending on the length of the growing period. According to these authors, Mongolia covers the arid and semi-arid temperate zone with a growing period ranging from 60 to 180 days (Johnson et al., 2006; Li et al., 2007). The main environmental challenges are strongly related to its continental climate conditions such as highly variable temperature and precipitation. Figure 1.2 shows a long dry season and short more humid conditions during the cold winter season, which is environmentally the most difficult period for grazing livestock. The warmest season is summer with an average temperature of 20°C, while the coldest season is winter with an average temperature of minus 18.3°C (1963-2014, Baitag weather station, WMO code 44265, 46.094° N, 91.552° E, 1186 m a.s.l). Around seventy percent of the total annual precipitation falls from April to September. Yet, the average annual air temperature has increased by 1.7°C during winter season in the Mongolian Altai Mountains since 1940s (Batima et al., 2005). Furthermore, annual precipitation decreased by 30-90 mm in the north-eastern regions while it increased by 2-60 mm in western regions of the country (Batima et al., 2005). However, in 2013 and 2014 the lower latitudes of the Mongolian Altai Mountains received much less (50 mm) precipitation than the long term average (WATERCOPE weather data).

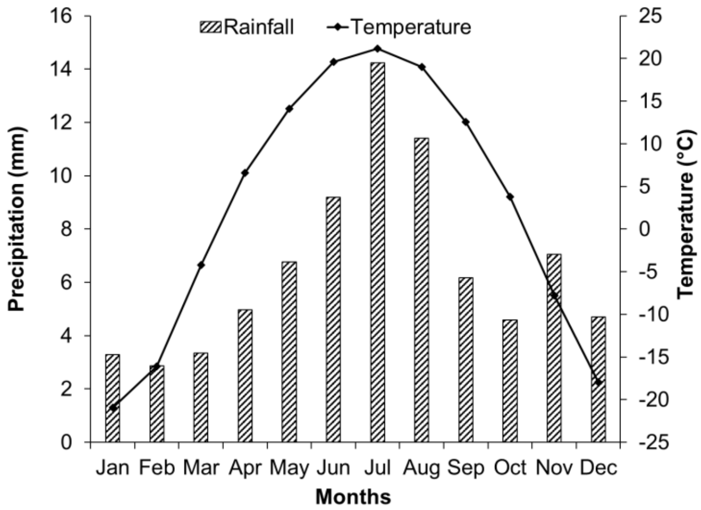

Figure 1.2. Climate diagram for the Mongolian Altai Mountains recorded at Baitag weather station in the centre of Bulgan county of Khovd province from 1963 to 2014. Data were provided by the WATERCOPE project.

Another environmental constraint to livestock husbandry is the landscape as such. Barzagur (2002) identified four different ecological-territorial zones in Mongolia, namely the Altai mountain zone, the Khangai-Khentii mountain zone, the steppe zone and the Gobi-steppe zone, which all differ in topographic, geographic and ecological conditions; in consequence, also livestock herding practices are different. The Altai mountain and Gobi-desert zones are more suitable to rear small ruminants, camel and yak, while the Khangai-Khentii mountain and the steppe zones are well suited for sheep, cattle and horse.

The main strategies of Mongolian herders to cope with these rough and / or highly unpredictable environmental variables have been and still are seasonal herd movements and hay preparation for the winter season (Fernandez-Gimenez, 2002). However, under the current economic situation, these traditional measures need to be backed by proper political and technological support (Fernandez-Gimenez and Le Febre, 2006). Therefore, some additional strategies have been suggested to sustain livestock and pasture land management, such as community-based pasture land management (Ykhanbai, 2004; Addison et al., 2013; Fernandez-Gimenez et al., 2015), index-based insurance systems (Bertram-Huemmer and Kraehnert, 2015), improving livestock productivity and health care, and introducing applicable technologies for watering (Asian Development Bank, 2013). For their successful implementation, also such supportive strategies require some socio-economic pre-conditions, such as efficiently organized institutions, sufficient financial resources, regulated land use and functioning market systems.

1.3 Socioeconomic challenges and opportunities

The socio-economic challenges to implement sustainable development strategies for Mongolia's grazing-based livestock husbandry are the lack of clearly defined and widely accepted official regulation of pasture use and the weak implementation of pasture management, poor market opportunities and irregular social and health care services to herder households in remote areas (Asian Development Bank, 2013). The number of herding households almost tripled from 1990 to 2014 (NSOM, 2014) with no formal limitation on animal numbers, and most herder families increasingly spent more time around water points, settlements such as soum centres, roads and seasonal camps (Ykhanbai et al., 2004). The reduced distances of transhumance movements and declining mobility pattern (Mearns, 2004; Janzen, 2005; Lkhagvadorj et al., 2013b) seem to be explained rather by institutional weaknesses than by environmental changes (Undargaa and McCarthy, 2016). The present Mongolian land law (provision 52; adopted in 2002) permits local governments to regulate pasture stocking rates, seasonal herd movements, and design reserve pastures for emergency cases; yet this law is not sufficiently implemented (Fernandez-Gimenez and Batbuyan, 2004; Munkhnasan, 2010). At the same time, another very useful informal traditional institution of pasture management is the *neg nutgiikhan or khot ail,* which is a small group of herder households who often camp together and pool their livestock to share labour. This institution lost its functions due to the strong formal regulations during the socialist government (Mearns, 1996; Fernandez-Gimenez et al., 2015). Therefore herders seem to act according to the "tragedy of the commons" theorem (Hardin, 1968) and seek their own convenience or profit rather than considering the ecological impacts of their activities. This causes overgrazing and land degradation at particular locations across regions and seasonal pastures (Okayasu et al., 2007; Erdenebat and Gerlee, 2014). Other reasons for such problems are the poor market opportunities to sell livestock products, and the shift of herders to crop cultivation as alternative income sources. Local markets are only available in relatively densely populated areas such as soum centres, which are the lowest administrative units of the country. If herders stay far away from a soum centre on better quality pasture, they have no immediate possibility to sell their products and buy needed (subsistence) goods, and bringing their agricultural products to the market place involves high transportation costs, especially in remote areas (Lkhagvadorj et al., 2013a). Staying on (better) remote pastures also entails difficulties in accessing formal social (child education) and health care services, which are only provided at the soum centre. Provision of mobile social and health care services for herders are possible but are not realized regularly due to a lack of financial and technical capacity of the local government (Asian Development Bank, 2013).

On the other hand, the country's population and especially the number of urban inhabitants is rapidly increasing (NSOM, 2014), mirroring the general Asian trend (UNFPA, 2014). Generally, population growth and urbanization have significant positive impacts on the demand for livestock products, including also wider range of trade (Thornton, 2010), which should open up better opportunities for local herders to generate more income from their livestock. In 2015, export of heat-processed meat from the animal disease free zone in Mongolia's western provinces (Uvs, Bayankhongor, Zavkhan, Gobi-Altai and Khovsgol) to China has taken off and opened attractive market opportunities to herders in these regions. However, individual herders cannot take advantages of such market opportunities themselves – they need private or public institutional support which is yet widely lacking (Sharma and Davaakhuu, 2015).

To summarize, the transhumant livestock husbandry system in Mongolia is still dwelling on mainly traditional animal and pasture management strategies and faces a number of constrains, but also some (new) opportunities. Many international scientists criticize the current herd and pasture management practices and regulations (Fernandez-Gimenez, 1999a; Okayasu et al., 2007; Sternberg, 2008; Fernandez-Gimenez et al., 2015), and consider the system's current development to be ecologically and economically unsustainable (Fernandez-Gimenez, 2006). Therefore, and particularly in the wake of the 2009/10 dzud, but also in view of rapid societal changes induced by Mongolia's massive mining activities (Murray, 2003), international donor organizations and the national government are recently paying more attention to the sustainable development of the country's livestock husbandry.

1.4 Study outline and research objectives

In view of the above introduced general constrains and opportunities of Mongolia's transhumant pastoral livestock system, this study focussed on the Mongolian Altai Mountain region in western Mongolia, which is one of the poorest regions in the country. Since livestock-based activities are the mainstay of the local population, the present PhD study thrived to assess the impact of pasture use, herbage production and livestock management on feed intake, body mass development and reproductive performance of sheep and goats. Through scenario analysis which combined the gained insights, sustainable livestock and pasture management strategies for the target region were evaluated. More specifically, this study aimed to:

- identify herder households' socio-economic characteristics, major livelihoods activities and general herd management practices (Chapter 2);
- analyse the nutritional situation of small ruminants, determine their grazing routes and behaviour (Chapter 3);
- explore the reproductive performance of the traditionally managed sheep and goats and assess the economic viability of the present and alternative herd management strategies (Chapter 4).

The results and insights that are presented in these three chapters are discussed coherently (Chapter 5) to better understand constraints and opportunities of livestock husbandry at the interface of the Altai Mountain and Dzungaria desert region along the Bulgan River Valley in western Mongolia. This discussion is leading to some recommendations for herders, and local and national governments 1) concerning herd and pasture management, 2) policy decisions and 3) livestock support programs.

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Chapter 2

An assessment of pastoral livelihood strategies in western Mongolia

2 An assessment of pastoral livelihood strategies in western Mongolia

Summary

The livelihoods of nearly half of Mongolia's population depend on animal husbandry. A sole dependency on livestock implies problems with inter- and intra-annual variability in climate, water and forage availability. The present survey characterized 225 agro-pastoral households along the Bulgan River Valley of Western Mongolia in terms of their livelihood strategies and farm and livestock management. The data originated from semi-structured interviews and were subjected to CATPCA and two-step cluster analysis. Results revealed four main livelihood strategies, namely commercial livestock keeping (31%), commercial livestock keeping plus semi-commercial field cropping (11%), commercial field cropping (7%) and semi-commercial livestock keeping plus subsistence field cropping (51%). The species composition of the livestock herds was diverse, but commercial livestock keepers focused on cashmere wool production. Livestock transhumance patterns still reflect traditional herding practices, but annual tracking distances are declining. Of secondary importance, cropping was seen as an additional and even alternative activity to livestock keeping by 18% of the surveyed households that could be classified as very poor. Therefore, a comprehensive development policy based on scientific studies is needed to sustain herder families and ensure better pasture utilization and marketing management.

2.1 Introduction

Mongolia is one of the few truly pastoral countries in the world (Suttie, 2005) with a 2000 to 3000 years old nomadic tradition (Rudaya et al., 2008). Although nowadays, mining contributes considerably to the country's economic growth (Suzuki, 2013), livestock husbandry has been, and still is, an important sector for Mongolia's economy and employment (Batima et al., 2005). The National Statistical Office of Mongolia reported that at the end of 2013 the agricultural sector contributed 15% to the national gross domestic product, which is equivalent to 7% of the country's total export income (Komiyama et al., 2013). Of this fifteen percent, 80% are derived from the livestock sector (NSOM, 2013). In addition, the livelihoods of approximately 1.5 million rural dwellers directly and indirectly depend on animal husbandry (Fernandez-Gimenez, 2002), which is almost half of Mongolia's population. By the end of 2012, 160,000 out of 208,000 livestock keeping households in Mongolia were characterized as true herder households whose livelihoods directly depended on animal husbandry; each herder household has on average four family members (NSOM, 2013).

The Mongolian Altai Mountains serve as the drainage divide for the rivers emptying into the Arctic Ocean Basin and the closed basins of Central Asia (Rudaya et al., 2008). The Bulgan River is one of these water bodies originating at the southern slopes of the Mongolian Altai and feeding into one of the inner Central Asian basins, the Ulungur Lake in China (Johnson et al., 2006). In Mongolia, the river flows through two different Bulgan counties, one located in Khovd province and one located in Bayan-Olgii province, and forms the Bulgan River Valley where it is joined by numerous medium- and small-size streams. In Mongolia, the lower part of the river (between 46°5'N / 91°14'E and 46°7'N / 91°9' E) has been protected since 2011 at the national level because of its importance for globally listed endangered species, such as wild beaver (*Castor fiber birulai*; USFWS, 1999; Chu and Jiang, 2009; Mongolian Government, 2011). The livelihoods of approximately 17,000 rural residents directly and indirectly depend on the Bulgan River catchment area by using the river water and bordering pastures for their daily needs and agro-pastoral activities, respectively. Since the 1990 opening of the Sino-Mongolian border, marketing opportunities improved and in consequence the local population increased by about 10% (Statistical Department of Khovd Province, 2013). At the end of 2012 about 9000 citizens, distributed over 2160 households, lived in the central settlement of Burenkhairkhan, Bulgan County

Animal numbers in the catchment area increased from 110,000 to 150,000 head between 1980 and 2004, and from 190,000 to 240,000 between 2005 and 2009 (NSOM, 2013). After the disastrous *dzud* (cold and snowy winter) of 2009/10, the livestock numbers declined abruptly to the values of the 1980s (Statistical Department of Khovd Province, 2013); yet, immediately afterwards the numbers of all livestock species started to increase again (Statistical Department of Khovd Province, 2013). While sheep clearly dominated herd composition until 1993, goats dominate the current livestock herds. The shares of cattle and horses were and are still relatively stable, whereas the share of camels has been gradually decreasing throughout the last decades (Statistical Department of Khovd Province, 2013; NSOM, 2013).

Several studies have addressed the constraints faced by nomadic people in the Altai Mountains and other regions of Mongolia. Fernandez-Gimenez (2002) reported that pastoral nomads live an economically unstable life, because they are keeping their animals on vulnerable rangelands exposed to drought and disastrous events. Lkhagvadorj et al. (2013a) pointed out that nomad families primarily rely on their own livestock for subsistence purposes, whereby monthly cash income from livestock husbandry amounted to 55 USD per household in 2010, 70% of which comes from selling cashmere wool. However, the increasing number of cashmere goats is feared to harm grassland ecosystems more than other domestic livestock species, such as sheep, cattle and yak, since goats graze the entire plant leading to the destruction of sods (Roningen, 1999), and thus to the degradation of valuable pasture land.

With the present study, we aimed to characterize the livelihood strategies of rural households along the lower part of Bulgan River Valley in Western Mongolia. The main objectives were to (i) identify the households' socio-economic characteristics, (ii) explore current livestock management, and (iii) characterize the major livelihood activities. This first assessment will help to determine opportunities and constraints for agro-pastoral livelihoods in the surveyed region, and identify possible measures to overcome the latter and strengthen the former.

2.2 Materials and methods

2.2.1 Research site

The present study was carried out in two administrative units along the Bulgan River, namely in Bulgan county (Bulgan county, belonging to Khovd province) and in the Sonkhel administrative subunit (belonging to the other Bulgan county, located in Bayan-Olgii province; Figure 2.1). The study region is located at the interface of the Mongolian Altai Mountains and the Dzungarian Basin (Grubov et al., 2001), in a steppe and semi-desert ecosystem characterized by long and cold winters, dry and hot summers, low precipitation (rainfall and snow) and high temperature fluctuations (Batima et al., 2005). The average amount of precipitation is higher upstream, in the mountainous locations, and decreases towards the southern part of the Bulgan River Valley. Annual air temperature averaged 2°C over the last past 50 years at Bulgan county centre; however, average annual temperatures have increased by 1.4°C over the same period of time (Gomboluudev and Davaanyam, 2012). The year can be divided in two main seasons, namely the rainy and warm season and the dry and cold season. The first season comprises spring and summer, from May to early October. The second season comprises the months of November until late April, which corresponds to late autumn and winter. Bulgan (46°05'N, 91°32'E) is the largest populated county in Khovd province and also has the largest settlement area. It is located at the lower altitudes (1184 m a.s.l.) of the Bulgan River Valley and covers a land area of 810,500 ha, of which 517,700 ha is pasture, 1,200 ha is arable land, and 1,300 ha is for haymaking. The average annual precipitation in the county centre amounts to 77 mm and monthly mean temperature fluctuates between +20.9 °C (July) and -20.3 °C (January) (Frerkes, 2013).

Sonkhel (46°47'N, 91°18'E) is one of the seven administrative subunits of Bulgan county in Bayan-Olgii province, and is located at the upper part (2432 m a.s.l) of the Bulgan River Valley. The average annual precipitation at Sonkhel is 129 mm of which 55% occur during the summer season. Average annual temperatures fluctuate between +15 °C (July) and -21 °C (January) (Statistical Office of Bayan-Olgii Province, 2013).

2.2.2 Data collection

In a 5 km radius around each of the six weather stations installed within the framework of the WATERCOPE project (www.watercope.org) all households encountered were approached for their participation in the survey (Table 2.1; Figure 2.1). Individual interviews, mostly with the male household head or in very few cases with his wife, were conducted in 225 households on the basis of a pre-tested semi-structured questionnaire. The interviews took place between May and September 2012 and covered questions related to the socio-economic characteristics of the household (size, age, gender structure, education level of household head, and employment status of family members), cropping activities (field sizes and locations, crops grown, cropland management, and product marketing), and livestock activities (herd composition and size, feeding management, products harvested, and marketing strategies). The education level of the household head was classified into six different groups (illiterate, primary, middle and high school, technical academy, university). Sheep and goats were addressed as small ruminants, whereas cattle, horses, camels and yak were defined as large animals. All animal numbers were also converted into sheep units (SU; Annex 2.1). Herd mobility was assessed by asking for the approximate distance in kilometers between seasonal pastures. The cash income from livestock husbandry was estimated based on sales of live animals, raw cashmere wool, sheep and camel wool, as well as animal skins. Self-consumption of products such as meat, milk, cereals, tubers and vegetables, was not addressed in the questionnaire. Households that owned animals, but did not herd themselves, were not considered as livestock managers (Mongolian Parliament, 2006). All monetary information was converted from the national currency Mongolian National Tugrik (MNT) into US Dollar (USD) based on the average exchange rate during May to September 2012 (1 MNT=0.00074 USD; www.oanda.com).

Table 2.1. Study locations, ordered by increasing altitude, in Khovd* and Bayan-Olgii** provinces, along the Bulgan River in the Mongolian Altai Mountains.

Location	Eastern longitude	Northern latitude	Elevation (m a.s.l.)*	Description
Bulgan-gol*	91° 04'	46° 07'	1133	Spring and autumn pasture
Bulgan-soum*	91° 34'	46° 05'	1181	County centre and crop fields
Bayan-gol*	91° 24'	46° 20'	1323	Crop fields and pasture
Kheltgiikhad**	91° 21'	46° 38'	1611	Spring and winter pasture
Turgen**	91° 20'	46° 49'	1889	Crop fields, spring and winter pasture
Sonkhel Lake**	91° 30'	46° 39'	2170	Summer pasture

* *a.s.l. above sea level*

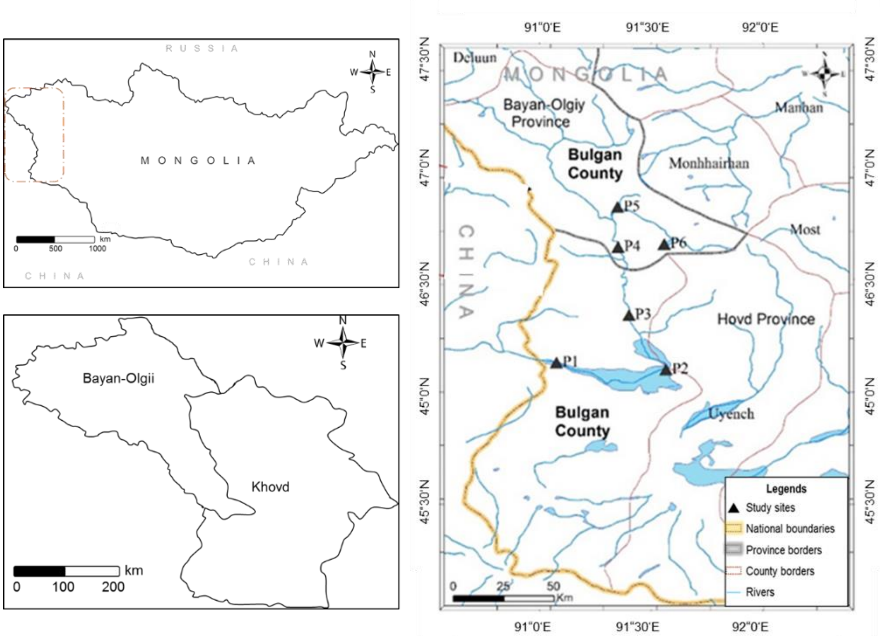

Figure 2.1. Study location (upper left) in Western Mongolia, shared between Khovd and Bayan-Olgii provinces (lower left) and covering six different sites (right), namely: P1-Bulgan-gol, P2-Bulgan-soum, P3-Bayan-gol, P4-Kheltgiikhad, P5-Turgen, P6-Sonkhel Lake.
The map was prepared by Dr. Serik Doman (Xinjiang Academy of Animal Sciences).

2.2.3 Statistical analyses

Data was analysed with the Statistical Package for Social Sciences SPSS-PC Version 20.0 (IBM Corp, 2011). Twenty-nine initial variables were selected based on their competence to clarify the livelihood of pastoral families (Annex 2.2). Households of similar livelihood strategies were identified by subjecting the initial 29 variables to a Categorical Principal Component Analysis (CATPCA), in order to explore variable importance and interdependencies (Dossa et al., 2011). The main advantage of CATPCA is the simultaneous consideration of multiple categorical and continuous variables in one analysis and the ability to determine nonlinear relationships between variables. For the selection of the most important explanatory variables, a component loading >0.5 was set and assigned variables were retained for subsequent two-step-cluster analysis. The number of fixed clusters was determined based on the Bayesian information criterion (BIC). A silhouette value of cohesion and separation at 0.6 was accepted for the clear assignment of obtained clusters. In a third step, the 29 initial variables, which were all not normally distributed (Kolmogorov-Smirnov test of residuals), were used to compare the effects of location and cluster by applying Chi-square test, Mann–Whitney U test, or Kruskal–Wallis tests (depending on the scale of data). Significance was declared at

$p \leq 0.05$. Linear relationships between variables were analysed using the Pearson's correlation coefficient.

2.3 Results

2.3.1 Household clusters

The most influential variables, reflected by the length of their vectors in the two-dimensional CATPCA plot (Annex 2.3), were the variables related to the main livelihood strategies and respective assets, namely: "managing livestock" (yes/no), "cropping fields" (yes/no), "size of cropping plus haymaking areas" (ha), "number of small ruminants", "number of large animals", as well as "cash income from livestock production" (in USD). With these variables, four homogeneous livelihood strategy clusters were defined (Table 2.2): commercial livestock keeping (cL), commercial livestock keeping plus semi-commercial field cropping (cLscC), semi-commercial livestock keeping plus subsistence field cropping (scLsC), and commercial field cropping (cC).

Table 2.2. Distribution of the interviewed households (n) into four livelihood clusters at the six study locations in Khovd* and Bayan-Olgii** provinces, Western Mongolia, 2012.

Location	House-holds (n)	Commercial livestock keeping (cL)	Commercial livestock keeping plus semi-commercial field cropping (cLscC)	Commercial field cropping (cC)	Semi-commercial livestock keeping plus subsistence field cropping (scLsC)
Bulgan-gol*	6	6	0	0	0
Bulgan soum*	100	19	14	10	57
Bayan-gol*	8	4	1	2	1
Kheltgiikhad**	12	4	0	0	8
Turgen**	77	16	9	5	47
Sonkhel Lake**	22	19	2	0	1
Total	225	68	26	17	114

2.3.1.1 Commercial livestock keeping (cL)

Households (n=68) of this cluster (Table 2.1) were located in Bulgan-gol (9%), Bulgan-soum (28%), Bayan-gol (6%), Kheltgiikhad (6%), Turgen (23%) and Sonkhel Lake (28%). Household size (Table 2.3) was smallest in this cluster compared to the other three clusters ($p > 0.05$). On average, households in this cluster kept 104 and 23 small ruminants and large animals, respectively. The animals were actively herded by these households all year around, leading to an annual average of 135 km tracking distance, the farthest distance across the different clusters ($p \leq 0.05$). These households did not cultivate crops and vegetables, but managed 2.5 (±2.28) ha of haymaking area on average. Livestock played the main role for satisfying household needs and earning cash, with the latter amounting to an average amount of 1360 USD per year (Table 2.7).

2.3.1.2 Commercial livestock keeping plus semi-commercial field cropping (cLscC)

This cluster was comprised of 26 households that were mainly located in Bulgan-soum (54%) and Turgen (35%; Table 2.1). Compared to other clusters, the average household size was largest and with the oldest average age of household head (Table 2.3). Average herd size in this cluster was 347 SU broken down into 211 small ruminants and 47 large animals on average. Livestock resources were the most important source of cash income (Table 2.5) and were sold directly to local traders when cash was needed. An average amount of 1212 USD per year of additional cash income was provided through crop farming. Most (81%) of the 26 households were cultivating some vegetables such as potato, carrot, cabbage, plus the cereals wheat and rye. These products were occasionally sold, but most production was used for family consumption. The average field cropping and haymaking areas per household were the highest ($p \leq 0.05$) in this cluster (Table 2.3), and the same was true for the average cumulative value of assets owned by cLscC households.

2.3.1.3 Commercial field cropping (cC)

The households falling in this cluster were only found in Bayan-gol, Turgen, and Bulgan-soum. They comprised 7%, 10% and 25% of the households interviewed in these locations, and were Torguud and Kazakh dominated. About one fourth of the respective household heads had completed technical school (Table 2.4). Herd size averaged 24 of small ruminants and 11 large animals, but none of the families actively herded their animals, and thus herd mobility was the lowest among all clusters (Table 2.6). Twenty-four percent of these households reported substantial losses of livestock during the 2009/10 *dzud*, one of the major reasons why they started cultivating vegetables and cereals in the settlements close to the Bulgan River and its tributary in Turgen. The average sizes of their crop and haymaking fields were 0.4 ha and 3.0 ha, respectively, which were significantly higher than field sizes encountered in cluster cL ($p \leq 0.05$). The sale of cultivated products (including hay) contributed more to the household cash income (736 USD per year) than livestock husbandry. Income from the latter was the lowest

(220 USD per year) among all clusters (p≤0.05). Similarly, the total value of assets was lowest (p≤0.05) in this cluster (Table 2.3).

2.3.1.4 Semi-commercial livestock keeping plus subsistence field cropping (scLsC)

Most interviewed households (n=114, 51%) were assigned to this cluster, which was present at all study locations except Bulgan-gol (Table 2.1). The respective household heads were the youngest ones; this cluster held the highest attainable level of education, at the same time the share of illiterate household heads was lower than in the other clusters (Table 2.4). Furthermore, families on average owned 64 and 18 small ruminants and large animals, respectively (Table 2.3).

Table 2.3. Household structure, main activities, cropland and herd size and value of assets of four livelihood clusters in Khovd and Bayan-Olgii provinces, Western Mongolia, 2012. Means ± standard deviation

Variables	Livelihood clusters*				Average
	cL	cLscC	cC	scLsC	
n	68	26	17	114	225
HH** size (n)	4.6±1.9	5.2±1.3	5.3±1.5	5.3±1.9	5.1±1.7
Adults >18 years (n)	2.7^{b}±1.3	3.9^{a}±1.5	3.3^{a}±1.3	3.3^{ab}±1.6	3.2±1.4
Employed adults (n)	1.8^{b}±1.2	2.6^{a}±1.2	2.2^{b}±1.0	2.0^{b}±1.5	2.1±1.1
Cropping (% of HH)	0^{c}	87^{b}	100^{a}	82^{a}	67
Cropland size (ha)	0.0^{b}±0.0	0.8^{a} ±1.4	0.4^{b} ±0.6	0.4^{b} ±0.7	0.4±1.2
Hay making area (ha)	2.5^{b}±2.3	8.5^{a}±12.3	3.0^{b}±4.7	2.1^{b}±1.6	3.1±5.0
Livestock keeping (% of HH)	100^{a}	100^{a}	0^{b}	100^{a}	75
Small ruminants (n)	104^{b} ±65	211^{a} ±92	24^{d} ±26	64^{c} ±45	90 ±76
Large animals (n)	23^{b} ±16	47^{a} ±37	11^{c} ±10	18^{bc} ±11	22 ±20
Total livestock (SU)***	167^{b} ±100	347^{a} ±194	62^{c} ±56	122^{b} ±65	157 ±123
Value of assets (USD)****	1980^{ab}±2392	4732^{a}±8167	977^{b}±1845	1803^{ab}±2048	2133±3530

* cL - commercial livestock keeping; cLscC - commercial livestock keeping plus semi-commercial field cropping; scLsC - semi-commercial livestock keeping plus subsistence field cropping; cC - commercial field cropping.
**HH=household
***USD=US Dollar; assets counted are: car, motorcycle, tractor, bicycle, television, solar panel, snuff bottle, hunting gun, sewing machine, mover for grass, plough
^{abc} In rows, small superscripts following means indicate significant differences between livelihood clusters according to Kruskal-Wallis test.

The average cash income from animal husbandry was considerably less than in clusters cL and cLscC, but slightly higher than in cluster cC (p≤0.05). All scLsC households were also cultivating vegetables and fruit trees, particularly in Bulgan-soum (59%), Turgen

(60%) and in Kheltgiikhad (58%). The average surfaces of crop and haymaking fields were 0.4 and 2.1 ha, respectively, and the harvested produce was used for family consumption.

2.3.2 Household and herd characteristics

The 225 households interviewed in the six study locations represented 13% of all households in both provinces; the households belonged either to the Uriankhai, Torguud, or Kazakh ethnic group (Table 2.4). Most Torguud were encountered in Bulgan-soum, Bulgan-gol and Bayan-gol, while a mixture of ethnicities inhabited the Sonkhel Lake area. Nonetheless, there was no clear relation between ethnic group and cluster. The average size across all households was 5.1 family members, with an average of three adults potentially contributing to the household's daily work. Across all locations the average age of the household head ranged from 43 to 50 years, and most household heads (97.3%) were literate. Most households (92%) managed livestock for self-consumption and to earn cash, the main species being cattle and goats (each kept in 94% of the livestock managing households). Only 8% of the households did not manage any livestock.

Table 2.4. Ethnicity, age, and education level of household heads of four livelihood clusters in Khovd and Bayan-Olgii provinces, Western Mongolia, 2012.

	Ethnicity (%)				**Education level (%)**					
Livelihood cluster*	**Uriankhai**	**Torguud**	**Kazakh**	**Age (years)**	**Illiterate**	**Primary school**	**Secondary school**	**High school**	**Technical school**	**University**
cL	28	54	18	47 ±14	3	24	34	29	4	6
cLscC	15	58	27	50 ±13	0	12	38	38	4	8
cC	12	59	29	47 ±12	6	12	18	35	24	6
scLsC	34	43	23	46 ±11	3	9	35	33	14	6
Average	28	49	22	47 ±12	3	14	34	33	11	6

* cL - commercial livestock keeping; cLscC - commercial livestock keeping plus semi-commercial field cropping; scLsC - semi-commercial livestock keeping plus subsistence field cropping; cC - commercial field cropping.

A total of 35,396 animals and an average herd size of 157 SU per family were recorded (Table 2.3). Goats (63%) dominated livestock herds, followed by sheep (18%), cattle (11%), horses (4%), camels (3%) and yak (1%). In addition, the maximum number of animals for one species in a herd was found for goats, with 338 head. Yak were least present, with a maximum of 21 head per herd. Most of the species were kept in all six locations except for yak, which was only present at the higher altitudes upstream of the Bulgan River (Kheltgiikhad, Turgen, and Sonkhel Lake).

Calculation of livestock species richness and diversity allowed for further insights into the composition of livestock herds in the study region (Table 2.5). The highest species richness was found in Kheltgiikhad, while the lowest one was found in Bulgan-soum. In contrast, livestock diversity was highest in Turgen, but lowest in Bayan-gol. The latter location also exhibited the lowest evenness value, whereas for Turgen and Bulgan-soum the highest values were calculated. Species accumulation curves, saturated at two levels of richness, depended on whether five or six animal species were kept in a location. The Shannon diversity accumulation showed more variability in the diversity distribution, potentially ranging from 0.71 (Bayan-gol) to 1.18 (Sonkhel Lake). A positive linear relationship was found between altitude and livestock species richness ($r=0.667$, $p \leq 0.05$), Shannon diversity ($r=0.714$; $p \leq 0.05$) and evenness ($r=0.265$, $p \leq 0.05$) among the six locations. The richness and Shannon diversity were significantly different across clusters ($P \leq 0.05$), whereas no difference was found for Shannon evenness between clusters. Animal species diversity in herds of cluster cC was the lowest of all clusters ($p \leq 0.05$).

Table 2.5. Livestock species richness, Shannon diversity and Shannon evenness for herds encountered at the six study locations in Khovd* and Bayan-Olgii** provinces, Western Mongolia, 2012.

Location	Richness	Shannon diversity	Shannon evenness
Bulgan-gol*	4.8	0.96	0.61
Bulgan-soum*	3.3	0.79	0.67
Bayan-gol*	3.8	0.62	0.43
Kheltgiikhad**	5.3	1.01	0.61
Turgen**	5.0	1.07	0.67
Sonkhel Lake**	5.2	1.04	0.64

2.3.3 Livestock feeding strategies and seasonal mobility

During the warm and rainy season, livestock species relied purely on grazing pastures at higher altitude mountain plateaus along the Bulgan River. Only cL, cLscC and scLsC households offered salt to their livestock as a supplement during this season. Mostly the salt was collected for free from a public saltlick within the Bulgan River Valley; occasionally, it was bought for small amounts of money or exchanged against young small ruminants. Among the six locations and four clusters, no significant difference could be determined for the feeding strategy of livestock during the spring and summer seasons.

During the dry and cold season, the pastures were still important resources for livestock feeding, particularly for animals in good physical condition and non-lactating animals. Camels and horses fed autonomously on large pasture areas throughout the year; only 8.5% of all interviewed households offered salt to those animals. Dairy cows, yaks, weak small ruminants and working horses were offered supplemental feed at the homestead during the winter time (Figure 2.2A), whereby in cluster cLscC a higher diversity of supplemental feeds was offered to the animals than in the other clusters. The supplement for cattle was mostly based on grass hay, cereal bran and salt. Grass hay and cereal bran feeding were equally practiced across all clusters, while wheat straw or rye were distributed only by cL and cLscC households (Figure 2.2A).

Grass hay and cereal bran were also the most common supplemental feeds for weak and small ruminants (Figure 2.2B), although significant differences were found across the clusters. The highest usage of grass hay for small ruminants was found in cluster cLscC, and the highest proportion of cereal bran was offered in cluster scLsC. The proportion of households feeding grass hay to their weak small ruminants was slightly higher in Bulgan-soum ($p \leq 0.05$) than in the other locations. In Bulgan-gol and Sonkhel Lake, households did not offer salt to their weak small ruminants. However, nearly 50% of the households in Bulgan-soum and Bayan-gol supplied salt to small ruminants.

As far as herd tracking is concerned, four different locations were visited throughout one year, namely winter, spring, summer and autumn pastures. The average distance from winter to spring, spring to summer, summer to autumn and autumn to winter pastures was reported to be 9, 40, 34 and 10 km, respectively. This resulted in a total distance of approximately 93 km per year for transhumant movements. The maximum distances reported for the seasonal movements of individual herds were 160 km (winter-spring), 230 km (spring-summer), 150 km (summer-autumn) and 130 km (autumn-winter). The yearly herd mobility in cluster cL was significantly higher than in clusters cC and scLsC, but similar to the herd mobility in cluster cLscC (Table 2.6). The longest average yearly tracking distances were found in cluster cL and cLscC, amounting to 136 and 129 km per herd, whereas the shortest average yearly tracking distance (41 km) was reported for cluster cC ($p \leq 0.05$).

Table 2.6. Distances covered (in km) by herd movements between seasonal pasture areas in Khovd and Bayan-Olgii provinces, Western Mongolia, 2012, as determined in interviews. Means ± standard deviation

Livelihood cluster*	Winter-spring	Spring-summer	Summer-autumn	Autumn-winter	Yearly tracking distance
cL	13^{a} ±20	59^{a} ±52	52^{a} ±48	12^{a} ±24	136^{a} ±122
cLscC	17^{ab} ±37	56^{a} ±54	46^{ab} ±47	14^{a} ±16	129^{a} ±112
scLsC	6^{ab} ±12	28^{b} ±40	24^{c} ±36	10^{b} ±22	68^{b} ±82
cC	8^{b} ±15	15^{b} ±37	16^{cb} ±39	2^{ab} ±10	41^{b} ±92
Average	9 ±21	40 ±48	34 ±43	10 ±21	93 ±105

***** cL - commercial livestock keeping; cLscC - commercial livestock keeping plus semi-commercial field cropping; scLsC - semi-commercial livestock keeping plus subsistence field cropping; cC - commercial field cropping.

[abc] In columns, small superscripts following means indicate significant differences between livelihood clusters according to Kruskal-Wallis test.

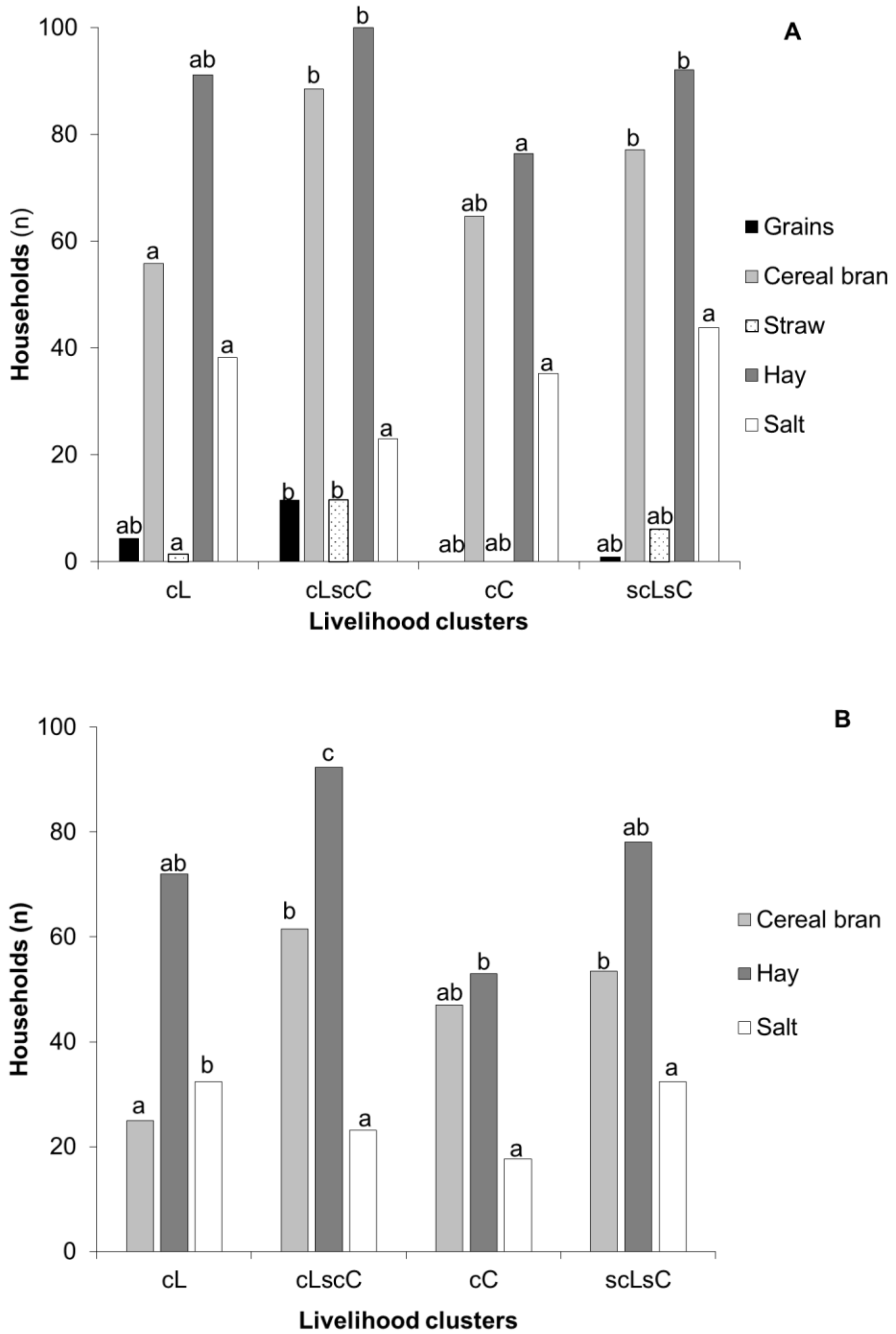

Figure 2.2. Number of households per cluster offering different types of supplemental feeds to their large animals (A) and small ruminants (B) during the dry and cold season in western Mongolia. For the cluster abbreviations see Table 2.6.
[a, b] Superscripts on bars indicate significant differences between the clusters tested by Mann-Witney U-test.

2.3.4 Cash income from livestock husbandry

Reportedly, livestock supplied meat and milk for home consumption and cash income to the households. Cash income from livestock was primarily from sales of cashmere fibre (71%), live animals (20%), sheep and camel wool (2%), and animal skins (7%). A mean annual cash income of 1348 USD per household and an annual per capita income of 77 USD were calculated from the obtained information on product sales (Table 2.7). On average, a household sold 21.3 kg of cashmere at 40 USD per kg in 2012. The sale of live animals mostly occurred when cash was needed for household demands, but only 48 out of 225 households sold a total of 560 small ruminants for an average price of 59 USD per head. Other animal species were rarely sold: cattle (36 animals, mean 343 USD per head, 23 families), horses (21 animals, mean 436 USD per head, 12 families), and camels (12 animals, mean 432 USD per head, eight families). Skins were sold when households slaughtered for home consumption and the price depended on the animal species. On average 7, 16 and 18 USD per piece was gained for one small ruminant skin, cattle skin and horse skin, respectively. Before 2011, sheep wool was rarely sold due to low prices. However, the sale of sheep and camel wool experienced a revival in 2011 after the Mongolian Government established a new program named "Bonus for sheep and camel wool", which aims at encouraging national enterprises to process wool.

Table 2.7. Yearly household cash income (in USD) from sale of livestock and its products in Khovd and Bayan-Olgii provinces, Western Mongolia, 2012. Means ± standard deviation.

Income sources	Livelihood clusters				Average
	cL	cLscC	cC	scLsC	
Live animal sales	240^{b} ±491	1273^{a} ±2379	83^{b} ±261	86^{b} ±192	270 ±930
Sheep and camel wool sales	34^{a} ±75	111^{a} ±178	5^{b} ±20	7^{b} ±21	27 ±81
Cashmere wool sale	986^{b} ±811	2803^{a} ±2549	220^{d} ±299	617^{c} ±543	951 ±1254
Animal skin sale	98^{b} ±57	197^{a} ±154	39^{c} ±38	88^{b} ±56	100 ±82
Total livestock income	1359^{b} ±1124	4385^{a} ±3472	347^{d} ±515	798^{c} ±6030	1348 ±1801
Crop sales	2^{b} ±12	1212^{a} ±4073	736^{a}±2334	199^{a}±686	397±1619
Overall revenues	1360^{b}±1126	5598^{a}±4681	1083^{cb}±2791	997^{b}±908	1645±2423

* cL - commercial livestock keeping; cLscC - commercial livestock keeping plus semi-commercial field cropping; scLsC - semi-commercial livestock keeping plus subsistence field cropping; cC - commercial field cropping.

[abc] In columns, superscripts following means indicate significant differences between the clusters according to Kruskal-Wallis test.

The market price of sheep wool at Bulgan-soum was still low in 2012; however the monetary bonus was higher than the market price (1.5 *versus*. 0.2 USD per kg). A strong relationship was found between the total number of animals kept by a household and its total annual cash income from livestock produce ($r=0.605$, $p\leq0.05$, $n=224$).

2.4 Discussion

2.4.1 Livelihood systems and income generation

Grazing-based and mixed crop-livestock production are the typical and predominant land use systems of Mongolia (Carlos and Henning, 1995; Andrew et al., 2009). Therefore, it is not surprising that the families settling along the Bulgan River Valley were classified into three different pastoral (cL) and agro-pastoral livelihood clusters (cLscC, scLsC) with only 17 out of 225 household being pure agriculturalists (cC). Even though the majority (92%) of the interviewed households kept livestock, most (70%) of them also cultivated crops and indicates that crop farming is the second pillar of livelihood. This is similar to other counties within Khovd province that are located along the Buyant River Valley (Janzen and Hartwig, 2006). However, crop farming is less prominent in other regions of Mongolia, as only river valleys offer the opportunity to cultivate irrigated vegetables, cereals and some fruit trees. The four livelihood clusters determined along the Bulgan River Valley differed from each other in their socio-economic characteristics, herd size, cropland surface, combination of livestock and cropping, as well as market orientation. The livelihood strategy of cluster cL was solely based on livestock and characterised by extensive herd movements between autumn and winter pasture areas in the Dzungarian desert and spring and summer pasture areas in the Altai mountain region. The opposite was true for the livelihood strategy of cluster cC, which relied entirely on field cropping, leading to a sedentary lifestyle (needed for the sowing, weeding and watering of the crop fields) and very low herd mobility in cases of cC households keeping animals. Even though households in clusters cLscC and scLsC were similarly involved in livestock keeping and cropping, they clearly differed in herd size, crop area, production orientation, cash income, and the extent of long distance livestock movements. Accounting for valuable assets, total number of livestock and cash income from livestock sales plus cash income from crops sales, the best-off households were in cluster cLscC and the poorest were in clusters cC and scLsC. However, according to Johnson et al. (2006), the average herd size of 157 SU across the studied households is not sufficient to support a family's livelihood. Similarly, the National Statistical Office of Mongolia estimated that the subsistence of a herding family with 5 members requires a minimum of 170 animals (NSOM, 2004), yet 88% of the surveyed families had lower herd sizes. However, families in the cLscC cluster are most likely able to maintain their livelihood in terms of livestock number according to the assessment of Bakei (1993). The reported shifts of households (particularly those in clusters scLsC and cC) from a pure livestock-based livelihood towards a mixed or pure cropping system after the disastrous winter of 2009/10 might be interpreted as a voluntary (scLsC) or forced (cC) response to disaster.

Similarly to what was reported by Wang et al. (2013) for steppe and desert regions (south-eastern provinces), all livestock species and their produce were sold to local traders at prices that were much lower than those encountered in the central region of the country. For instance, local prices per adult sheep and cattle in 2012 were 70 USD and 345 USD, while the respective prices in the capital city were 120 USD and 640 USD in the same year (NSOM, 2013). Only the price for cashmere fibre did not differ considerably between different regions of the country. Across the four clusters, the sale of cashmere contributed 63-70% of cash income from the livestock sector, which is consistent with the results of a previous study in the Altai mountainous region (Lkhagvadorj et al., 2013a). These authors along with Shombodon and Williams (2001) mentioned the rural populations' difficulties in selling other livestock products, such as meat, milk, dairy products and skins, due to remoteness of settlements, lack of transportation possibilities to county centers, weak infrastructure in the county centres as well as limited access to larger regional markets. Due to this, livestock keepers are very interested in increasing cashmere goat numbers in order to secure their cash income, which is clearly demonstrated by the official livelihood statistics for the county of Bulgan (Figure 1.1 and 2.3) and by the findings of Johnson (2009) for desert and desert steppe regions of Mongolia.

Field cropping activities (clusters cLscC, ScLsC and Cc) were more frequently found in Bulgan-soum, Turgen, and Bayan-gol than at Sonkhel Lake, Bulgan-gol and Kheltgiikhad. This is due to the fact that the these three locations are more suitable for cultivating vegetables and cereals thanks to their wide and flat plains and deep soils as compared to the narrow and rocky valleys of Kheltgiikhad and the harsh high altitude conditions of Sonkhel Lake. The reasons for the absence of farming activities at Bulgan-gol are the lack of infrastructure and its location in a nature reserve close to the Sino-Mongolian border.

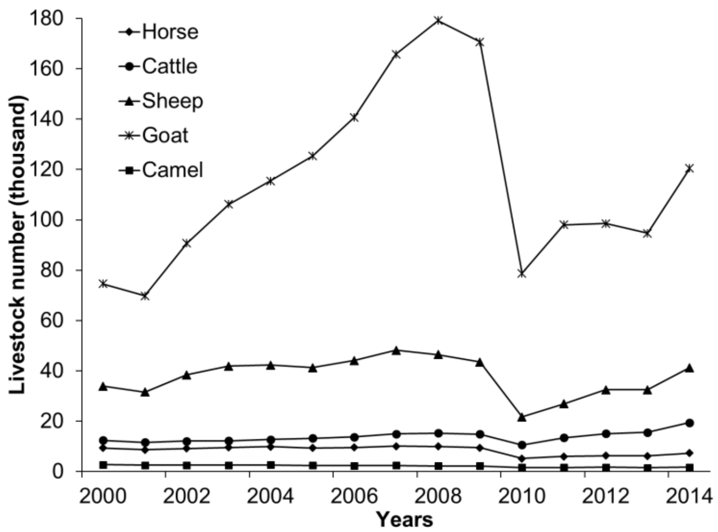

Figure 2.3. Development of livestock numbers in Bulgan county of Khovd province from 1970 to 2014 (data provided by National Statistical Office of Mongolia). The sharp decline in 2009/2010 was due to *dzud*.

Although there was no clear differentiation between ethnic groups, ethnical preferences were still found to affect the livelihood strategy. Torguud and Uriankhai were mainly found in clusters scLsC and cC. The traditional field cropping knowledge of those groups increased, especially during the 70 years of socialism, and contrasts with the very strong pastoralist background of Kazakh people (Reynolds, 2006) and seems to have added to the observed differences between ethnic groups (Gokcumen et al., 2008; Dulik et al., 2011).

2.4.2 Livestock diversity and management practices

The observed livestock species richness and diversity illustrates how many different animal species are kept by herders at different locations. The livestock richness and diversity of family herds living upstream of the Bulgan River Valley (at Kheltgiikhad and Turgen) points to the strategy to utilise, in an optimised way, the seasonally abundant high quality vegetation given the rough terrain and cold climate. This goes along with the findings of Fernandez-Gimenez (2002) and Chuluun (2008) who stated that traditional and ecological knowledge of herders, and particularly the diversification of their herd composition, plays an important role for coping with the strongly varying climatic conditions of the mountain and forest steppe zones of Mongolia. However the Shannon evenness values show that different animal species were not equally represented in the total number of surveyed livestock; across all locations goats were the dominant species (62.7%), followed by sheep (17.6%). This may have a negative effect on pasture vegetation (Mayer et al., 2009; Fernandez-Lugo et al., 2009), but is due to the high economic importance of goats for the herder households (Lecraw et al., 2005). In terms of topography of the different locations, most (59%) of the herder households stayed at locations below 1400 m above sea level in a semi-desert zone, which is more suitable to raise goats than other animal species (Fernandez-Gimenez, 2002). Also consistent with this author is the finding that the share of yak and horses increases along the elevation gradient of the six different locations while the opposite occurs for sheep and camels.

Across seasons and clusters, the vegetation of natural pastures was the most important feeding resource for all livestock species. This finding is consistent with Bat-Oyun et al. (2010) who reported that pastures are the major food source for livestock in Mongolia. Therefore, herders' feeding strategies can be differentiated between two main seasons (Gendaram, 2009); in the rainy and warm season, animals can ingest enough good quality fodder to build up body fat reserves (especially fat rump sheep, camels, and yak) for coping with the harsh dry and cold season. Although pasture land is government property, herders are allowed to use it freely. Their seasonal mobility is influenced by weather and environmental conditions. Herders classify pasture areas into summer, autumn, winter and spring pastures using different types of criteria, such as aboveground net primary production and suitability of the vegetation for different livestock species, topography and elevation, and drinking water availability (Tomorjav, 2004; Lkhagvadorj et al., 2013) as well as distance from the homestead (Fernandez-Gimenez, 2002). The herders in our study region moved at least four times a year between the seasonal pastures, thereby covering an annual average distance of 93 km. This indicates the continued relevance of a highly mobile herding strategy for adequate animal nutrition in this spatially and temporally highly variable environment (Fernandez-Gimenez and Le Febre, 2006; Wang et al., 2013). Household mobility mostly followed the course of the Bulgan River that, together with its tributaries, provides water and high biomass availability along its shores. The Sonkhel Lake area, the coldest place of the studied locations, is used only during summer when livestock, particularly yak, prefer to graze under cooler conditions (Fernandez-Gimenez, 2002; Togtokhbayar and Tserendash, 2012). The winter and spring pastures are located at lower altitudes close to the Chinese border, about 120 km south of the Bulgan River and close to the Dzungarian desert steppe. These pastures are used because these regions are warmer during the dry and cold season and are characterised by longer vegetation periods, thus providing fodder for a longer time of the year compared to higher altitude locations.

Across livelihood clusters, livestock mobility differed largely due to the families' different degrees of dependence on livestock keeping for direct and indirect income generation. As is expected from their vocation, clusters cL and cLscC seasonally moved their herds longer distances, indicating that these families try to closely adapt to the current environmental conditions. Although internal livestock movement on one seasonal pasture occurs, it seems to be less important among the interviewed households than it was driving the previous two decades. Similar to our results, the Asian Development Bank, (2013) reported that the present day average and seasonal livestock mobility distances have decreased by 20-30 km from the socialist era in desert-steppe regions. During the period of 1959-1990, collectivisation introduced new scientific technologies into the traditional nomadic animal husbandry system, as a means to facilitate the most efficient use of pasture. Introduced technologies included monitoring carrying capacity, installation of wells and pasture regulations (Upton, 2010). However after the fall of collectivisation, regulations on animal husbandry weakened and relied on individual herder decisions (Fernandez 2002). In other words, livestock management shifted backwards to more traditional herding practices, in comparison to the socialist era (Lkhagvadorj et al., 2013b).

Grass hay, cereal bran, straw, sometimes wheat or rye grain, as well as salt were used as supplements during the dry and cold season, which is consistent with findings from other Central Asian countries (Devendra and Sevilla, 2002). Suttie (2000) suggested limiting animals' access to summer and autumn pasture areas for a certain period per year to produce sufficient hay, which is the most important feed during the winter and spring time in Mongolia. The current local technologies employed for preparing and stocking hay and supplemental feeds and their ubiquitous uses were introduced during Mongolia's socialist period (Upton, 2010). During that time, large investments had been made into the livestock sector, particularly in animal feeding (Fernandez-Gimenez, 1999; Sternberg, 2008). The grass hay and cereal straw, respectively, were harvested from haymaking areas on natural pasture and cropped fields from late August to mid-September and were stored in the yard at the families' winter homestead. Where possible, haymaking areas were irrigated by trench diversion of river water onto nearby pastures. However, only few households could irrigate their haymaking areas due to lack of water resources and labour. Improved and efficient irrigation systems along the river could increase hay production, which is a prerequisite for lowering animal mortalities during harsh winters. Depending on weather conditions, hay and straw were offered to the animals on a daily basis from the end of November or mid-December onwards. Cereal bran and grain were mostly purchased at the local market; both were fermented or mixed with water before being offered - in small quantities - to weak small ruminants, lactating cows and working horses, a practice also reported by Suttie (2000); feeding of these supplements was mostly practiced between January and March. However the frequency of offering grains was irregular and most probably limited by purchasing costs and lack of knowledge regarding their efficient use. Overall, the livestock feeding strategies encountered in the study area, particularly during the dry and cold season, were similar to those reported by Devendra and Thomas (2002), although these authors did not address Mongolia as a country with agro-pastoral production systems, due to the strong dependence of Mongolian livestock on grazing natural pastures.

2.4.3 Present cash income and future livelihood trajectories in Bulgan county

The overall share of total cash income from livestock production and cropping activities was 82% and 18%, respectively. The total average income from livestock production was comparatively higher (1348 USD) than from cropping (297 USD). According to the national definition of the poverty line, interviewed households could be generally classified as poor; yet due to measurement and valuation differences our results are not comparable to the national poverty line. Our results corroborate the findings of Fernandez-Gimenez et al. (2015) that diversification of animal species in a herd is important in allowing herders to use different types of pastures and to obtain cash income from different species of livestock. As the Mongolian economy has only a limited capacity to diversify away from the dependence on animal husbandry (Borgford-Parnell, 2009), intra-sector diversification is necessary.

The border point between China and Mongolia in Bulgan county has the potential to improve regional livelihoods through the purchasing of inexpensive products from China, such as construction materials and solar panels to generate electricity, which grants the opportunity to watch television, use refrigerators, and charge mobile telecommunication devices. Additionally, the border point facilitates knowledge exchange on rural development and agricultural practices via the support of the local county governments of Bulgan/Mongolia and Qinghe/China.

The number of herder households has increased almost 10 times from 550 (1992) to 1425 (2002) (Statistical Department of Khovd Province, 2013). This indicates that many families were involved in animal husbandry instate-owned industries and organizations, which collapsed in 1990 (Borgford-Parnell, 2009). It is likely that these families are inexperienced when it comes to herding practices. These knowledge-poor families and their next generation mostly configure the present herder-community along the Bulgan River Valley. Their livelihoods are not very diverse and still highly depend on mobile livestock husbandry, with the exception of small-scale cropping nearby settlements. Consequently, these herders with urban background prefer to send their children to bigger cities for education where they live and get employment, resulting in 65% young people in Mongolia residing in cities (Shatz et al., 2015). Herders believe that working and living in a city is more stable and better than being a herder (Lkhagvadorj et al., 2013b). Unfortunately, the bigger cities do not have the potential to supply all graduated students or young people from the countryside with jobs. Therefore, at least half of them have to go back to their parents in the countryside and begin herding livestock, which they did not plan for their future. Therefore, the Mongolian Government decided to teach young herders about herding strategies, livestock management and marketing of livestock products within the frame work of the Mongolian Livestock Program which receives 1% of the annual national budget (Mongolian Government, 2010). Nonetheless, there is almost no assessment of the benefits of this activity for young herders. The rural to urban migration flows will continue in the near future unless development in remote areas occurs rapidly (Mearns, 2004).

2.5 Conclusions

The herder families along the Bulgan River Valley have to cope with poor living conditions and practice traditional livestock husbandry and small-sized cropping. Their income sources cannot be diversified due to the lack of livestock and agricultural market possibilities in this remote rural area. Herd management is partly carried-out by inexperienced herders and is becoming more sedentary with shortened migration distances between pastures. This pattern seems likely to continue throughout the near future and will most likely result in the decrease of the number of herder families and in the degradation of pastures along the lower part of Bulgan River Valley. Therefore herder households should be supported by local and central governments with improved pasture utilization regulations and more sustainable market opportunities for livestock products, in order to diversify and sustain their income opportunities.

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Annex

Annex 2.1. Conversion coefficients for herbivore livestock into sheep units

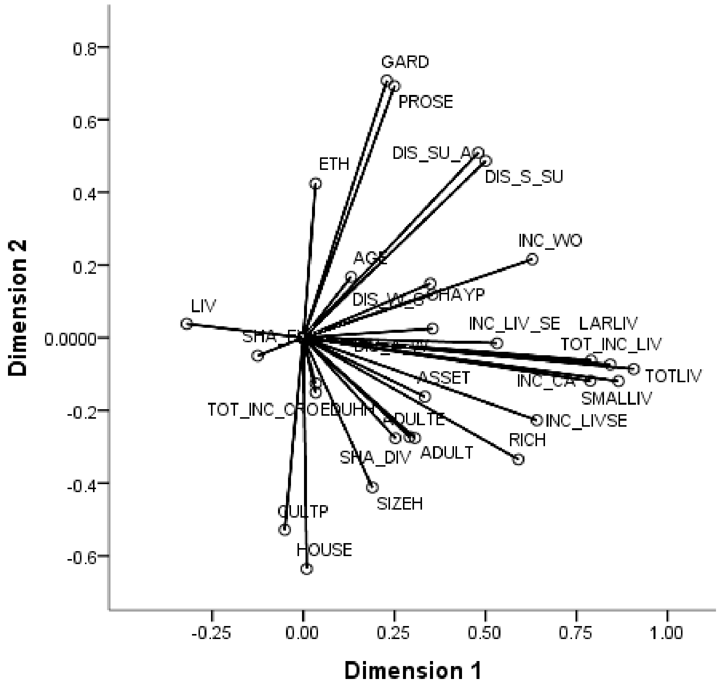
Sheep		Goat		Cattle		Horse		Camel**	Yak**
Adult***	Young*	Adult	Young*	Adult	Young*	Adult	Young*	Adult	Adult
1	0.5	0.9	0.4	5	3.5	5	3.5	7	3

** ≤1 years old, ** mixed age, *** standard animal; Source: Hu and Zhang, 2006*.

Annex 2.2. Description of household socio-economic variables used in categorical principal component analysis (CATPCA) on 225 households in Khovd and Bayan-Olgii Provinces, western Mongolia.

Variable	Description
AGE	Age of household head (years)
ETH	Ethnicity of household head (Torguud, Uriankhai, Kazakh)
EDUHH	Formal education level of household head (none, primary, middle and high school, technical, university)
SIZEH	Total household size defined as total number of permanent family members
ADULT	Number of family members aged above 18 years old
ADULTE	Number of adult family members who can contribute to daily household work
HOUSE	Where do you live? (Tent, house, both)
GARD	Involvedness of cultivating crops (yes/no)
CULTP	Size of cultivated area (ha)
PROSE	Share of selling produced agricultural products
HAYP	Size of hay making area (ha)
TOTP	Total size of field area owned by household (ha)
ASSET	Value of properties (USD)
LIV	Household owns livestock (yes/no)
TOTLIV	Total number of livestock owned by household (sheep unit)
STALIV	Number of status animals /horse and camel/ owned by household (sheep unit)
LARLIV	Number of large animals (cattle, yaks, horses, camels) owned by household (sheep unit)
SMALLIV	Number of small ruminants (sheep and goats) owned by household (sheep unit)
INC_LIV_SE	Income from live animal sale (USD)
INC_WO	Income from sheep and camel wool sale (USD)
INC_CA	Income from cashmere sale (USD)
INC_LIVSE	Income from animal skin sale (USD)
TOT_INC_LIV	Total income from animal production (USD)
TOT_DIS	Total distance of livestock mobility per year (km)
DIS_W_S	Distance between winter and spring pastures (km)
DIS_S_SU	Distance between spring and summer pastures (km)
DIS_SU_A	Distance between summer and autumn pastures (km)
DIS_A_W	Distance between autumn and winter pastures (km)
TOT_INC_CRO	Total income from cropping activities (USD)

Annex 2.3. Plot of components loadings obtained from CATCPA for describing the relationship among household socio-economic characteristics



Chapter 3

Vegetation quality and quantity along the grazing itineraries, and grazing behaviour of small ruminants on mountain pastures in the Mongolian Altai

3 Vegetation quality and quantity along the grazing itineraries and grazing behaviour of small ruminants on mountain pastures in the Mongolian Altai

Summary

The natural pasture is the key resource for livestock husbandry systems in Mongolia and recently pastures are receiving a relatively high grazing pressure that is assumed to negatively affect pasture productivity. Therefore the grazing itineraries of small ruminants (sheep and goats) and the herbaceous biomass offer, in terms of quantity and quality, along the daily itineraries was studied. Additionally, the animals' grazing behaviour and their feed intake were determined during the spring and summer seasons of 2013 and 2014. Across the two years, the average daily distance walked by sheep and goats, respectively, was 13 ±1.3 km and 14 ±0.9 km ($p>0.05$), and the grazed area averaged 64 ±11.7 km^2 and 71 ±9.2 km^2 per day. Both variables slightly decreased from spring (June) to early and late summer (July and August) in each year. Varying the length of the daily grazing itinerary and adjusting it to the biomass on offer seems to be the only strategy to secure a requirement-covering feed intake of small ruminants. The herbage dry matter (DM) yield along the daily itinerary was a bit higher (837 kg DM/ha) in 2014 than in 2013 (711 kg DM/ha; $p>0.05$). The concentrations of DM and cell wall constituents (neutral and acid detergent fibre) in the pasture vegetation increased from June to August in both years, whereas the crude protein and phosphorus concentration declined ($p\leq0.05$). The intake of dry matter and proximate diet components of sheep and goats was similar across the two years ($p>0.05$) and 67% and 66% of the ingested organic matter (OM) were digested ($p>0.05$). The intake of feed DM and nutrients from the natural pasture vegetation during the summer season apparently covered the requirements for maintenance plus growth of the local small ruminant breeds, with the exception of their phosphorus requirements. Therefore a source of macro- and micro-minerals should be offered to the small ruminant herds during the summer season. The behavior of grazing sheep and goats was similar across the summer months, in which the animals spent 56%, 31%, 10% and 2% of their daily time on grazing, resting, walking and other activities. With regards to the diurnal rhythm of grazing, the afternoon seems

the vital day time for small ruminants to secure their daily feed intake, which should be considered in the daily herding practices.

3.1 Introduction

Mongolia has the largest area of common pasture land in the world (Upton, 2010), which is divided into four different zones based on ecological conditions and herding practices, namely: Altai mountain, Khangai-Khentii mountain, steppe and desert (Barzagur, 2002). The latter author suggested that, due to its ecological and geographical conditions, the Altai mountain zone is particularly suitable to raise small ruminants (sheep and goats) and yaks. The pasture vegetation types within the Altai Mountain zone were identified as mountain steppes and alpine meadows (Zemmrich, 2007; Dulamsuren et al., 2014), located at an average elevation of 2450 m a.s.l. The mountain steppes and alpine meadows are used mainly in the spring and summer seasons each year. Fernandez-Gimenez (1999) reported that Mongolia's pastures were grazed sustainably for most of the last century (socialist era) during which animal numbers remained relatively constant. However, nowadays the pastures are exposed to a considerably higher grazing pressure, whereby sharp increases in animal numbers as a result of the introduction of market economy in the 1990s (Batima et al., 2005; Lkhagvadorj et al., 2013a; Statistical Office of Khovd Province, 2014) and climatic influence (warming and lesser precipitation; Batima et al., 2005) are two important drivers. Impacts of those two major challenges together with other socio-economic and environmental constraints (pasture regulation, herding management and lack of feed) are mostly limiting pasture production, animal reproductive performances and livestock herding practices across the country (Munkhtsetseg et al., 2007; Lkhagvadorj et al., 2013a; Miao et al., 2016). Under these challenging conditions, the main strategy to use the native pasture in an environmentally friendly way was, and still is, the seasonal mobility of Mongolian herders and their flocks. Yet, herding practices of livestock keepers changed substantially under the newly established socio-economic conditions, due to loss of pasture utilization regulation, dismantling of subsidies and services for transportation, lack of labor for livestock mobility and rural poverty (Fernandez-Gimenez, 2006). In the recent past, herders reduced the frequency of herd movement per year, shortened distances between seasonal pastures (Lkhagvadorj et al., 2013a, Chapter 2), and changed herd structure in favour of goats and to the detriment of camels and yak. The loss of traditional herding knowledge increased the herds' vulnerability to extreme weather events such as *dzud* and drought (Fernandez-Gimenez, 2000; Fernandez-Gimenez et al., 2012). The dzud is defined by Middleton et al. (2014) as a "*Mongolian term for severe winter weather disaster in which deep snow, severe cold and other adverse conditions render forage inaccessible or unavailable, resulting in high rates of livestock mortality",* and similar descriptions were given by Fernandez-Gimenez et al. (2012) and Addison and Brown (2014). Such vulnerability leads to rural poverty through increased livestock loss; livestock is the basis of livelihood and income for more than 160,000 families across the country, but during the last dzud event in 2009/10, 20% of the national herd (Fernandez-Gimenez et al., 2015) and 52% of the livestock in our study region was lost (Middleton et al., 2014).

The native pasture is the main source of feeding for small ruminants in remote areas such as the Mongolian Altai Mountain region where animals rarely receive supplementary feed. The pasture supplies feed to 52 million of livestock which directly provide livelihoods to 366,000 people (NSOM, 2014) across Mongolia. A good nutritional status of grazing small ruminants is very important for healthy and well-performing livestock, and it depends on the nutritional values of plants consumed on pasture and on the amount ingested (Sun et al., 2008). Since the 1950s the Mongolian pasture vegetation and its feed value receive scientific attention; in a normal year its dry matter (DM) yield reaches maxima during the last months of summer season (June to August), from when it reduces by 27-35%, 60-63% and 65-70% in autumn (September to November), winter (December to February) and spring (March to May) across all ecological zone of the country (Tserendulam, 1968; Togtokhbayar, 1995; Murray et al., 1998; Togtokhbayar, 2006; Tserendash, 2000; Nergui et al., 2011; Otgonjargal, 2012). However, pasture yield varies significantly year by year and location by location depending on annual precipitation (Munkhtsetseg et al., 2007) and utilization management (Briske et al., 2008). The quality of pasture vegetation was reviewed by Nergui et al. (2011) and these authors reported crude protein and total fiber concentrations (in DM) of 10-17% and 65-70%, and organic matter digestibility of 25-67% across the country. For summer pastures in the Mongolian Altai Mountain region the organic matter digestibility was estimated at 61-71% by Tserendulam et al. (1968). Zemmrich (2007) reported that the dead dry matter of vegetation still keeps a high nutrient value during the winter season, whereas Tserendash (2000) and Togtokhbayar

(2006) concluded that its quality is not sufficient to meet livestock's maintenance energy requirements and therefore animals lose approximately 22% of their body weight in winter. Sasaki et al. (2012) found a substantial reduction in the nutritional value of pasture vegetation with increasing grazing pressure in south-eastern Mongolia.

Despite this body of general information on pasture quality and vegetation availability across Mongolia, Gendaram (2009) argued that research on pasture vegetation as a source of animal feed has been neglected during the last 25 years when most of the scholars focused on the botanical composition of pasture flora and its changes under different environmental and anthropogenic influences. Therefore, the assessment of the production and quality of the natural pasture vegetation as the main source of animal feed in Mongolia under the present herd management and climatic trends is important to plan further sustainable pasture management, and sustain herd productivity along with the majority of rural livelihoods depending thereupon. Since the natural pastures at the interface of the Mongolian Altai Mountains to the Dzungaria desert, due to their remoteness, received only little scientific attention, the purpose of this study was to identify the nutritional situation and grazing behavior of the local small ruminant herds in order to explore opportunities and constraints for sustainable pasture and herd management in this westernmost region of Mongolia.

3.2 Materials and methods

3.2.1 Site description

The study focused on the traditional pastoral system which utilizes, in a transhumant manner, alpine meadows in the Altai Mountains and desert steppe ecosystems along the Bulgan River Valley, forming the transition area from the mountains to the Dzungaria desert in western Mongolia (Tsegmed, 1969). Administratively the study area is mostly located in the territory of Bulgan county of Khovd province, which is one of the most densely populated counties within the province (1.1 people per km^2), has a very high livestock density (3.7 animals per km^2 pasture) and is furthest away (386 km) from the province centre Khovd (Statistical Office of Khovd Province, 2014). The area extends geographically from 91° east to 92° east in longitude and 46° north to 47° north in latitude; elevation ranges from 1100 to 3250 m a.s.l (Frerkes, 2013). Climatically the study site is situated in the semi-arid and arid climatic belt of the Temperate Climate Zone; its climate is characterized by long and cold winters, dry and hot summers, low precipitation (rainfall and snow) and high temperature fluctuations (Batima et al., 2005; Wehrden and Wesche, 2007).

The major type of land use system is pasture-based transhumant animal husbandry; pastures are divided into seasonal areas namely spring, summer, autumn and winter pasture; depending on their geographical location, biomass composition and production these pastures are only used in the respective periods of a year (see also Chapter 2). The pasture areas provide livestock feed and drinking as well as irrigation water (for hay fields) to herds and livestock keepers, and are used by approximately 9,500 people keeping 150,500 domestic animals (Statistical Office of Khovd Province, 2014); they also host an unknown number of wildlife. Small ruminant (sheep and goats) density on spring and summer pastures is estimated at 0.6 and 1.3 sheep units (SU) per hectare and herds are covering daily grazing distances of about 12 km (Jordan et al., 2016). For the analysis of herd management, the four distinct seasons can be grouped into two main parts of the year, the warm and rainy spring-summer season (April - September) and the cold and dry autumn-winter season (October - March). Pastures used in spring (46°23' N 91°05' E, 1820 m a.s.l) and summer (46°37' N, 91°35' E, 2830 m a.s.l) are situated on high-altitude plateaus in the Altai Mountains. The surface of spring pastures is covered with gravelly and rocky erosion debris predominantly consisting of granite and slate rock (Grunert et al., 2000), while the summer pasture surrounds a small and slightly salty lake which provides drinking water for animals. Botanically, the spring and summer pastures are typical Alpine steppes characterized by perennial forbs (*Artimesa frigida, Potentilla bifurca*, *Potentilla acaulis*), grasses (*Koeleria sp.*) and sedges (*Carex duriuscula*) (Chuluunkhuyag, pers. comm.; Yunatov, 1976; Zemmrich, 2007). This area is characterized by extremely continental climate, and the average annual rainfall and air temperature recorded in 2013 and 2014 were -4.5°C and 305.4 mm (data provided by WATERCOPE project, funded by IFAD). The autumn pastures are located along the Bulgan River and are covered with riverine meadow vegetation consisting of shrubs (*Achnatherum splendes, Caragana spinosa, Halimodendron halodendron, Tamarix ramosissima*), herbs (*Glycyrrihiza uralensis, Oxytropis glabra, Halerpestes sarmentosa*) and some trees (*Populus laurifolia, Salix turanica*) as well as some grasses *(Potentilla anserine, Achnatherum splendens, Carex duriuscula, Carex melanantha, Hordeum brevisubulatum, Poa attenuate*) (Chuluunkhuyag, pers. comm.; Yunatov, 1976; Beket, 1989). On these pastures, average annual air temperature and rainfall recorded in 2013 and 2014 at 1130 m a.s.l. were 3.8°C and 49.6 mm, respectively (data provided by WATERCOPE project). The winter season is spent in the desert steppe below 1680 m a.s.l., due to warmer temperatures and higher forage availability on these pastures. There the vegetation bears various grasses (*Stipa gobica, Stipa glareosa)*, perennial forbs (*Artemisia sp., Eurotia ceratoides, Nanophyton erinaceum*) and bulb-forming geophytes *(Allium polytrihizum)* as well as sub-shrubs *(Convolvulus gotschakorii, Salsola dshungarica)* (Chuluunkhuyag, pers. comm.; Yunatov, 1976; Zemmrich, 2007).

3.2.2 Data collection

Data was collected in June, July and August 2013 and 2014, respectively, which represent spring, early summer, and late summer season in this study. Each data collection period comprised 7 days for goats and for sheep, respectively. During the first two days of each monitoring period, 5 sheep and 5 goats were weighed using a digital electronic hanging scale (range 5 - 300 kg, accuracy 0.5 kg) to determine live weight (LW). During each monitoring period, the animals' grazing itinerary was determined along with their total daily faecal excretion. Biomass samples along the animals' grazing itineraries were collected, and in 2013, the daily grazing behavior of animals was observed visually in parallel to the tracking of their movements.

The goats and sheep for these measurements were about 24 months old Mongolian native breeds; all were castrated males with an average live weight of 41±2.4 kg (goats) and 48±1.6 kg (sheep). On all pastures, animals had free access to drinking water and locally available natural minerals. All selected animals were grazing within one mixed herd, which consisted of over 500 individuals. The herd grazed on its own, whereby the herder guided the animals towards the intended grazing direction each morning (herd-release mode, Turner et al., 2005) and once a day passed by on horseback to check on the animals and prevent mixing with other herds.

3.2.2.1 Orientation and length of animals' grazing itineraries

The itinerary data was collected using GPS collars (GPS PLUS Globalstar, Vectronic aerospace GmbH, Berlin, Germany) in order to determine the directions and length of the animals' daily grazing itineraries on the spring and summer pastures in 2013 and 2014. During each data collection period, GPS collars were fitted onto three goats during three days, and then, for another three days, onto three sheep; geographical positions (latitude, longitude and altitude) along with time were recorded at one minute intervals for 3*24 h continuously. When changing the collars from the goats to the sheep the recorded goat data was downloaded and saved on a laptop PC. In addition to these pasture-based recordings, at least one small ruminant carried a GPS device during transhumant movements from the spring to the summer and from the summer to the autumn pastures to determine the length of each seasonal movement.

3.2.2.2 Herbage mass along the grazing itineraries and chemical composition

Herbage mass along the grazing itinerary was determined on one day of each monitoring period using a 50 cm x 50 cm sampling frame. Biomass samples were taken at each 500 m along the grazing itineraries of small ruminants from their starting point in the morning to their return point in the evening. Litter (dead plant material accumulated on the ground) and non-forage plants were not included in the herbage sample. At every sampling point, percentage of vegetation cover (crown cover), stone cover and minimum, mean and maximum plant height were determined directly. Furthermore, plants within each sampling frame were classified into four main species groups namely grasses, annual herbs and shrubs. Plants refused by animals were not accounted for. Then the herbaceous biomass inside each sampling frame was clipped at 1 cm height above ground. After the total fresh weight of the clipped biomass was determined directly in the field (portable electronic scale, range 0.1 to 3000 g), the samples were air-dried in cotton bags to determine their air dry weight. Afterwards, samples were ground to 1 mm particle size using a FOSS sample mill (Cyclotec TM 1093, Haan, Germany). The dry matter (DM) and organic matter (OM) concentrations were determined by drying sample material at 105°C and incinerating at 550°C (Naumann and Bassler, 2004). Phosphorus (P) and calcium (Ca) concentrations were determined, using spectrophotometry (Hitachi U-2000, Tokyo, Japan), thereby employing the P-yellow method and flame photometer (BWB Technologies, Halstead, United Kingdom) as described by Chu and Taylor (2015). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined in an ANKOM 200 fiber analyzer (Ankom Technology, Macedon, New York, USA) according to van Soest et al. (1991) applying the protocol of Schiborra et al. (2010). Carbon (C) and nitrogen (N) concentrations were determined by a CN analyzer (vario MAX CN; Elementar Analysensysteme, Hanau, Germany). NIRS calibration procedure was applied to predict the concentrations of OM, N, NDF, ADF, P and Ca in the biomass samples that were not analysed wet-chemically (Reddersen et al., 2013) and the calibration model described by Jordan et al. (2016) was used to determine their proximate compositions. The concentration of crude protein (CP) was calculated based on the N concentration of the samples (Allen et al., 2011).

3.2.2.3 Grazing behavior observation

The three castrated male sheep and goats, respectively, that were collared with GPS devices were followed by an observer at a distance of approximately 100 m from their departure until their return to the yurt, which is the small ruminants' resting place during night time. The grazing behavior of these animals was monitored for one day each per animal during three consecutive days per species; these periods coincided with the first three days of GPS tracking (3.2.2.1) and faeces collection (3.2.24) in 2013. Behavior was observed during day light grazing time (from 7 a.m. to 9 p.m.) and was grouped into morning (7 - 10 a.m.), noon (11 a.m. – 3 p.m.), afternoon (3 – 7 p.m.) and evening (7 p.m. onwards). The observations were done with binoculars at 5 minutes intervals to identify the activity of the animal at that specific moment (instantaneous observation; Schlecht et al., 2004). The observed activities were classified following Lin et al. (2011) as grazing, resting, walking and other activities. Biting/harvesting grass, chewing and walking between feeding stations were referred to as grazing, while walking for searching forage and walking faster without grazing were counted as a walking. Resting comprised different forms of resting (resting while standing without rumination, while lying without rumination, while standing with rumination and while lying with rumination). Interaction with peers, between mother and kid, as well as drinking water and ingesting soil or rubbish were classified as other activities.

3.2.2.4 Determination of feed intake and digestibility

Faecal samples were collected from five animals including the three collared with the GPS devices plus two uncollared animals per species, using the total faecal collection method (Doyle et al., 1994; Gordon, 1995) to estimate daily feed intake. In the evening of the second weighing day (3.2.2), faecal collection bags were attached to the animals and stayed for five consecutive days (5 x 24 h). Bags were emptied twice within 24 h, depending on the mass of faeces excreted. The total amount of faeces was weighed fresh and then air-dried in cotton bags in the shade. At the end of the collection period, when all samples were dried, each sample was weighed again, pooled by animal and period, thoroughly homogenized, subsampled (200 g air dry material), ground through a 1.5 mm screen, and analysed for chemical constituents. DM, OM, NDF, C, N, P and Ca concentrations of faecal samples were determined using the same methods and procedures as described for herbage analysis (3.2.2.2).

Organic matter digestibility (OMD) was calculated from the CP concentration in faecal OM using the regression equation published by Wang et al. (2009), which was derived from digestibility trials in sheep comprising 721 individual observations (Eq. 1).

$$y = 0.899 - 0.644 * \exp\left(-\frac{0.5774 * \text{faecal CP (g/kg OM)}}{100}\right) \qquad \text{(Eq. 1)}$$

where y is organic matter digestibility (%) of the ingested diet, 0.899, 6.44 and -0.5774 are the fixed-effect parameters and CP is crude protein.

Organic matter intake (OMI) was then estimated by dividing total faecal OM output by the indigestible fraction of the diet (1 – OMD/100) and expressed in g OM/day (Gordon, 1995).

$$y = \frac{\text{Total faecal output (g OM/day)}}{(1 - \text{OMD (\%)}/100)} \qquad \text{(Eq. 2)}$$

where y is organic matter intake (g OM/day) of pasture vegetation, and OMD is organic matter digestibility of the ingested diet in percent.

Based on OMI of pasture vegetation, the intake of dry matter and major chemical components (CP, NDF, ADF, P, Ca) were calculated based on their concentration in the biomass samples (3.2.2.2).

3.2.2.5 Analysis of GPS data

All GPS raw data obtained from daily tracking of sheep and goats were corrected for outliers (GPS positions estimated from only 3 satellites) and failed GPS readings (GPS positions estimated from less than 3 satellites), and then converted from original geographic coordinates system to UTM (Universal Transverse Mercator) grid projection (WGS 1984, zone 46N). Afterwards, successively logged positions were merged per animal (three sheep and three goats, separately) and month/year (June, July and August) using the software package ArcGIS 9.2 (ESRI Corp, Redlands, California, USA) (Jordan et al., 2016). The horizontal distance covered in three days of tracking was divided by the total tracking time in order to calculate daily length of the grazing itinerary. A buffer of 50 m width to both sides of the sheep and goat itineraries was plotted along the merged tracks and defined as the grazed area. This surface was divided by the number of tracking days to calculate the grazed area per herd and day.

3.2.3 Statistical analysis

The statistical data analysis was performed in SPSS version 20.0 for Windows (IBM Corp., 2011) with a two-tailed significance level of $p \leq 0.05$. Mean values of daily itinerary length, size of grazed areas, quantity and quality of pasture vegetation and animal feed intake as well as faecal excretion (dependent variables) of sheep and goats were analysed to determine effects of month (June, July and August), year (2013 and 2014) and animal species (sheep and goat) as well as their interactions. Furthermore, animal daily grazing behavior (proportion of time devoted to grazing, resting, walking and other activities) was compared for diurnal patterns (morning, noon, afternoon and evening).
First, the residuals of data were checked for normal distribution using Shapiro-Wilk test, then a Levene's test was run to check for homogeneity of variance. Pair-wise comparison of means was carried out using independent t-test and one way ANOVA for homogeneously distributed variables, and Mann-Whitney-U and Kruskal-Wallis test for heterogeneously distributed variables in the cases of two or more independent variables. The generalized linear model was used to determine interactions between independent variables (month, year and animal species).

3.3 Results

3.3.1 Orientation and length of animals' grazing itineraries

Across the two years, the average daily distance walked by sheep and goats, respectively, was 13.3 km and 14.3 km ($p>0.05$) during the months of June, July and August. In both years, goats covered considerably longer distances than sheep in June ($p\leq0.05$), whereas in July and August the daily itinerary lengths of sheep and goats were similar ($p>0.05$). In both years, daily itinerary lengths of both species slightly decreased from June (longest pathways) to August (shortest pathways; Figure 3.1). In goats, average daily itinerary length was significantly higher in June than in July and August ($p\leq0.05$), while the difference between the latter months was not significant in both years (Annex 3.1). In sheep, length of the daily itinerary did not vary significantly between months within and across the two years (Annex 3.1). The individual maximum itinerary length for sheep and goats was 18.2 km/day and 21.3 km/day, and the minimum was 9.3 km/day and 9.5 km/day, respectively.

Across the two years, the average size of grazed area per day of sheep (64.1 ha) and goats (70.6 ha) was significantly different ($p\leq0.05$). Furthermore, the daily grazed area of goats was larger than that of sheep in June in both years ($p\leq0.05$), whereas values were similar during the other months ($p>0.05$). The maximum and minimum sizes of grazed areas for sheep and goats were 99.6 ha/day vs. 21.3 ha/day, and 126.7 ha/day vs. 20.0 ha/day, respectively. In 2013, goats grazed within a smaller area (58.2 ha/day) than sheep (62.0 ha/day), while in 2014 they grazed within a larger area (79.0 ha/day) than sheep (66.2 ha/day; Annex 3.1). Largest areas were usually grazed during June each year and decreased in July and August ($p\leq0.05$).

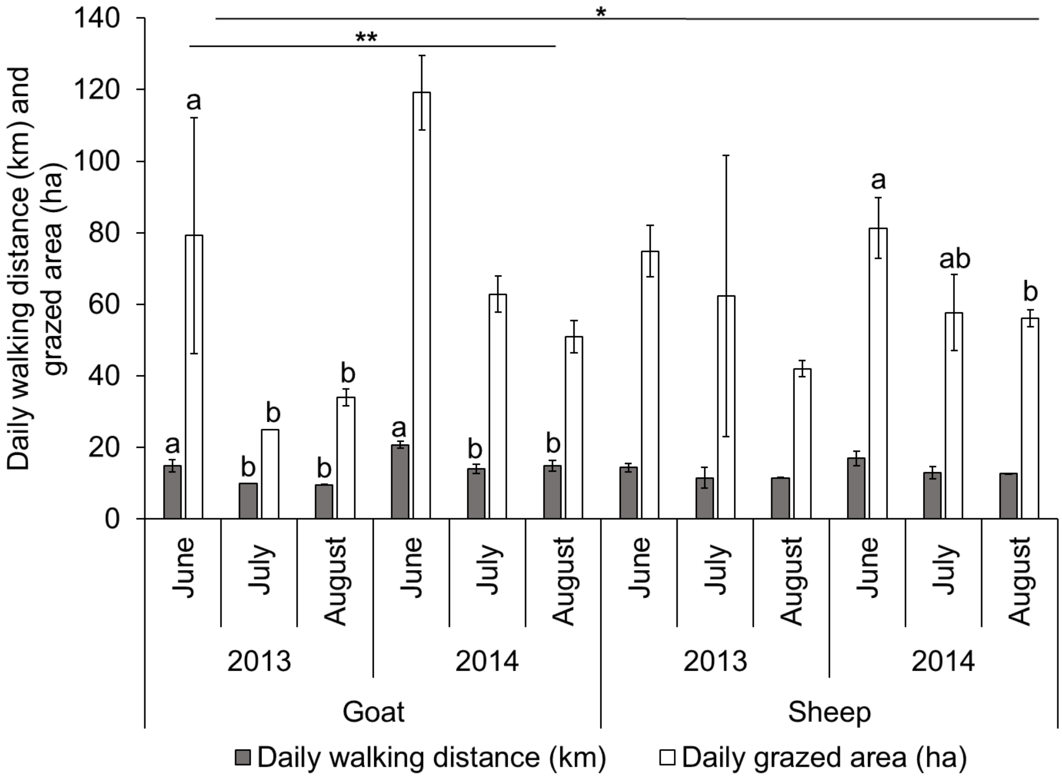


Figure 3.1. Average daily walking distances and grazed areas of transhumant sheep and goats on Mongolian Altai Mountain pastures during the summer season (June to August). The whiskers on bars represent one standard deviation. Statistical difference between years within goat (**$p \leq 0.01$) and between animal species (* $p \leq 0.05$) are shown. [a, b] Superscripts on bars indicate significant differences between the months within the year according to Kruskal-Wallis test. Bars without superscript are not significantly different.

3.3.2 Quantity and quality of herbaceous vegetation on spring and summer pasture

The general characteristics of the spring and summer pastures are presented in Table 3.1. The vegetation cover on spring and summer pastures ranged from 37% to 71%. The highest vegetation cover was recorded in July in both years while considerably lower vegetation coverage was found on the spring pasture (June). Average vegetation height was slightly higher in spring than in summer (July and August) 2013, while there was no significant difference between the months and pastures in 2014. Overall vegetation cover did not differ between years ($p>0.05$) whereas the vegetation height was higher in spring 2013 than in spring 2014 ($p \leq 0.05$). The same was true for total stone cover, whereby the stone cover was higher on the summer pasture than on the spring pasture in both years ($p \leq 0.05$), due to the fact that the summer pastures were located in the alpine meadow zone with partly shallow soil profiles.

Herbage yield (kg DM/ha) on spring and summer pastures in 2013 was slightly different between months, whereas there were no considerable differences in 2014. The highest biomass yield was found in July 2014 and slightly decreased in August 2014 ($p>0.05$). In 2013, the highest amount of biomass was measured in June compared to July and August 2013, as well as to June 2014 ($p\leq0.05$). Herbage yield did not differ significantly between the two years although summer pastures performed slightly better in 2014 than in 2013.

Herbage yield (kg DM/ha) along the grazing itineraries of small ruminants is presented in Figure 3.2. The highest herbage yield was recorded at 3.0 - 4.5 km distance from the home base in June and August and at 9 - 10 km distance in July. The lowest amount of biomass in all three months was found nearby the home base, at the starting and end point of the daily itinerary. By inspecting the itineraries, it appears that small ruminants mostly grazed within 4.5 - 5.5 km radius around the home base during the spring and summer seasons.

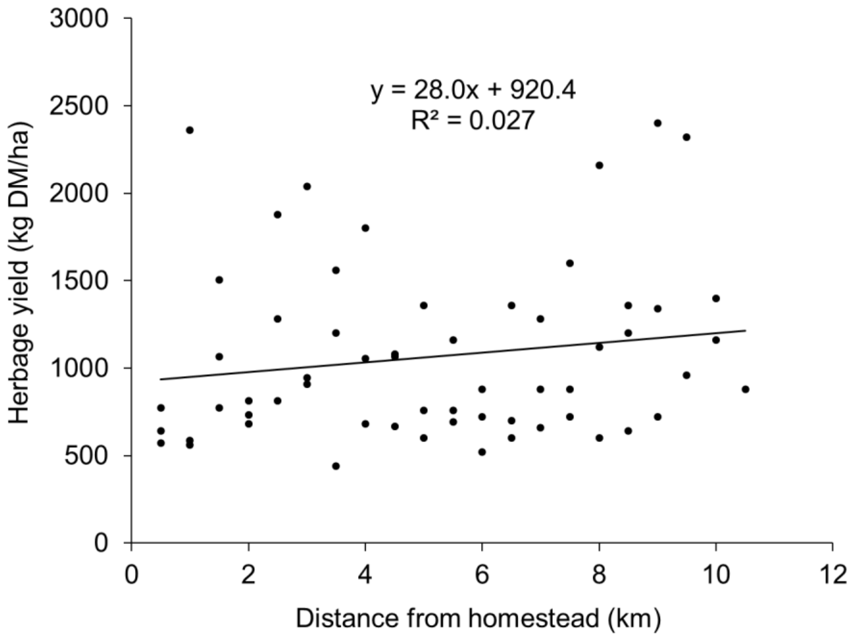


Figure 3.2. Relationship between distance from homestead (yurt) and biomass yield along small ruminants' daily grazing itineraries on spring and summer pastures (not differentiated) in the Mongolian Altai mountains.

Table 3.1. Pasture vegetation characteristics and herbage yield on spring (June) and summer (July, August) pastures utilized by small ruminants in the Mongolian Altai Mountains in 2013 and 2014.

Year	Month	n	**Altitude** (m)	**Herbage yield** (kg/ha DM)	**Vegetation cover** (%)	**Stone cover** (%)	**Vegetation height** (cm)
2013	June	39	1743 ^{c}	986 $^{A, a}$	43.4 ^{b}	2.1 ^{b}	15
	July	26	2940 ^{a}	821 ^{ab}	6.78 ^{a}	6.9 ^{a}	6
	August	19	2532 ^{b}	601 ^{B,b}	44.3 ^{b}	7.2 ^{a}	9
	SEM		46.3	47.3	2.91	0.84	0.6
	p		***	**	**	***	***
2014	June	15	1832 ^{c}	844 ^{B}	26.7 ^{b}	9.2	6
	July	21	2841 ^{a}	904	76.3 ^{a}	12.7	8
	August	18	2517 ^{b}	777 ^{A}	58.1 ^{a}	8.2	9
	SEM		45.8	66.5	3.89	2.34	0.4
	p		***	n.s.	***	n.s.	n.s.
Year effect	June		n.s.	**	n.s.	n.s.	n.s.
	July		n.s.	n.s.	n.s.	n.s.	n.s.
	August		n.s.	***	n.s.	n.s.	n.s.

n = Number of samples, SEM = standard error of mean. p = probability value, ** $p \leq 0.01$, *** $p \leq 0.001$, n.s. = non-significant.

$^{A, B}$ In columns, capital letters following means indicate significant differences for a month between the two years according to independent T-test and Mann-Witney U-test.

^{abc} In columns, small superscripts following means indicate significant differences between months within a year according to one way ANOVA.

The nutritional quality of pasture vegetation grazed during different months of spring and summer are summarized in Table 3.2. The average DM content of pasture vegetation in both years significantly increased from June to August while the CP concentration considerably decreased. The CP concentration decreased more rapidly (by -34.4%) from spring to late summer 2013 compared to 2014 (-21.8%). Cell wall constituents in vegetation (NDF and ADF) increased from June to August of both years, in accordance with maturation of the herbaceous plants. Evidently the maximum NDF concentration (617 g/kg DM) was found in August 2013 whereas the minimum (453 g/kg DM) was determined in June 2013. The Ca and P concentrations of vegetation decreased from June to August in both years. The decreases for P in both years and for Ca in 2013 were significant ($p \leq 0.05$), but the decrease for Ca in 2014 was not significant.

Table 3.2. Dry matter concentration (DM, g/kg fresh matter) and other major proximate constituents (in g/kg DM) of herbaceous pasture vegetation sampled on spring (June) and summer (July, August) pasture in the Mongolian Altai Mountains in 2013 and 2014.

Year	Month	DM	OM	CP	NDF	ADF	Ca	P
		g/kg FM	g/kg DM					
2013	June	473 ^{B,c}	919 ^{a}	125 ^{A,a}	453 ^{B,c}	279 ^{b}	9.8 ^{A,a}	1.8 ^{A,a}
	July	617 ^{b}	898 ^{B,b}	129 ^{a}	520 ^{b}	290 ^{A,b}	7.8 ^{A,b}	1.4 ^{b}
	August	767 ^{a}	902 ^{b}	82 ^{b}	617 ^{a}	332 ^{A,a}	4.9 ^{c}	1.1 ^{c}
	SEM	16.8	2.3	3	9.8	5	0.4	0.04
	p	***	***	***	***	***	***	***
2014	June	742 ^{A,a}	913 ^{a}	101 ^{B,b}	509 ^{A,b}	291 ^{a}	5.1 ^{B}	1.4 ^{B,a}
	July	592 ^{B,b}	923 ^{A,a}	127 ^{a}	523 ^{b}	248 ^{B,b}	5.5 ^{B}	1.3 ^{ab}
	August	749 ^{a}	898 ^{b}	79 ^{c}	579 ^{a}	298 ^{B,a}	4.1	1.1 ^{b}
	SEM	18.3	2.5	3.8	9.2	6.3	0.3	0.04
	p	***	***	***	**	**	n.s.	**
Year effect	June	**	n.s.	*	**	n.s.	**	*
	July	n.s.	*	n.s.	n.s.	*	*	n.s.
	August	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.

FM = Fresh matter, DM = Dry matter, OM = Organic matter, CP = Crude protein, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, Ca = Calcium, P = Phosphorus, SEM = standard error of mean. p = probability value, *$p \leq 0.05$, ** $p \leq 0.01$, ***$p \leq 0.001$, n.s. = non-significant.

$^{A, B}$ In columns, capital letters following means indicate significant differences for a month between the two years according to independent T-test and Mann-Witney U-test.

^{abc} In columns, small superscripts following means indicate significant differences between months within a year according to one way ANOVA test and Kruskal-Wallis tests.

3.3.3 Animals' grazing behavior

Across the three months of observation in 2013, sheep spent on average 57%, 30%, 11% and 2% of day time on grazing, resting, walking and other activities, respectively (Table 3.3), and values in goats were very similar (grazing 56%, resting 32%, walking 10%, other activities 2%). There were no significant differences in the proportion of time spent by both species on the four activities between months (June, July and August). However, for both species, the lowest proportion of time spent grazing was recorded in July whereas the highest was found in June for sheep and in August for goats. The proportion of time spent on resting and walking of both species gradually decreased from June to August. When comparing different periods of the day (morning, noon, afternoon and evening), the proportion of time spent on grazing and resting considerably differed for both animal species ($p \leq 0.05$, Figure 3.3 and Annex 3.3). Across all months, the shortest proportion of time spent grazing and the longest proportion of time spent resting was recorded in the morning in comparison to noon, when grazing lasted longest and resting shortest, respectively. The proportion of time spent grazing in the afternoon and evening was considerably higher than in the morning for both species ($p \leq 0.05$), whereas the proportion of time devoted to walking and other activities by both species did not vary during a day ($p > 0.05$).

Table 3.3. Proportion (%) of day time (7 a.m. – 9 p.m.) of sheep and goats allocated to different activities on spring (June) and summer (July, August) pastures in the Mongolian Altai Mountains in 2013.

Animal species and month		**Grazing**	**Resting**	**Walking**	**Other**
Sheep	June	56	26	16	2
	July	51	27	20	2
	August	54	33	11	2
	SEM	3.7	3.5	1.7	0.5
	Probability	n.s.	n.s.	n.s.	n.s.
Goats	June	56	29	13	2
	July	52	34	11	3
	August	61	28	10	1
	SEM	3.7	3.5	1.7	0.5
	Probability	n.s.	n.s.	n.s.	n.s.
Effects of factors					
Species		n.s.	n.s.	n.s.	n.s.
Month		*	n.s.	n.s.	n.s.
Species*Month		n.s.	n.s.	n.s.	n.s.

SEM = standard error of means, * $p \leq 0.05$, n.s. = non-significant.
Probability values for comparison across months and years are according to Kruskal-Wallis test and Mann-Whitney U-test, respectively. Probability values for effects of factors are according to generalized linear model test.

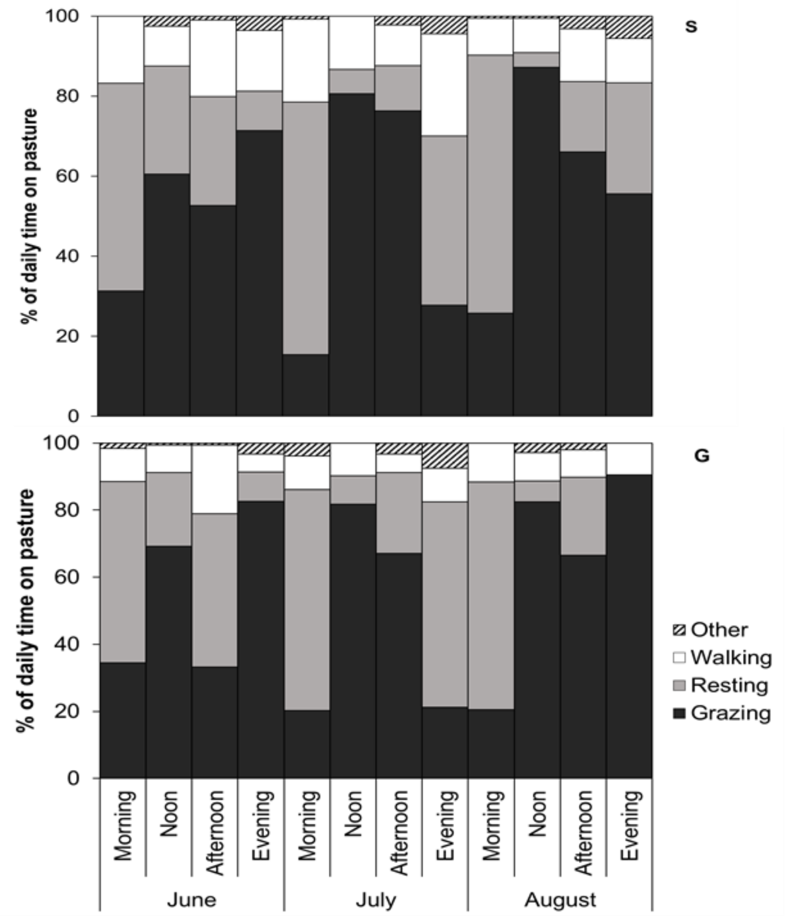


Figure 3.3. Diurnal activity patterns of sheep (S) and goats (G) grazing on Mongolian Altai Mountain pastures during spring (June) and summer (July, August) 2013.

3.3.4 Animal feed intake and digestibility

The live weight (LW) of sheep and goats, and the digestibility of organic matter (OMD) of the ingested diet as derived from the faecal CP concentration, along with the intake of major diet constituents (g/kg$^{0.75}$ LW) from pasture vegetation grazed during June, July and August 2013 and 2014 is depicted in Table 3.4. The sheep and goats monitored for their feed intake gained substantially in LW from June to August in both years. LW gain of sheep in 2013 was higher than in 2014 ($p \leq 0.05$), whereas LW gain of goats did not differ across the years ($p > 0.05$).

OMD was much higher in 2013 than in 2014 ($p \leq 0.001$), and decreased significantly from June to August in both years and species, whereby the decrease was slightly higher in 2013 (sheep: -14%, goats: -17%) than in 2014 (sheep: -7%, goats:-13%). OMD values were affected by significant interactions of month*year and month*species (Annex 3.2); however, OMD was not different between sheep and goats (Annex 3.2; $p > 0.05$).

Table 3.4. Live weight (LW, kg) of sheep and goats, digestible organic matter concentration (OMD, g/kg OM) of the diet and daily intake of major diet constituents (g/kg$^{0.75}$ LW) on spring (June) and summer (July, August) pasture in the Mongolian Altai Mountains in 2013 and 2014.

Species	Year	Month	LW	OMD	**Daily intake** (g/kg$^{0.75}$ LW)						
					DM	**OM**	**CP**	**NDF**	**ADF**	**P**	**Ca**
Sheep	2013	June	44 ^{A,b}	723 ^{A,a}	77 ^{b}	72 ^{b}	9 ^{b}	31 ^{b}	19 ^{b}	0.13 ^{a}	0.74 ^{A,a}
		July	48 ^{ab}	703 ^{A,b}	99 ^{A,b}	92 ^{A,b}	12 ^{A,a}	48 ^{A,a}	28 ^{A,a}	0.13 ^{A,a}	0.73 ^{A,a}
		August	51 ^{A,a}	622 ^{c}	63 ^{b}	58 ^{b}	4 ^{c}	36 ^{b}	20 ^{b}	0.06 ^{b}	0.3 ^{b}
		SEM	1.2	11.9	4.9	4.5	0.9	2.4	1.3	0.01	0.06
		p	*	***	***	***	***	***	**	***	*
	2014	June	34 ^{B,b}	669 ^{B,a}	81	76	8	39	22 ^{a}	0.1 ^{a}	0.38 ^{B}
		July	40 ^{B,a}	678 ^{B,a}	57 ^{B}	53 ^{B}	7 ^{B}	28 ^{B}	13 ^{B,b}	0.07 ^{B,ab}	0.29 ^{B}
		August	42 ^{B,a}	623 ^{b}	64	60	5	35	18 ^{ab}	0.07 ^{b}	0.25
		SEM	1.5	7.6	5.1	4.8	0.6	2.5	1.5	0.0	0.02
		p	**	***	n.s.	n.s.	n.s.	n.s.	*	*	n.s.
	Year effect	June	*	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
		July	**	*	**	**	*	*	**	*	*
		August	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Goats	2013	June	38 ^{b}	724 ^{a}	86	81	10 ^{ab}	38	23	0.14 ^{A,a}	0.73 ^{A,a}
		July	40 ^{b}	684 ^{b}	92 ^{A}	86 ^{A}	11 ^{A,a}	44 ^{A}	24 ^{A}	0.13 ^{A,a}	0.66 ^{A,a}
		August	46 ^{a}	599 ^{c}	64	59	5 ^{b}	36	19	0.07 ^{b}	0.28 ^{A,b}
		SEM	1.5	14.2	6.6	6.2	1	2.9	1.6	0.01	0.07
		p	**	***	n.s.	n.s.	*	n.s.	n.s.	*	*
	2014	June	34 ^{b}	684 ^{a}	66 ^{a}	62 ^{a}	6 ^{a}	32 ^{a}	18 ^{a}	0.09 ^{B,a}	0.33 ^{B,a}
		July	37 ^{a}	656 ^{b}	47 ^{B,b}	44 ^{B,b}	6 ^{B,a}	23 ^{B,b}	11 ^{B,b}	0.06 ^{B,b}	0.25 ^{B,b}
		August	41 ^{a}	595 ^{c}	52 ^{ab}	49 ^{ab}	4 ^{b}	28 ^{ab}	14 ^{ab}	0.05 ^{b}	0.2 ^{B,b}
		SEM	1.3	11.7	3.4	3.2	0.4	1.6	1.0	0.0	0.02
		p	**	***	*	*	**	*	**	*	**
	Year effect	June	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**	*
		July	n.s.	n.s.	**	*	*	*	**	*	*
		August	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*

DM=Dry matter, OM=Organic matter, CP=Crude protein, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, P=Phosphorus, Ca=Calcium, SEM=standard error of mean. p=Probability value, *$p \leq 0.05$, ** $p \leq 0.01$, ***$p \leq 0.001$, n.s. =non-significant. $^{A, B}$ In columns, capital letters following means indicate significant differences for a month between the two years according to independent T-test and Mann-Witney U-test. ^{abc} In columns, small superscripts following means indicate significant differences between months within a year according to ANOVA and Kruskal-Wallis test.

In sheep the intake of the major diet components (DM, OM, CP, NDF, ADF, P and Ca) was significantly different between the months in 2013, while only ADF and P intake were different in 2014 (Table 3.4). In goats, the intake of all major diet components in 2014 and of CP, Ca and P in 2013 were different across the months ($p \leq 0.05$). In both small ruminant species, the highest and lowest intake of all diet components was found in July 2013 and in July 2014, respectively. The feed intake of sheep and goats was similar in both years for June and August. Intake of all components was not substantially different between the animal species, even though sheep consumed 3.0-6.5% more nutrients per day than did goats. Interactions of month, year and species did not noticeably affect intake of pasture vegetation (Annex 3.2; $p > 0.05$).

3.3.5 Nutrient excretion of small ruminants

Total daily faecal excretion of sheep and goats and the respective chemical composition is presented in Table 3.5. The overall faecal excretion of sheep and goats showed no difference ($p > 0.05$). However, the lowest and highest amounts of faeces were excreted in June and July for both animal species in 2013, and quantitative excretion in August was in-between these two months. In 2014, total excretion of sheep remained relatively constant across months, whereas it differed markedly in goats, with the highest and lowest defaecation recorded in August and July. The DM content of faeces (g/kg FM) of both animal species did not differ between months in both years ($p > 0.05$), with the exception of the low DM concentrations recorded for sheep (263 g DM/kg FM) in July 2014. Concentrations of other chemical components (OM, N, NDF, C and P) of faeces were almost all different between the months of a year, except for the NDF concentration in goat faeces in 2014. OM, N, C and P concentrations in faeces of both species substantially decreased from spring (June) to late summer (August) in both years whereas the NDF fraction in goat faeces slightly increased throughout the measurement periods.

Table 3.5. Total daily faecal excretion per animal (g DM/head*d, g DM/kg$^{0.75}$ LW*d) and concentrations of major proximate constituents in faeces of sheep and goats grazing spring (June) and summer (July, August) pastures in the Mongolian Altai Mountains in 2013 and 2014.

Variable	2013					2014					Year effect		
	June	July	August	SEM	p	June	July	August	SEM	p	June	July	August
Sheep													
Faecal excretion (g DM/head*d)	414^{b}	$604^{A,a}$	535^{a}	26.6	**	410	318^{B}	465	27.8	n.s.	n.s.	**	n.s.
Faecal excretion (g DM/kg$^{0.75}$ LW*d)	24^{b}	$33^{A,a}$	28^{ab}	1.4	*	30	20^{B}	29	2	n.s.	n.s.	*	n.s.
DM (g/kg FM)	341	329^{A}	321^{A}	7.8	n.s.	321^{a}	$263^{B,b}$	$268^{B,a}$	9.1	**	n.s.	*	*
OM (g/kg DM)	$819^{B,a}$	819^{a}	$781^{B,b}$	5.3	***	$851^{A,a}$	835^{a}	$797^{A,b}$	6.8	***	*	n.s.	*
N (g/kg DM)	$29^{A,a}$	$27^{A,ab}$	18^{b}	1.3	**	$24^{B,a}$	$25^{B,a}$	19^{b}	0.8	***	*	*	n.s.
NDF (g/kg DM)	$512^{B,b}$	544^{ab}	571^{a}	8.7	**	$559^{A,a}$	519^{b}	574^{a}	7.4	***	*	n.s.	n.s.
C (g/kg DM)	$447^{B,a}$	449^{a}	$427^{B,b}$	2.8	**	$459^{A,a}$	455^{a}	$434^{A,b}$	3.3	**	*	n.s.	*
P (g/kg DM)	$5.7^{A,a}$	5.2^{a}	3.1^{b}	0.3	**	$4.3^{B,ab}$	4.8^{a}	3.5^{b}	0.2	**	**	n.s.	n.s.
Goats													
Faecal excretion (g DM/head*day)	379	503^{A}	509^{A}	29.9	n.s.	313^{ab}	$274^{B,b}$	$381^{B,a}$	17.2	*	n.s.	**	*
Faecal excretion (g DM/kg$^{0.75}$ LW*d)	26	32^{A}	29	2.1	n.s.	22	18^{B}	23	1.1	n.s.	n.s.	***	n.s.
DM (g/kg FM)	347	353^{A}	358^{A}	13.9	n.s.	301	253^{B}	263^{B}	10.3	n.s.	n.s.	**	**
OM (g/kg DM)	$864^{B,a}$	834^{b}	829^{b}	5.3	**	$876^{A,a}$	822^{b}	839^{b}	7.7	**	*	n.s.	n.s.
N (g/kg DM)	$31^{A,a}$	$25^{A,b}$	18^{c}	1.5	***	$27^{B,a}$	$22^{B,b}$	17^{c}	1.2	***	*	*	n.s.
NDF (g/kg DM)	521^{b}	540^{b}	585^{a}	8.1	***	538	562	572	7.7	n.s.	n.s.	n.s.	n.s.
C (g/kg DM)	480^{a}	$451^{A,ab}$	446^{b}	4.5	**	476^{a}	$440^{B,b}$	449^{b}	7.9	***	n.s.	*	n.s.
P (g/kg DM)	5.4^{a}	$5.4^{A,a}$	3.2^{b}	0.3	**	5.3^{a}	$4.6^{B,b}$	3.4^{c}	0.2	***	n.s.	*	n.s.

FM = Fresh matter, DM = Dry matter, OM = Organic matter, N = Nitrogen, NDF = Neutral detergent fiber, C = Carbon, P = Phosphorus, SEM = standard error of mean, p = Probability value, *$p \leq 0.05$, ** $p \leq 0.01$, ***$p \leq 0.001$, n.s. = non-significant.

$^{A, B}$ In rows, capital letters following means indicate significant differences for a month between the two years according to independent T-test and Mann-Witney U-test. ^{abc} In rows, small superscripts following means indicate significant differences between months within a year according to one way ANOVA and Kruskal-Wallis test.

3.4 Discussion

3.4.1 Herbage yield and quality on Mongolian Altai mountain pastures

Herbaceous biomass production on pastures strongly depends on annual precipitation and its intra-annual distribution in arid and semiarid areas (Ellis and Swift, 1988), which was confirmed for the Mongolian context (Fernandez-Gimenez and Allen-Diaz, 2001; Sasaki et al., 2012; Zemmrich et al., 2010). Accordingly, herbage yield on summer pasture was higher in 2014 (837 kg/ha DM) than in 2013 (711 kg/ha DM). In 2014, higher snow cover occurred from September 2013 to March 2014, which is an important moisture source for vegetation at the beginning of spring (i.e., start of the vegetation period, which normally occurs between late April and early May) or even later (Johnson et al., 2006; Li et al., 2007). The snow melt was followed by a sufficiently high amount of rainfall together with warmer temperatures during 2014 spring and summer months, especially in May; so conditions for regrowth of pasture vegetation after a first utilization by small ruminants were also favourable (Figure 3.4). Within 2014, the highest herbage mass was determined in July; Miyazaki et al. (2004) and Munkhtsetseg et al. (2007) reported a higher correlation of precipitation and herbage yield in July than in June and August. Also, as a general rule for Mongolian pastures, biomass yield is highest in July and gradually decreases (Tserendash, 2000), which was the pattern also observed here. Although the pastures investigated here were subdue to a high grazing pressure during the summer season (Jordan et al., 2016), negative effects on biomass yield should have been small due to the short duration of the grazing periods (1.5 months) per pasture (Schönbach et al., 2012). Across years and pastures, the herbage yield determined at the moment of grazing (values presented here) was higher (900 kg DM/ha) than the values measured before grazing (535 kg DM/ha; Jordan et al., 2016), due to regrowth of pasture vegetation during the grazing season (Nergui et al., 2011). However, overall average herbage yield in both years was much lower than previously reported values from the Altai mountains of Mongolia (1050-1500 kg DM/ha; Tserendash, 2000), which may be explained by lower precipitation and higher grazing pressure in the present study period (see Chapter 1) as compared to pastures and situations studied by the mentioned authors.

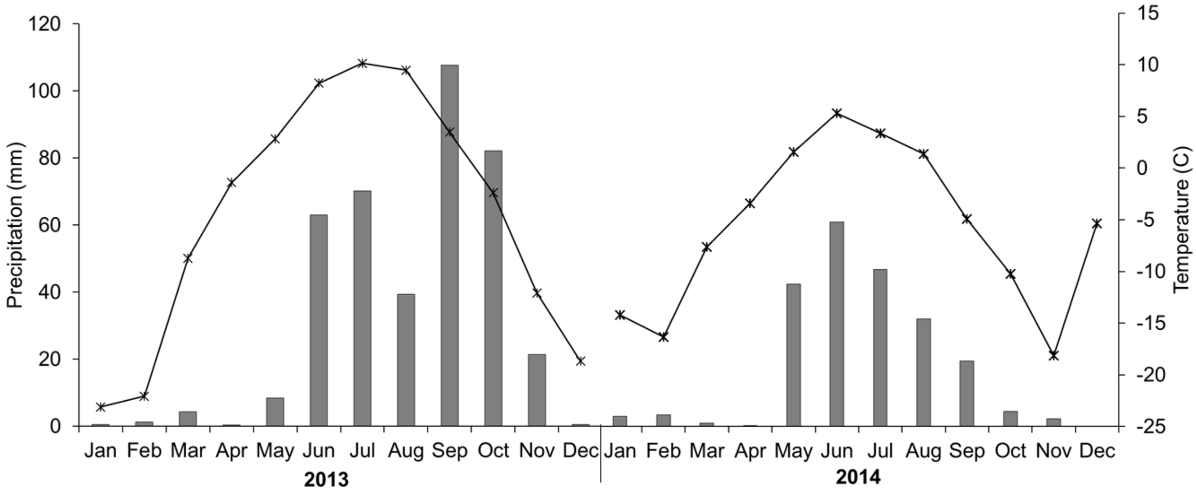


Figure 3.4. Precipitation (bars) and temperature (lines) diagrams for the summer pasture in 2013 and 2014 recorded at Sonkhel Lake weather station in the Mongolian Altai Mountains. Data were provided by the WATERCOPE project.

The general quality parameters of the pasture vegetation such as OM and CP concentrations, cell wall constituents and mineral concentrations were in accordance with expected values for the different phenological stages of herbaceous vegetation (Kilcher, 1981), and with values presented for pastures in Mongolia (Murray et al., 1998; Togtokhbayar, 2006). At advanced stages of growth (flowering and seeding) the OM and CP concentrations declined whereas the concentrations of NDF and ADF increased, due to a declining leaf to stem ratio and an increasing diameter of the stem of the growing plant (George and Bell, 2001; Enriquez-Quiroz et al., 2016). The quality of the pasture vegetation was best in July, given high concentrations of CP and low concentrations of NDF and ADF, which is in agreement with Tserendash et al. (2011) that maturity of vegetation on high alpine pastures only occurs in August. For Altai summer pasture similar to our study area, Tserendulam (1968) reported a concentration of 110-120 g digestible CP/kg DM in August, and a concentration of 108 g CP/kg DM was found by Murray et al. (1998). The lower average CP concentration found in the present study (80 g CP/kg DM) may be due to differences in precipitation and temperatures (Batima et al., 2005; Munkhtsetseg et al., 2007) and/or grazing pressure (i.e. selection of the grazing animals), but might also indicate that pasture quality is gradually declining in the Altai mountains similarly to the trend observed in Mongolia's forest steppe (Tserendash, 2000). Furthermore, the present CP concentration was 1-5% lower in comparison to values reported for Mongolia's mountain forest steppe (Otgonjargal, 2012), steppe (Togtokhbayar, 1995) and desert steppe (Murray et al., 1998), but similar to the mountainous zone of the country (Daalkhaijav and Lkagvajav, 1997), while the NDF and ADF concentrations were much higher than values reported in the mentioned studies. The concentrations of Ca and P were in agreement with values reported by Togtokhbayar (1995) and Tserendash (2000).

3.4.2 Intake of feed and nutrients and excretion of faeces

Generally, intake of all diet constituents by sheep and goats decreased from June to August 2013, which is in agreement with findings of Hu et al. (2014) from Inner Mongolia where similar environmental conditions exist. ADF intake of sheep and DM, OM, NDF and ADF intake of goats slightly increased from July to August 2014, which might be explained by the better regrowth of the plants on the summer pasture in this year (see 4.1). Yet, sheep and goats ingested similar amounts of nutrients across the two years which agrees with findings of Huston et al. (1988), Nergui et al. (2011) and Riaz et al. (2014). These authors all interpreted this similarity in feed intake between sheep and goats as a result of high quality feed on high mountain pastures in Mongolia, which occurs only between May and October. With the exception of the CP intake of sheep in August 2014, CP and Ca intakes were sufficient to cover the respective requirements for maintenance and growth, whereas the intake of DM and P (in July and August) were not sufficient to meet maintenance plus growth requirements of small ruminants according to the values tabulated by NRC (2007). The deficient nutrient (and energy) intake of sheep and goats partly showed in their live weight development, where no substantial increase was observed in July and August in both years (Table 3.4). The present findings only partly match with reports of Togtokhbayar (2006) and Hu et al. (2014) who pointed to deficient nutrient intake of sheep and goats outside the growing season in Inner Asia. From our results it might be suggested to offer mineral-rich supplements during the summer season, to stimulate the animals' feed intake (Gendaram, 2009; Nergui et al., 2011), or also provide other supplement feeds. Moreover, adjusting the grazing management at summer pasture by increasing the frequency of herd moves and more often changing pasture locations (Jordan et al., 2016; Chapter 2) might also improve nutrient supply to sheep and goats.

The crude protein concentration in the excreted faeces was used to estimate organic matter digestibility (OMD) of the extensively grazed native pasture; this method is highly recommended because of its good representativeness of the quality and digestibility of the ingested feed which strongly relates to undigested microbial protein in the faeces (Boval et al., 2003; Lukas et al., 2005; Schlecht and Susenbeth, 2006; Wang et al., 2009; Peripolli et al., 2011). The question of using either species- and forage-specific equations or rather general ones for a wide range of forage-based diets is mostly answered in favor of more general equations by the mentioned authors, since there are no substantial differences between the different types of equations available from different studies. The organic matter digestibility of ingested pasture vegetation was estimated at 623-723 g OMD/kg OM and 595-724 g OMD/kg OM for sheep and goats, respectively, and higher values were estimated for June (spring pasture) and July (summer pasture) in both species. Especially the summer values (July and August) were consistent with previously reported digestibility values for dry matter (DMD) summarized in the review of Nergui et al. (2011), which ranged between 610-672 g DMD/kg DM.

Since the development of plants at the alpine meadows (July) is retarded as compared to lower-lying areas (June pasture), the similar digestibility values calculated for June and July may be explained by a similar development stage of plants. The lower digestibility values calculated in August reflect the maturation of the alpine pasture plants. The substantially higher CP and lower NDF concentration in the diet selected in 2013 may be due to a slower and incomplete vegetation development in the first year of study. Slightly higher OMD of the sheep's diet in June and July 2013 as compared to June and July 2014 may have been due to a lower ability of sheep than of goats to digest fibrous feeds (McCabe and Barry, 1988; Domingue et al., 1991). This might at the same time explain why very similar OMD values were recorded for goats in 2013 and 2014.

The faecal excretion of animals can be a good source of manure (Gu et al., 2004) and on pastures is an important source of recycled OM and nutrients to the soil, allowing for sustained biomass production (Edmeades, 2003). Since small ruminants' faeces are recycled within the pasture and are not used for heating and cooking (as are faeces of cattle and yak), they benefit vegetation growth and quality through improving soil fertility (Edmeades, 2003). Both sheep and goats excreted 30-45% of their total daily DM intake (g/kg$^{0.75}$ LW) as faeces, with lower proportions (31-35%) in June and July (for sheep), which is similar to values (32%) reported by Smith and Frost (2000).

3.4.3 Animals' grazing itineraries and size of grazed areas

The lengths of daily grazing itineraries of Mongolian native breeds of small ruminants showed a trend similar to those previously reported for goats on high mountain pasture in semi-arid Oman as well as in (flat) West Africa, decreasing from spring to autumn seasons (Schlecht et al., 2006; Schlecht et al., 2009). However the length of sheep itineraries (14.3 km/d) was longer in the present study as compared to Fierro and Bryant (1990: 4.6 km/d in the dry highlands of southwest America) and Lin et al. (2011: 4.7- .4 km/d in the Inner Mongolian steppe). The differences might be explained by herd management, pasture expansion and topography as well as biomass availability, since much smaller (4 and 2 ha) areas were used and animals were corralled during night time in the two mentioned studies. Also, the relatively heavy grazing occurring at our summer pasture (Chen et al., 2007; Jordan et al., 2016) might have prolonged the itinerary length since Animut et al. (2005a) showed that itinerary length increases when grazing intensity increases in similar climatic contexts. In agreement with the findings of the latter authors and Schlecht et al. (2009), sheep and goats walked for a certain distance from the home-base to reach a targeted real grazing area in the morning, due to the lower availability of vegetation around their night resting point (yurt/camp site). This was also reflected in their activity patterns where a larger proportion of time (15-19%) was spent on walking in the morning than later in the day by both species. The decreasing seasonal difference in the itinerary lengths of sheep and goats could be interpreted by improving vegetation availability on the pasture from spring to late summer, as was also discussed by Schlecht et al. (2006). However, the longest itinerary length was recorded in June in both years. June often marks the beginning of the growing season in Mongolia, especially in high mountain areas (Li et al., 2007; Nergui et al., 2011). At this time fresh herbaceous vegetation grows first in depressions (where there was more snow cover, thus higher soil moisture than on slopes and elevated spots). These grasses and forbs are preferred over dwarf shrubs (also mostly found in depressions) by small ruminants, but as the depressions are scattered across the landscape, the animals will walk further distances.

Generally, sheep and goat itineraries were longer (13.5 km/d) in spring and summer season than the average 9-10 km/d reported by Jordan et al. (2016), whereas the present values closely match the findings of Kawamura et al. (2005) for small ruminants in Inner Mongolia. Joly et al. (2013) found that small ruminants graze at an average 5.1 km distance from the home-base during the summer season in the Mongolian Gobi region, which is within the radius from home base found here (6.75 km/d), and the 3.5-6.5 km radius reported for summer herding of sheep and goats for different regions of Mongolia (Gendaram, 2009).

The daily area grazed was strongly and positively correlated to the length of the daily grazing itinerary (R^2=0.989, $p \leq 0.05$), as a result of the way these areas were calculated; therefore seasonal differences in size of grazing areas can be interpreted in the same way as the variations in itinerary length.

3.4.4 Activity patterns of sheep and goats on pasture

The behavior of grazing sheep and goats in this study matches well with a previous report that the longest grazing phases occur in the afternoon and the shortest in the morning (Lin et al., 2011). These authors also observed that the proportion of time spent grazing increased whereas the proportion of time spent resting and walking decreased from June to August, which is comparable to our diurnal grazing behavior observations. However the lower grazing and higher resting share at noon and in the early afternoon observed for both species in June as compared to July and August might be explained by the distance between pasture and water source as well as weather condition (Kawamura et al., 2005). In June the animals visited a small stream as only water source, located a bit off the home-base at noon and rested there for 1.5 - 2 hours due to its cooler environment than at the pasture. Then they restarted grazing when air temperatures decreased and a bit of wind came up – a condition especially suiting sheep (herder G. Dashdavaa, pers. comm.). The resting time during July and August was reduced by 16-20% in both sheep and goats due to cooler weather at the higher altitude of the summer pasture, and an immediate access to drinking water near the home-base. Furthermore, day length decreases from June to August, to which ruminants were observed to adjust their grazing time (Hejcmanova et al., 2009; Lin et al., 2011). Since sheep and goats (or rather their herders) avoided to graze at night in order to prevent risk of predation by wolves (also mentioned by Rutter, 2006), limiting the grazing behavior observation to day time was not causing bias. However, Lin et al. (2011) argued that estimations of resting time per day principally underestimate the duration (absolute or percentage) of this activity of which the major share occurs during night time, particularly in sheep and goats (Animut et al., 2005b).

3.5 Conclusions

The present study explored the monthly variation in grazing itinerary length and grazing behavior of sheep and goats at spring and summer pasture in the Mongolian Altai, as well as the nutritional situation of small ruminants in terms of biomass availability, feed quality, and feed and nutrient intake. From the results it seems that prolonging the length of grazing itineraries seems to be the only strategy to secure a requirement-covering feed intake of small ruminants. As such practice may enhance the animals' energy expenditure for walking, low growth rates or live weight changes, respectively, result, which was observed in this study.

The grazing behavior of small ruminants is similar between sheep and goats and across the summer months, however the two species behave differently during day time due to differences in biomass availability and palatability, water sources and daily weather condition as well as their interactions with the herders. The grazing behavior observations suggest that afternoon is the most important day time for small ruminants to secure their daily feed and nutrient intake, which might be worth considering in daily herding practices. The daily intake of sheep and goats from the natural pasture vegetation during the summer season seemed to cover maintenance plus growth requirements of the local breeds, with the exception of their mineral requirements (here: especially P). Therefore a source of macro and micro minerals should be offered to the small ruminant herds during the summer season.

Since the present study was limited to observations and measurements of adult castrated male animals, this fact and the low number of animals involved might limit the relevance of the above results. Therefore, the current measurements should be repeated with a higher number of animals of different sex and physiological stage, and during longer periods. Nevertheless, some of these first insights into the interdependencies of herbage yield and quality, itinerary length and grazing behavior as well as feed and nutrient intake could already serve some reconsideration of herding and supplementation practices within the framework of discussions amongst livestock managers and policy maker on how to secure sustainable use of high mountain pastures and the productivity of animal husbandry depending thereupon.

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Annex

Annex 3.1. Average length of the daily grazing itinerary and size of the daily grazed area of transhumant sheep and goat in the Mongolian Altai Mountains in 2013 and 2014

Species	Year	Month	**Daily itinerary length** (km)	**Daily grazed area** (ha)
Goats	2013	June	16.8 [B,a]	110.9 [a]
		July	9.9 [B]	24.9 [B,b]
		August	9.6 [B,b]	34.1 [b]
		SEM	0.78	5.78
		Probability	***	***
	2014	June	20.8 [A,a]	119.2 [a]
		July	14.4 [B]	62.8 [A,b]
		August	14.7 [A,b]	50.9 [b]
		SEM	5.14	10.38
		Probability	***	***
	Year effect	June	*	n.s.
		July	n.s.	***
		August	**	n.s.
Sheep	2013	June	14.4	74.9
		July	11.5	62.3
		August	11.5	42.0
		SEM	0.96	9.57
		Probability	n.s.	n.s.
	2014	June	16.9	81.3 [a]
		July	12.9	57.7 [ab]
		August	12.7	56.2 [b]
		SEM	0.91	5.14
		Probability	n.s.	*
	Year effect	June	n.s.	n.s.
		July	n.s.	n.s.
		August	n.s.	n.s.

SEM = standard error of mean. *$p \leq 0.05$, ** $p \leq 0.01$, ***$p \leq 0.001$, n.s. = non-significant.

[A, B] In columns, capital letters following means indicate significant differences for a month between the two years according to independent T-test.

[abc] In columns, small superscripts following means indicate significant differences between months within a year according to one way ANOVA.

Annex 3.2. Effects of animal species, month, year and their interactions on OM digestibility (OMD) and quantitative intake of major diet constituents by small ruminants grazing summer pastures in the Mongolian Altai Mountains

Predictor	OMD	DM intake	OM intake	CP intake	NDF intake	ADF intake
Species	0.387	0.203	0.234	0.603	0.225	0.174
Month	*0.000*	*0.008*	*0.006*	*0.000*	0.737	0.124
Year	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Species*month	*0.002*	0.867	0.891	0.850	0.612	0.518
Species*year	0.787	0.144	0.123	0.079	0.107	0.168
Month*year	*0.000*	*0.001*	*0.001*	*0.001*	*0.001*	*0.000*
Species*month*year	0.547	0.619	0.649	0.833	0.397	0.228

DM = Dry matter, OM = Organic matter, CP = Crude protein, NDF = Neutral detergent fiber, ADF = Acid detergent fiber. Significance level of 0.05 used for determining differences; probability values written in italic are showing significant effects of individual variables or interaction of predictor variables on the dependent variables.

Annex 3.3. Proportion (%) of the daily time on pasture spent on different grazing activities by transhumant sheep and goats in the Mongolian Altai Mountains (spring and summer 2013)

	Sheep			
Day time	**Grazing**	**Resting**	**Walking**	**Others**
Morning	29[c]	51[a]	19	1
Noon	74[a]	13[c]	11	1
Afternoon	63[a]	19[b]	15	2
Evening	48[ac]	30[abc]	17	4
Probability value	***	**	n.s.	n.s.
	Goats			
Morning	30[c]	53[a]	15	2
Noon	78[a]	12[b]	9	1
Afternoon	55[b]	31[ac]	11	2
Evening	63[ab]	25[cb]	9	4
Probability value	***	**	n.s.	n.s.

*p≤0.05, ** p≤0.01, ***p≤0.001, n.s. = non-significant.
[abc] In columns, small superscripts following means indicate significant differences between months.

Chapter 4

Reproduction management of transhumant small ruminants flocks in the Mongolian Altai Mountains

4 Reproduction management of transhumant small ruminants flocks in the Mongolian Altai Mountains

Summary

Domesticated animals are the second most important income and livelihood source in Mongolia, and especially small ruminants (sheep and goats) are vital for rural subsistence. They account for 87% of the total number of livestock in the country. This chapter therefore analyzes the reproductive performance and economic profitability of local breeds of sheep and goats under the present management and alternative management improvement options. A progeny history survey was used to collect data on reproduction performances of breeding ewes and does and on culling strategies for breeding female and male animals. Based on data collected from 83 ewes and 173 does and their offspring (330 lambs and 462 kids) of 21 herder families, the reproduction parameters were calculated and then integrated into the bio-economic PRY Herd Life model to simulate the current management (SQ) and three alternative scenarios namely: modified culling (MC), improved feeding *(*IF) and the combination of MC and IF. Additionally, male and non-pregnant female sheep (n=301) and goats (n=445) from 5 and 4 herds, respectively were weighed in order to determine the animals' body weight in different sex and age groups. The average age at first parturition of ewes and does was about 27 months, and the parturition interval was close to 13 months long. This was due to the herders' breeding strategy which takes into account the local environmental constraints such as seasonal feed supply and harsh winter weather conditions. The parturition rates (50% - 96%) and abortion rates (6% - 47%) of both species varied year by year, reflecting feed supply on the natural pastures and weather conditions, especially during the spring and winter seasons. But these variables were also influenced by the herding knowledge of the livestock keepers. The simulation of present and alternative herd management strategies with the PRY Herd Life model showed that the current management of small ruminants is profitable with an average annual monetary output of 24 € and 26 € per unit of sheep and goat (female animal with offspring), respectively. Modifying the culling (scenario MC) of unproductive (female) and surplus (male and female) animals has the potential to improve the economic benefit per sheep and goat, and stabilize herd size. However, successful implementation of such alternative

management needs a well-functioning market that absorbs live animals and offers possibilities to transform carcasses into attractive meat products.

4.1 Introduction

The majority of domesticated animals worldwide are kept in developing countries (Shrestha and Fahmy 2005), one very outstanding example being Mongolia where livestock production is the second most important sector after mining (NSOM, 2013). Therefore, many studies focused on Mongolian livestock husbandry (Fernandez-Gimenez, 1999; Andrew et al., 2009; Upton, 2010) and animal production systems (Roningen, 1999; Lecraw et al., 2005; Batsaikhan et al., 2007) as well as on the utilization of pastures, which are the most important source for feeding for livestock in Mongolia (Tserendash, 1993; Fernandez-Gimenez, 2002; Fernandez-Gimenez and Le Febre 2006; Zemmrich, 2007; Sternberg, 2008; Jamsranjav, 2009; Bat-Oyun et al., 2010; Chuluun et al., 2011). Other studies analysed the husbandry systems' vulnerability to environmental conditions (Begzsuren et al., 2004; Batima et al., 2005; Chuluun, 2008; Middleton et al., 2014; Fernandez-Gimenez et al., 2015) in the last two decades. A number of studies have also investigated the livelihood strategies of local pastoralist people (Mearns, 2004; Lise et al., 2006; Lkhagvadorj et al., 2013b; Wang et al., 2013). All of these studies agreed that most rural livelihoods directly depend on livestock husbandry, and the livestock husbandry itself relies on natural pasture vegetation which in composition and yield totally depends on annual precipitation and its distribution in time and space. However, the production performance and potential of small ruminants, especially goats, in poor Central Asian areas such as Mongolia have not been sufficiently studied or documented (Iñiguez, 2004). Generally, Mongolia's rural inhabitants are described as poor; according to the Mongolian Government (2013), 49 to 51% of all poor people across the country are living in remote areas. The Bulgan River Valley in the Altai-Dzungarian region in the utmost southwest of the country is one of those remote areas where the traditional pastoral transhumant livestock husbandry system is combined with small-sized semi-irrigated arable farming (Chapter 2). However, traditionally managed extensive husbandry of sheep, goats, cattle, horses and camels, and, at higher altitude pastures, yak, is the dominant farm type. These animals are very well adapted to the harsh topography and climate prevailing in the region and are managed on pasture throughout the year as a result of many centuries of traditional

breeding and selection along with long term agro-ecological evolution under Central Asian conditions (Bynie, 2002). The Mongolian native breeds of sheep and goats (*Khalkh*) dominate (90%) small ruminant herds (Donrov et al., 1998; NSOM, 2014) across the country and provided meat, milk, and manure which is used as fertilizer for crop fields, and they deliver an important share of household income through sales of cashmere and wool fibre (Degen, 2007). In this traditional extensive pastoral husbandry system (Carlos and Henning, 1995) with its strong dependence on seasonal mobility (Blench, 2001) between low-lying winter pastures, alpine summer meadows and intermediately situated spring and autumn pastures (Chapters 2, 3), sheep and goats are often shepherded together and receive more care by their owners than other species because they are very vulnerable to risks such as sudden change in weather conditions, loss at pasture and wolf predation (Lkhagvadorj et al., 2013b). Breeding female and male animals are always kept separately except during breeding season which stretches from early October to mid-November. From spring to late autumn, small ruminants spend the night near the yurt and in the morning are taken out to pasture for grazing. Most herders sent their animals to pasture between 9 a.m. and 4 p.m., whereby herding is mostly done by men and only in summer time (holiday season) by children; however, some livestock owners also leave their animals to graze on their own outside of cultivated areas.
Year-round, livestock feeding is thus mostly relying on the vegetation of natural pastures, but in winter small amounts of hay harvested on natural, often irrigated pastures or in floodplains, are offered as supplement feed to small ruminants, along with cereal straw, cereal bran and salt (Chapter 2; Batjargal et al., 2013). The pastureland is owned by government but access is free to every herder, its utilization is not strictly regulated and grazing rules are poorly implemented (Munkhnasan, 2010), despite vast traditional ecological knowledge on fine-tuned pasture utilization and seasonal mobility (Fernandez-Gimenez, 2002). As pasture utilization management may have significant impacts on animal reproductive performances (Bosman et al., 1997), and small ruminants are essential for rural livelihoods (Alexandre and Mandonnet, 2005), pasture management also matters with respect to the latter domain.

Especially the goat is described as a multifunctional animal that produces many useful products and services (Peacok, 1996). In Mongolia, goats and sheep mainly serve slaughtering and consumption in the household and cash earning through live animal sales and marketing of milk, hair/wool, and skin. Owners of larger herds commonly sell live small ruminants at local markets, and local prices per sheep and goat were 49 € and 35 € respectively, during the time of study, whereby prices vary depending on body condition/fatness and age (Chapter 2). Another main role of goats as an income source for households is the sale of their cashmere, of which the regional price per kg was 31.1 € in 2012 (Chapter 2, Lkhagvadorj et al., 2013a). The price varies from year to year as it is closely connected to the global cashmere market (van der Westhuysen, 2005), but also exposed to government policies (Lecraw et al., 2005). As the cashmere yield averages 250 to 300 g per animal and year (Yokhama et al., 2009; Mandakh et al., 2011), local herders prefer to increase their herd sizes rather than to improve the performance of their animals in order to meet their demand for cash. This shows in the increasing share as well as total numbers of cashmere goats in the national livestock herd of Mongolia as well as in the study region during the past 20 to 30 years (Chapter 1). Such development is affecting the health of Mongolia's rangelands, and numerous recent studies point to the worrying increase of livestock numbers, grazing pressure and decrease of pasture productivity (Fernandez-Gimenez and Allen-Diaz, 1999; Chen et al., 2007; Bat-Oyun et al., 2010; Khishigbayar et al., 2015). Being somehow in contrast with herders' strategies, in 2010 the Mongolian government, in the framework of the Millennium Development Goals, adopted a huge policy program named "Mongolian livestock". This program aims to improve animal productivity and health as well as pasture utilization and management (Mongolian Government, 2010). In the western part of the country, the program focuses on eradicating infectious animal diseases, and provides local herders with more market opportunities. Overall however, the poor infrastructure and remoteness of rural areas make it challenging for the national government to achieve its aims. Within this context, investigation and improvement of livestock reproduction strategies are seen as an important contribution to improve animal productivity and reduce poverty of rural inhabitants (Mongolian Government, 2013). So far, remote areas in western Mongolia received considerably less scientific (and policy) attention than the central and northern parts of the country. Consequently, information on the performance of extensively grazed native sheep and goat breeds in this region are only available from a few project reports and BSc theses (Nomundari, 2010; Munkhjargal, 2012).

For this reason, the objectives of this study were (I) to explore the current reproductive performance parameters of traditionally managed sheep and goats in the arid to semi-arid Altai-Dzungarian region of western Mongolia, (II) to assess the efficiency of resource (feeds, nutrients) conversion into valuable products (meat, hair), and (III) to access the economic viability of the present management of small ruminants.

4.2 Materials and Methods

4.2.1 Study area and animal species

This study was conducted with true transhumant herder households in the Mongolian Altay Mountains in western Mongolia (for details see Chapter 2). Within this livestock husbandry system the small ruminants (sheep and goats) are the central species for herders' livelihoods, providing meat, milk and fiber. Small ruminants are not only important due to their wide distribution but also because the Mongolian gene pool hosts several fine and semi-fine wool sheep breeds that are well adopted to country's climate (Batsukh and Zagdsuren, 1991). However, in the study region, the present economic importance of cashmere wool resulted in a sheep to goat ratio in mixed herds of 1:3 in 2013, which strongly contrast with the situation prevailing during the country's socialist period (Chapter 1; Lkhagvadorj et al., 2013a).

Out of 15 local or indigenous sheep breeds, the Mongolian native sheep breed (*Khalkh)* is the one most widely distributed throughout the country and is referred to as multipurpose (mutton, wool and milk) and low productive as compared to other breeds; cross-breeding with more productive breeds is therefore very popular (Batsukh and Zagdsuren, 1991). Adult *Khalkh* sheep are medium-sized and fat-tailed with straight back, small to medium sized head and straight shoulders and legs. The males have curved horns and females are mostly polled (98%). The coarse wool is white with black and brown spots around eyes, ears and nose, sometimes the head is black or brown. Wool yield averages 1.6 kg for adults, out of this 62% can be considered to be clean wool. The fat-tail is of medium size and weighs 1.5 to 4 kg depending on nutritional conditions. Ewes normally lamb once a year, the lambs are mostly single with a birth weight of about 4 kg (Byambasaikhan and Minjigdorj, 2015), They grow fast until 7 months of age, when they normally have reached 9.4 times their birth weight (Chadraabal et al., 2011). Male lambs that are not needed for breeding are castrated at 1.5 - 2 months of age and raised for mutton and wool. Their body development is completed at 65 months of age; the dressing percentage is about 46.5% (Chadraabal et al., 2011).

The Mongolian native *(Khalkh)* breed of goat is one of the about 10 local breeds and is raised for cashmere, milk and meat. Its population size amounted to 22 million head (42% of all goats in Mongolia) in 2014. The breed is well adapted to desert and mountain climate conditions; it is very actively and selectively grazing and strong in climbing rocky terrain. The animals are small sized and mostly covered with red, black, blue and white or lighter hair (Mandakh et al., 2011). Does give a birth once a year, the mostly single kid weighs around 3.0 kg and grows rapidly; most male kids are castrated at 1.5 to 2 months and are kept for cashmere production up to 60 months of age. Depending on type, location and management, the cashmere yield ranges between 250-350 g per year for adults and 170-210 g for animals up to one year (Yokhama et al., 2009). If milked, does can yield up to 50 litres of milk during 150 days. Even though goats are not primarily kept for meat production, aged animals play an important role for household meat consumption; their dressing percentage approximates 39-44% (Mandakh et al., 2011).

4.2.2 Data collection

4.2.2.1 Livestock survey

Data collection focused on Mongolian native (local) breeds of sheep and goats which are more important for the local pastoralists' livelihoods as compared to the other species (Chapter 2; FAOSTAT, 2013). Among the families interviewed in the baseline survey (Chapter 2), only 21 true transhumant pastoral households were considered who, during summer time, herded their animals at Sonkhel Lake (see Chapter 2 for location details). A progeny history survey (Swift, 1981) was used for data collection in summer 2013 and 2014. The progeny history approach asks livestock owners to recall the reproductive history of their breeding female animals by answering to a structured questionnaire (Kaufmann, 2005; Riedel et al., 2014). Variables such as date of birth of breeding females, mode, date and location of acquisition, type of breed, milk yield class (high, middle and low), offspring number, birth dates, sex, mortality or destiny of offspring, incidences of abortion, as well as culling age of breeding males and females are recorded. The data is complemented by information on sales ages and prices of marketed animals. These data were collected from 173 breeding does and 83 breeding ewes of 21 and 16 herders; in addition, information on 330 lambs and 462 kids was recorded from the sampled breeding females. Based on this data set, the reproduction traits age at first parturition (AFP) and parturition interval were calculated for each breeding female individually, while parturition and abortion rates, litter size as well as offspring mortality were determined for the sampled population of sheep and goats, respectively (Table 4.1), according to the very detailed information given by Kaufmann (2005), Dickhoefer et al. (2012) and Riedel et al. (2014).

Table 4.1. Definition of reproduction parameters of Mongolian native breed of sheep and goats.

Parameter name	Definition
Age at first parturition*	Time span between date of birth and date of first parturition of a breeding female
Parturition interval*	Time span between two subsequent parturitions
Parturition rate	Number of successful deliveries of all pregnant females divided by total number of pregnant females per herd and year
Litter size*	Number of live offspring in one parturition
Abortion rate	Number of abortions divided by the total number of pregnancies of all breeding females per herd and year
Culling rate*	Number of animals taken out of a herd in a year divided by the total number of animals in the herd per year. Offtake can be due to gifting, slaughter, sale, exchange, payment.
Offspring mortality rate*	Number of offspring dying before weaning divided by the total number of offspring per year.

** Parameters introduced to PRY Life Herd model as an inputs.*

In order to determine the animals' live weight (LW) at culling (that is, slaughtering for own consumption or sale) in different sex and age groups, a stratified random sample of healthy male and non-pregnant female sheep (n=301) and goats (n=445) from 5 and 4 herds was weighed once using a digital electronic hanging scale (range 5 - 300 kg, accuracy 0.5 kg), a wooden bar and a hang mat. Weighing took place at the end of July 2014, a time when small ruminants reach their optimum body condition (Erdenetsogt, 2011). Five different non-linear growth models (Eq. 4.1-4.5; Brown et al., 1976; Fitzhugh, 1976) were applied to the obtained live weights of sheep and goats, respectively, using the statistical software R version 3.1.1 (R Core Team, 2014). While the logistic model (Eq. 4.3) fitted best to sheep data, the Bertalanffy model (Eq. 4.4) proved best for body weight prediction of goats.

Brody model: $y = A * (1 - b * e^{-k*t})$ (Eq. 4.1)

Gompertz curve: $y = A * e^{b*e^{-k*t}}$ (Eq. 4.2)

Logistic regression: $y = A * (1 + b * e^{-k*t})^{-1}$ (Eq. 4.3)

Bertalanffy model: $y = A * (1 - b * e^{-k*t})^{3}$ (Eq. 4.4)

Richards curve: $y = A * (1 - b * e^{-k*t})^{m}$ (Eq. 4.5)

*where **y** is the live weight (kg), **A** is the asymptotic value (= adult live weight), **t** is age in months, **b, k** and **m** are function variables, and **e** is Euler's number.*

As all surveyed breeding females were still in the herd at the moment of interview and no mortality (except culling) of offspring having reached adulthood was recorded during the survey, adult mortality was not calculated.

The prices for live sales of small ruminants of different sex and age were obtained during the baseline survey in 2012 (Chapter 2). The values were converted into Euro based on the World Bank exchange rate for 2012 (when 1 Euro equalled 1646.45 MNT) and were divided by the respective body weight per sex * weight class to obtain the price per kg of body weight.

4.2.2.2 Bio-economic modelling and scenario analyses

The determined reproductive parameters together with growth data of sheep and goats were entered in an upgraded version of the bio-economic PRY Herd Life model for Windows (Baptist, 1992) to assess potential herd development and body weight as well as monetary offtake potential per animal and year. The species-independent model computes weight and monetary outputs per animal in the herd based on body weights and sales prices for specified culling ages of male and female animals. In the interviews, the maximum life span of sheep and goats was reported at 112 and 99 months, and these ages were used as a cull-for-age threshold. Herd development and offtake under the current management (status quo, SQ) were modelled separately for sheep and goats using the species-specific reproduction parameters.

Since the progeny history interviews did not yield mortality rates for adult small ruminants (see 4.2.2.1), the values reported by Begzsuren et al. (2004) and Mahul and Skees (2007) were used for the PRY Herd Life model. Both studies estimated adult livestock mortality at 5% in a normal year, 18% in a year with a very harsh winter (*dzud*), and 7% in a drought year; such natural hazards on average occur once in 7 years (Statistical Department of Khovd Province, 2013). Therefore the weighted average of normal and disaster year mortality rate (8%) was used in PRY. For sheep older than 100 months and goats older than 73 months, a mortality rate of 80% was assumed given their low biological vitality (Batsukh and Zagdsuren, 1991).

To model daily feed energy intake, the metabolizable energy (ME) concentration of vegetation on natural pastures was taken from Togtokhbayar (2006); some additional data used for calculating feed costs are presented in Annex 4.1.

To test alternative management strategies that might improve the (reproductive) performance of small ruminants, three scenarios were established for each species (Table 4.2).

Table 4.2. Reproductive performances of sheep and goats under the traditional husbandry system in western Mongolia as determined in a progeny history survey (status quo, SQ), as compared to strategies of modified culling (MC), improved feeding (IF) and combination MC+IF.

Parameters	Unit	SQ	MC	IF	IF+MC
Sheep					
Cull-for-age threshold	months	112[a]	112[a]	112[a]	112[a]
Mortality rate	percentage	8[e]	8[e]	5[e]	5[e]
Age at first parturition*	months	27.4[a]	27.4[a]	24.0[b]	24.0[b]
Parturition interval*	months	12.9[a]	12.9 [a]	12.0[b]	12.0[b]
Litter size*	n parturition^{-1}	1.08[a]	1.08 [a]	1.20[b]	1.20[b]
Overall culling rate	percentage	32.1[a]	12.3[c]	32.1[a]	12.3[c]
Goats					
Cull-for-age threshold	months	99[a]	99[a]	99[a]	99[a]
Mortality rate	percentage	8[e]	8[e]	5[g]	5[g]
Age at first parturition	months	26.5[a]	26.5[a]	24.0[f]	24.0[d]
Parturition interval	months	12.74[a]	12.7[a]	12.0[f]	12.0[d]
Litter size	n parturition^{-1}	1.09[a]	1.09[a]	1.20[f]	1.20[d]
Overall culling rate	percentage	4.5[a]	10.3[c]	4.5[a]	10.3[c]

[a] Progeny history survey; [b] Chadraabal et al., (2011); [c] Own assumption; [d] Mandakh et al., (2011); [e] Own weighted average values based on Begzsuren et al. (2004) and Mahul and Skees (2007); [f] Bolikhorloo, (1975); [g] Begzsuren et al., (2004)

The first scenario only investigated modified culling (MC), assuming that herders could sell more non-breeding animals at optimal body weight to earn more money, as well as cull more breeding females of older age. The second alternative scenario was improved feeding (IF), assuming an improvement of reproductive traits by offering adequate amounts of good quality feed to breeding females during the winter season (December - March) when nutrient intake on natural pasture is deficient. Specifically, supplement feeding was assumed to increase the metabolizable energy (ME) concentration of winter feed from 5.6 MJ to 12.5 MJ ME per kilogram of feed dry matter (DM) by offering good quality hay grass (70%) and wheat bran concentrate (30%). Per sheep and goat, respectively, this supplement feeding amounted to 0.6 kg and 0.4 kg DM d^{-1} during the 4 months. Whereas hay grass is prepared by local herders from their hay making fields, concentrate feed is commercially available. Therefore, the cost of hay grass was calculated at 14 € t^{-1} DM including labour and machinery, while the price of wheat bran concentrate amounted to 120.3 € t^{-1} DM (http://www.altantaria.mn/; Annex 4.2). For the 120 days of supplementing period, the additional feed costs thus amounted to 16.5 € and 12.8 € for each sheep and goat, respectively. Due to improved feeding, average age at first parturition and parturition interval were reduced to 24 and 12 months as suggested by Bolikhorloo, (1975), and litter size was assumed to increase to 1.2 for both species, while all other parameters were not changed in this scenario. The third scenario investigated the effects of combing improved feeding and modified culling (IF+MC).

4.2.3 Statistical analysis

Statistical analyses were carried out using the Statistical Packages for Social Science (SPSS) software version 20.0 for Microsoft Windows (IBM Corp. 2011). All absolute values of metric data were expressed as mean value ± standard deviation. The residuals of all continuous data were tested for normal distribution using Shapiro-Wilk test; since data sets were not normally distributed, the Kruskal-Wallis test was used, while the Mann-Whitney U-test was applied to categorical variables. Reproductive parameters (age of breeding females, number of offspring, AFP, parturition interval, abortion and culling rates) and body weight were tested for differences between species. Within species, comparison was made between age classes and years. Significance was declared at $p \leq 0.05$.

4.3 Results

4.3.1 Growth performance

The average live weight of sheep was 48.8 kg (±7.19; n=167) for adult (>12 months) non-pregnant ewes and 55.2 kg (±12.66 n=63) for adult castrated males (Figure 4.1). Weights of goats were lower ($p \leq 0.05$), namely 39.0 kg (±6.10; n=218) for adult non-pregnant does and 48.7 kg (±10.92; n=190) for adult castrated males. In adult goats, maximum live weight (LW) was 61.5 kg for non-pregnant females and 71.9 kg for castrated males, and the minimum weight was 23.5 kg and 21.4 kg, respectively. In adult sheep, maximum live weight was 71.2 kg for non-pregnant females and 90.3 kg for castrated males; the respective minima were 29.2 kg and 31.9 kg. Castrated male animals were considerably heavier than female ones in both species. Average LW of lambs and kids (both aged about 1.5 months) was 7.9 kg (±2.33; n=15) and 5.8 kg (±0.98; n=20) for females and 8.2 kg (±2.18; n=18) and 6.7 kg (±0.38 n=17) for males, respectively, with insignificant differences between sexes.

The five non-linear models showed comparatively closer agreement of growth curves of small ruminants aged older than 12 months to actual live weight curves (Table 4.3). However the model of Richards computed the lowest results and had the poorest correlation coefficient in the goat herd ($p>0.05$). From the five non-linear models fitted to the animals' age x weight data, the logistic and Bertalanffy model fitted best and had the highest correlation coefficient for sheep and goats, respectively (Table 4.3). The average predicted live weight for adult animals was 44.5 kg and 41.5 kg for sheep and goats, respectively. Live weights of adult castrated male sheep and of ewes were predicted as 55.5 kg and 48.9 kg, whereas the respective values for goats were 48.8 kg and 39.0 kg, all very similar to actual live weights. The predicted live weight of adult male and female sheep at the culling age recorded during the progeny history survey was 52.2 kg and 40.6 kg, and 27.1 kg and 31.6 kg for male and female goats.

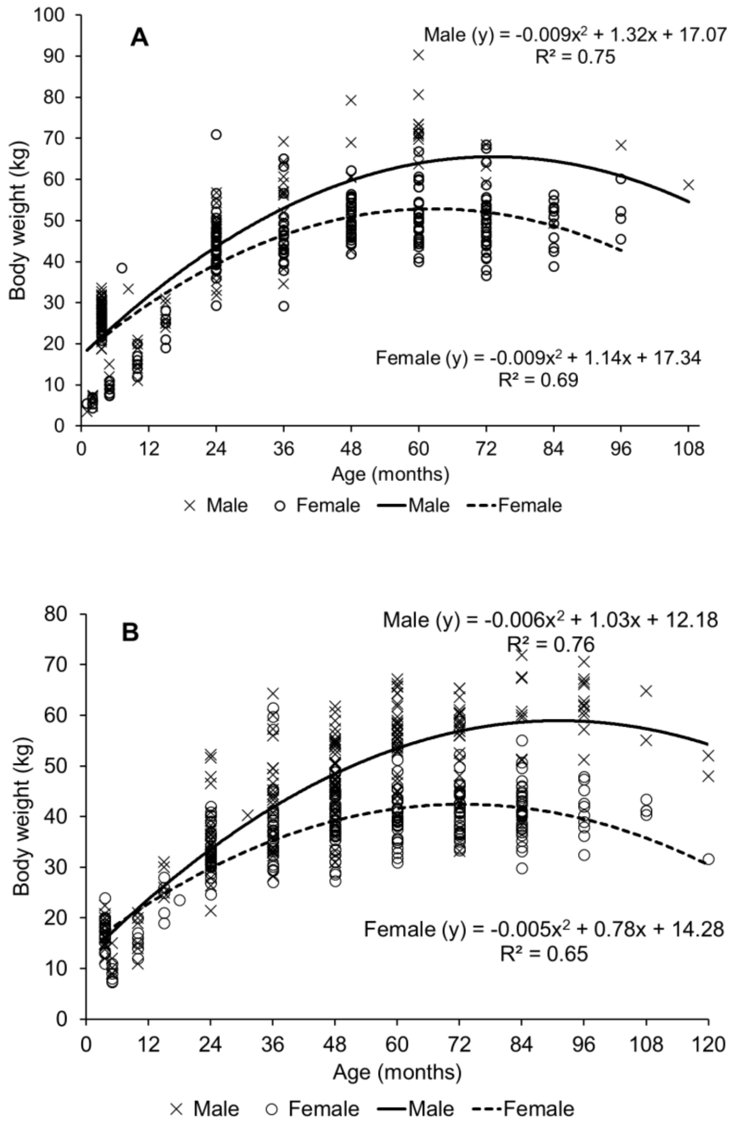

Figure 4.1. Body weights of sheep (A) and goats (B) under the traditional husbandry system in Western Mongolia. Filled dots represent male and blank dots represent female animals' weight data. Please note that x and y axes are scaled differently in graph A and B.

Table 4.3. Correlation coefficients among the models for average live weight (LW) of sheep and goats in the Mongolian Altai Mountains.

	Non-linear models				
Sheep					
	Brody	Gompertz	Logistic	Bertalanffy	Richards
Actual LW	0.762*	0.830*	0.857*	0.766*	0.820*
Brody		0.655*	0.784*	0.999*	0.670*
Gompertz			0.972*	0.659*	0.906*
Logistic				0.787*	0.923*
Bertalanffy					0.674*
Goats					
Actual LW	0.758*	0.837*	0.836*	0.837*	-0.600
Brody		0.904*	0.900*	0.902*	0.004
Gompertz			0.999*	0.999*	-0.076
Logistic				0.999*	-0.068
Bertalanffy					-0.066

* Indicates significance of correlation coefficients at $p \leq 0.05$.

4.3.2. Age of breeding female animals

The largest proportion (89.2% and 84.4%) of all breeding female sheep and goats were born within their herds, and only 10.8% and 15.6% had been exchanged with other local herders for purposes of improving herd quality and production. There was no report of purchasing breeding females during the progeny history survey, which indicates that herders do not buy females to extend their herds. The age of sampled females with at least one parturition before the survey (Figure 4.2) was significantly higher ($p \leq 0.05$) in ewes (76.8 ±18.93 months) than in does (58.4 ±20.46 months). The youngest and oldest ewe were 41 and 136 months old, whereas in does the respective values were 15 and 124 months. The largest proportion of ewes were 73 - 84 months old (36.1%, n=30), the largest proportion of does were 61 - 72 months old (30.1%, n=52). Ewes and does older than 85 months accounted for 30.1% and 11.6% of total breeding females, respectively.

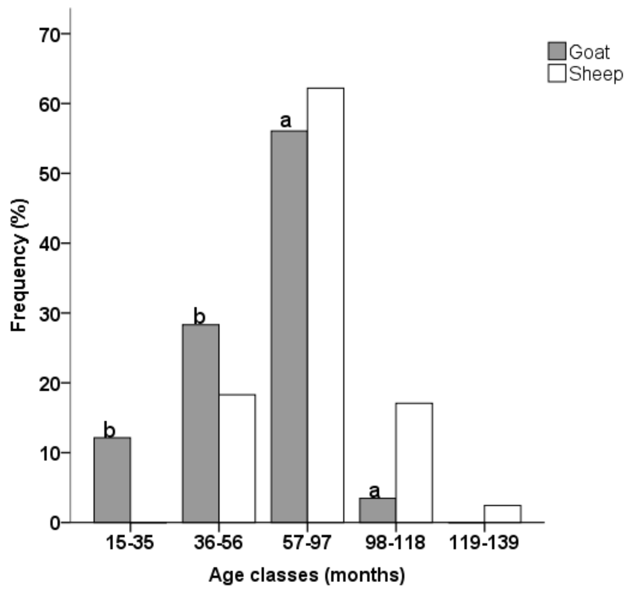

Figure 4.2. Age of breeding ewes (n=83) and does (n=173) under the transhumant livestock husbandry system in the Mongolian Altai Mountains. [a, b] Superscript letters on the bars indicate significant differences of frequency between age classes of goat population according to Kruskal-Wallis test.

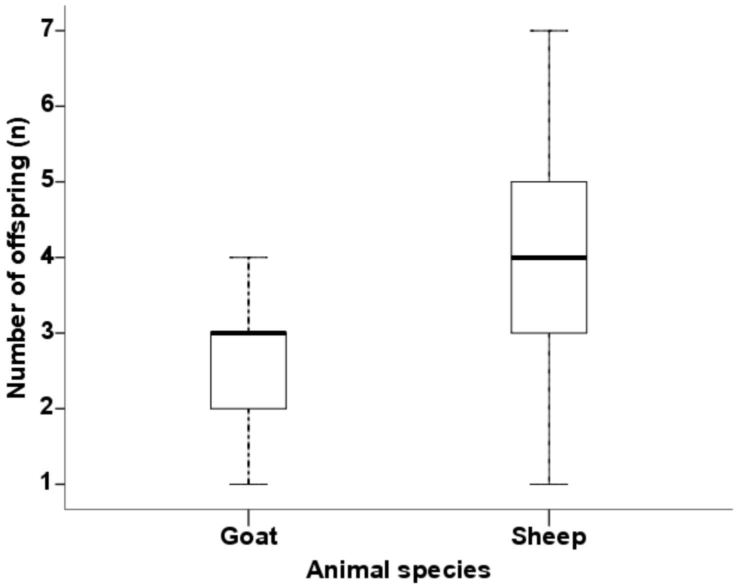

Figure 4.3. Number of offspring in the lifetime of a breeding ewe (n=83) and doe (n=173) under the current transhumant livestock husbandry system in the Mongolian Altai Mountains. The box represents the average number of offspring per female, the dark line signifies the median, and whiskers indicate the highest and the lowest number of offspring in the sampled breeding ewes and does.

4.3.3 Number of offspring per breeding female

With 4.0 ±1.37 lambs, the number of offspring of a breeding ewe (Figure 4.3) was significantly higher than of a doe (2.7 ±1.22; $p \leq 0.05$). The highest number of offspring reported for a breeding female was 7 lambs and 8 kids, respectively, but occurred in less than 3% of all breeding females. Most offspring (82% in does, 90% in ewes) were from single birth, the reminder from twin births in both species, with a higher occurrence of twins in goats than in sheep ($p \leq 0.05$). Only one triple birth was recorded for each animal species in the interviews, and these were not accounted for in further data analyses.

4.3.4 Age at first parturition (AFP) and parturition interval

Average age at first parturition of ewes and does (Figure 4.4) was 27.4 ±9.87 months and 26.5 ±9.65 months, respectively ($p > 0.05$). The earliest age at first parturition was 12 months, the latest 36 and 48 months in sheep and goats. Late age at first parturition (>48 months) occurred in 0% of ewes but in 1.7% of does, whereas 31.7% of ewes and 20.8% of does had their first delivery before 24 months of age. Average weaning age of lambs and kids was 4.0 ±1.09 and 5.0 ±0.23 months, respectively.

For both species, breeding males and females are only managed in the same herd in autumn, to avoid lambing during winter time when temperatures are very low and forage is scarce. In consequence, the parturition interval averaged 12.9 ±3.21 months in goats and 12.7 ±2.93 months in sheep ($p > 0.05$). A high proportion of females (93.4% in goats, 92.3% in sheep) had an average parturition interval of 12 months, whereas about 7% of breeding females in both species showed a parturition interval of 24 months.

4.3.5 Parturition rate, abortion rate and litter size

The average annual parturition rate of sheep and goats was 84.9% and 93.4%, with 1.1 offspring per year for goats and 1.0 for sheep. Generally, parturition rates were between 63% and 99% for sheep and 50% and 96% for goats during the years 2007 to 2009 (Figure 4.4A). The parturition rate declined to 36% in goats and 58% in sheep in 2010, which is after the 2009/10 dzud (winter disaster). The dzud impact on livestock performance was higher at lower altitude pastures along the Bulgan River than on higher altitude pastures in Mongolian Altai Mountains. After 2010, the annual parturition rate recovered more rapidly for goats (≥98%) than for sheep (67-96%).

Of all pregnancies recorded in sheep and goats, on average 6.5 ±11.05 and 6.7 ±12.79 out of hundred were aborted ($p \leq 0.05$). The highest abortion rates (47% for goats, 35% for sheep) were observed in 2010 (Figure 4.4B), the lowest rates occurred in 2013 for goats (3.48%) and in 2011 for sheep (5.35%). The abortion rate of goats varied significantly across years, whereas no difference in the abortion rate of sheep was found across years.

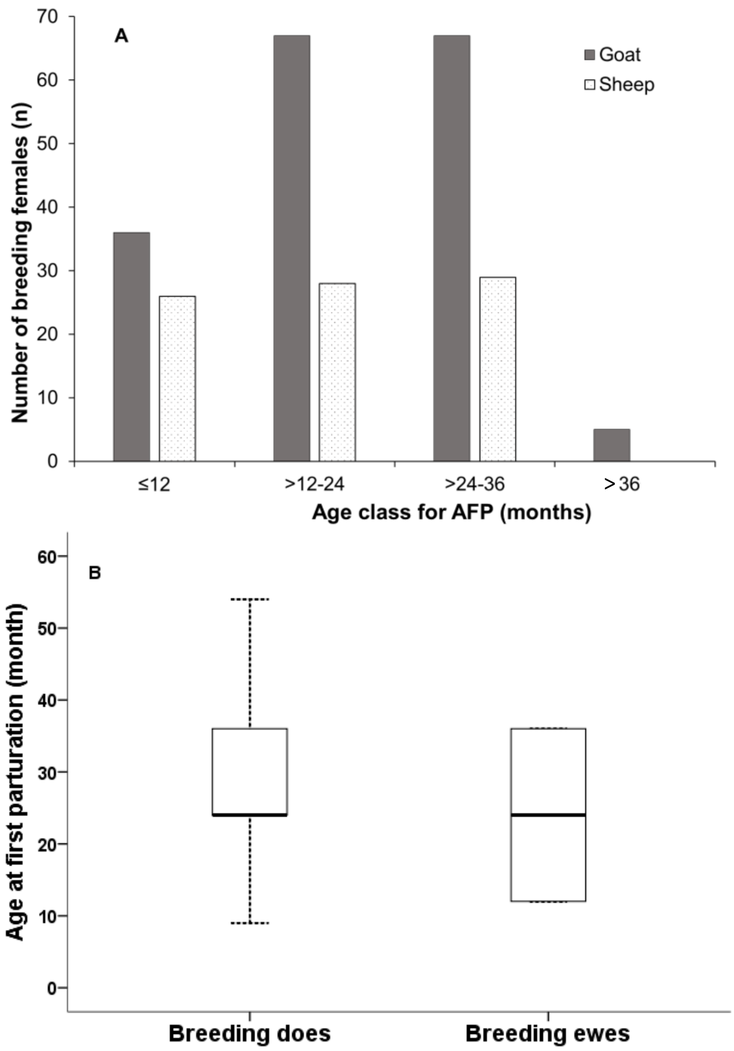

Figure 4.4. Age at first parturition (AFP) of sheep (n=83) and goats (n=173) under the transhumant livestock husbandry system in the Mongolian Altai Mountains. A) Frequency distribution; B) Mean age at first parturition. The box represents mean age at first parturition, the dark line signifies the median and whiskers indicate the earliest and the latest ages of first parturition.

4.3.6 Culling and offspring mortality rates

The mean culling rate of the sampled sheep and goats was 32.1% (n=52) and 4.5% (n=21), respectively. The overall average culling ages were 29.7 ±15.39 and 17.6 ±14.19 months in sheep and goats, respectively. Mostly male animals were culled in both herds, with the culling rate ranging between 52.3 - 67.3% for the years covered by the interview. The culling age for castrated male and female sheep was 18.2 ±12.44 months and 32.6 ±16.21 months as compared to 14.9 ±11.77 and 20.6 ±16.58 months in goats ($p \leq 0.05$). These different culling ages indicate that there seems to be no specific culling strategy related to production status and performance, yet. Out of the total of culled goats, 66.7% were slaughtered for family consumption and 23.8% were donated, while only 9.5% were sold for cash needs. Of culled sheep, 46.2% were used for family consumption, 44.2% were sold to local traders and the rest were donated. The average age at which an animal was sold slightly differed within and between the two species. Castrated male sheep were sold at an age of 34.7 ±11.64 months, while female sheep were sold at 16.0 ±8.48 months. In goats, castrated males and females were sold at the age of 8.5 ±0.50 and 16.0 ±8.00 months, respectively. The average live weight of sheep slaughtered or sold was 52.1 kg and 40.6 kg for castrated males and females according to the logistic model estimations. On the contrary, estimated culling weights of goats (Bertalanffy model) were much lower (27.7 and 31.6 kg for castrated males and for females). Sometimes animals younger than 6 months (9% in sheep and 23.8% in goats) were taken out of the herd by their owners and gifted to someone.

Offspring mortality was very low, with only 2.6% and 3.3% of all kids and lambs dying before weaning in the period covered by the interviews. The most frequently cited reasons for offspring mortality were cold weather, diarrhoea and loss on pasture. Adult mortalities were not calculated in this study due to lack of data. Owing to the nature of the survey, all breeding animals were still in their herds when the progeny history survey was conducted. Therefore no adult mortality could be calculated from our data but values from Begzsuren et al. (2004) and Mahul and Skees (2007) were used in order to run the PRY herd life model (see 4.2.2.2).

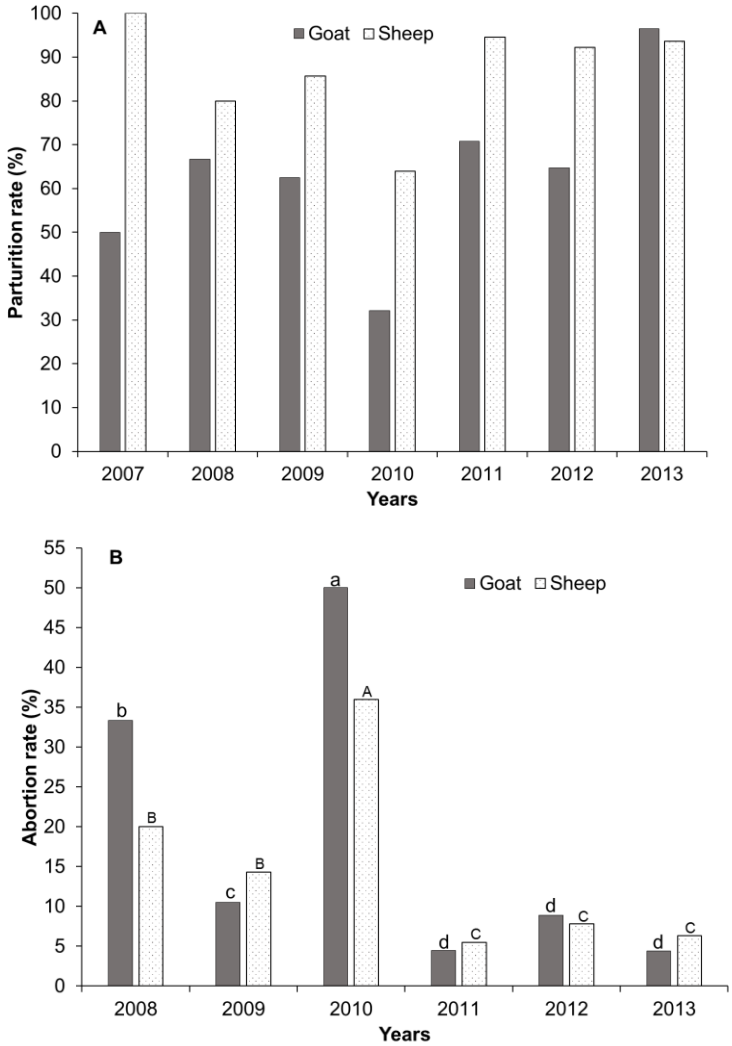

Figure 4.5. Annual parturition (A) and abortion (B) rates of small ruminants under transhumant livestock husbandry system in the Mongolian Altai Mountains. Superscript letters on the bars indicate significant differences in abortion rate between given years for sheep (capital letters) and goat (small letters). Please note that axes (x and y) in figures A and B are scaled differently.

4.3.7 Evaluation of present reproduction management and scenario analyses

An average herd of goats consisted of 57% breeding does, 19% surplus females and 24% surplus males according to the progeny history interviews and the baseline survey (Chapter 2), whereas the sheep herd comprised 68% breeding ewes and 32% surplus males but no surplus females. Under the present management (SQ), the annual herd expansion predicted by the PRY Herd Life model for a stable number of breeding females (Table 4.4) was considerably lower for sheep (0.1%) than for goats (17.2%), due to a lower culling rate and slightly higher parturition rate in the latter species which is raised for its cashmere in the first instance. Consequently, the long-term share of surplus females in the herd was estimated comparatively higher in goats (16%) than in sheep (0%), increasing the possible offtake rate in goats to 30% - a value much higher than reported by herders during the progeny history survey. On the contrary, the possible offtake rate computed by the model (27%) was lower than the rate reported by herders for their sheep population (32.1%). The predicted share of males in all culls varied from 53% for sheep and to 66% for goats, and was much higher than the share of culls of surplus females (0% and 30%, respectively). In comparison to the data obtained in the progeny history survey, the modelled values were slightly lower in sheep, but similar or slightly higher in goats. With regard to the economic performance of small ruminants under the present management, the annual revenue per sheep and goat was estimated at 23.79 € and 26.33 €, respectively, with >70% of the total output per sheep per year derived from culling of breeding females and surplus males. The total annual output per goat originated to 38.7% from sale of cashmere, 26.3% and 4.9% from culls of males and surplus females and 30.0% from culls of breeding females. These annual outputs can be referred to as revenue because there were no direct costs such as for supplementary feed. To accomplish this annual production and monetary revenue, each sheep and goat unit in the herd requires 833 kg and 636 kg of feed dry matter (DM) (Table 4.2), resulting in an output-input ratio of 0.03 € and 0.05 € per kg of feed DM.

With the alternative scenarios, the annual revenue and output-input ratio gradually increased when management changed. The annual herd expansion in scenario MC was estimated at 15.7% and 7.4% for sheep and goats, with a higher share of surplus females for sheep and a lower share for goats than in SQ. The total culls per year were 2-3% higher in both herds than in SQ. The annual monetary output per sheep increased by 15% under MC as compared to SQ, whereas it did not change for goats. The feed requirements to produce this output were somewhat lower for both species (715 and 548 kg DM per year per head) resulting in a 40% higher output-input ratio for sheep and a constant value for goats in comparison to SQ.

With scenario IF, herd expansion was estimated at 7.8% and 32% for sheep and goats, respectively. The sheep herd then consisted of 55% breeding ewes, 6% surplus females and 40% males, the goat herd of 52% breeding does, 23% surplus females and 25% males. The annual offtake rates of sheep and goats were 6% and 7% higher than those in SQ, particularly fuelled by a higher offtake of surplus females, while culls of males remained constant. Annual monetary outputs per sheep and goat unit were 33.69 € and 31.82 €, but the feed requirements were comparatively higher than the ones in SQ, due to supplementary winter feeding at a cost of 16.5 € and 12.8 € per sheep and goat. Subtracting feed costs from total annual monetary output resulted in a revenue of 17.2 € and 19.0 € per sheep and goat unit, respectively.

Table 4.4. Modelled results of PRY Herd Life for the local sheep and goat husbandry system in western Mongolia under present management (SQ) and for the scenarios of modified culling (MC), improved winter feeding (IF) and the combination MC+IF.

Output values	Units	SQ	MC	IF	MC+IF
Sheep					
Cull-for-age threshold, breeding females	months	112	112	112	112
Annual herd expansion	%	0.1	15.7	7.8	34.1
Breeding females (in herd)	%	68	55	54	43
Surplus females (in herd)	%	0	11	6	17
Males (in herd)	%	32	34	40	40
Total culls per year	%	27	30	36	37
Surplus females	%	0	20	9	28
Males	%	53	51	51	51
Annual revenue	€ $head^{-1}$	23.79	31.70	33.69	35.07
Required feed amount	kg DM $head^{-1}$ $year^{-1}$	740	715	626	606
Output-input ratio	€ kg^{-1} feed DM	0.03	0.04	0.06	0.06
Goats					
Cull-for-age threshold, breeding females	months	99	99	99	99
Annual herd expansion	%	17.2	7.4	32	24.1
Breeding females (in herd)	%	60	72	52	58
Surplus females (in herd)	%	16	7	23	17
Males (in herd)	%	24	22	25	26
Total culls per year	%	28	30	37	44
Surplus females	%	30	11	35	22
Males	%	66	55	60	52
Annual revenue	€ $head^{-1}$	26.33	26.45	31.82	32.56
Required feed amount	kg DM $head^{-1}$ $year^{-1}$	551	548	504	377
Output-input ratio	€ kg^{-1} feed DM	0.05	0.05	0.06	0.09

Scenario MC+IF yielded the highest values for annual herd expansion (34.1%), offtake rate (37%) and monetary output (35.07 €) in sheep and ranked second for these parameters in goats. Also, the share of breeding females in both herds was lower (43% for sheep, 58% for goats) than under SQ, indicating that overall herd composition consisted of young and productive individuals. With respect to offtake rate, the contribution of culled surplus females was highest among all scenarios. However, each year 606 kg and 377 kg of feed DM is required for per sheep and goat to reach the output, with one kg of feed DM yielding 0.06 € and 0.09 € of monetary output per animal unit. Costs of supplementary winter feeding amount to 14.9 € and 12.8 € to per sheep and goat, respectively, which decreases the annual revenue to 20.2 € and 19.7 € per animal unit and is only slightly higher (17% and 4%) than under scenario IF but considerably lower (25% and 15%) than under present management (SQ).

4.4 Discussion

4.4.1 Animal growth performance

The non-linear growth functions of Brody (1945), the logistic model (Reed and Pearl, 1927), the Gompertz curve (Winsor, 1932), von Bertalanffy's regression (1957) and the Richards model (Richards, 1959) have all been used to describe the growth of animals. Out of these five models, the logistic regression and Bertalanffy's model were frequently recommended for small ruminants as best non-linear growth models (Bilgin et al., 2004, Topal et al., 2004; Karakus et al., 2008; Hamouda and Atti, 2011; Dickhoefer et al., 2012). Also in the present case these two models showed higher correlation coefficients when fitted to actual live weight data than the other three models, whereas the Richards model showed a very poor correlation when applied to the sampled live weight data.

The average live weight of an adult non-pregnant female Mongolian native breed sheep in our sampled population was similar or slightly lower than weights reported for the same breed of sheep across Mongolia (Minjigdorj, 1996; Donrov et al., 1998). Consistently, the live weight of 7 months old lambs (30.3 kg) in our study was less than weights reported for the same age and breed (32.1 kg) from forest steppe and steppe regions of the country (Minjigdorj, 1996). For goats, the average live weight was slightly higher or similar to that of goats in the Mongolian Gobi desert (Nadmid, 2009). In our study, sheep reached a maximum live weight at 60-72 months and goats at 72-84 months of age, after which live weight by tendency declined in both species. By comparing the predicted values by nonlinear regression models to actual live weights of animals, the suitability of different models can be evaluated (Brown et al., 1976); in the present case all five non-linear models estimated a slightly higher average mature live weight for both species than the recorded average live weight. The asymptotic values (A) calculated by the Brody model were the highest compared to the other models, which was similar to previously reported comparisons (Brown et al., 1976; Dickhoefer et al., 2012). Yet, the asymptotic values from all five models were much lower than the measured maximum live weights in both sexes of both species. However, the estimations of the logistic (R^2=0.86 p≤0.05) and Bertalanffy (R^2=0.84 p≤0.05) models were the closest to the average live weights obtained from the actual sheep and goat weighing, and depicted the growth curves of sheep and goats better than the other models. The growth curve derived for goats by the Bertalanffy model showed a live weight increase until 4.5 years of age, after which it stabilized and then started to decrease, which was similar to the report of Nadmid (2009) from a literature review. The logistic growth curve, on the other hand, was very similar to other growth curves of sheep published in Mongolia (Chadraabal et al., 2011).

4.4.2 Reproductive performance

The reproductive performance of transhumant grazing animals in dry environments such as our study area is restricted by the genetic potential, the climate and the fluctuating nutritional situation (Bosman et al., 1997), as well as by herd management (Alexandre and Mandonnet, 2005). These challenges may render local breeds of small ruminants to low producers in terms of offspring (Degen, 2007), but as they are well adapted to the local environmental conditions and diseases, they perform better than exotic breeds.

In the study region, even though the earliest age at first parturition was reported to be 12 months, this was frequently viewed by the interviewed herders as too early and not desirable. Herders believed that early parturition has a negative impact on the animals' further performance such as survivability, productivity and grazing behaviour. This indirectly showed in reproduction management, since less than 10% of total surveyed ewes and does had their first parturition at 12 months of age. A relatively late age at first parturition (24 and 27 months) and long parturition interval (13 months) of ewes and does are quite common in Mongolia (Nadmid, 2009; Chadraabal et al., 2011; Mandakh et al., 2011). These authors reviewed reproductive parameters of almost all indigenous sheep and goat breeds in Mongolia, including the *Khalkh* types, and concluded that there were no significant differences between breeds as far as reproductive performance was concerned; differences existed however in production parameters such as dressing percentage, wool or cashmere yields and qualities. Nevertheless, values for fertility traits were slightly higher than in Chinese Hu sheep (Yue, 1996) and in Muzaffarnagari sheep under semi-intensive management in India (Mandal et al., 2007), as well as in traditionally managed goats in Oman (Dickhoefer et al., 2012). Similarly, in both species the litter sizes were much lower than those reported by these authors. It seems that the herders' seasonal breeding strategy and often insufficient feed supply to the sampled sheep and goats during winter time did contribute to lengthened parturition intervals and small litter size. The average abortion rate was 6% in a normal year but in the *dzud* year 2009/10 it increased to 35% and 47% for sheep and goats. For the same breed of sheep (0.6%) and goats (5.4%) lower abortion rates were reported from the forest steppe region of Mongolia (Ganbat et al., 2015), which might be explained by site differences in terms of forage availability and winter shelter conditions in the forested area. For the abortion rates, values were slightly higher for goats during 2008 to 2010, while after 2010 somewhat higher abortion rates were observed in sheep. At the same time, the parturition rate of goats recovered faster than that of sheep after the 2009/10 *dzud*. This seems to indicate that herders paid more attention to raising the cashmere goats rather than the sheep in order to secure their livelihoods as soon as possible after the 2009/10 *dzud*. As cashmere is a highly priced and regularly harvested commodity, this strategy allowed herders to quickly increase their herd sizes and simultaneously earn money.

The culling rate was higher in sheep than in goats, underlining the economic importance of cashmere fibre and sheep meat (live) sales for the families' cash income (Chapter 2). However, von Wehrden et al. (2015) pointed out that the goat population in Mongolia had increased independently from the global market of cashmere in the last decades. This might be explained by the fact that livestock mortality is very much dependent of adverse weather events, especially drought and *dzud*, to which goats are considered to be most susceptible (see below). These reasons for having many goats seem to be confirmed by the ratio of sheep to goats (1:3) at county level (NSOM, 2014).

Based on data collected for 33 years from 324 counties of Mongolia, the annual mortality rates for both species were estimated at 5% of total animals without *dzud* and drought impact (Mahul and Skees, 2007). The same authors also reported an annual mortality rate of 5% for adult sheep and goats in our study area (Bulgan County, Khovd Province). Begzsuren et al. (2004) estimated the annual mortality rate in a normal year at 4.8%, and increases to 12-20% in the event of drought or *dzud*. During the 2009/10 *dzud*, overall animal losses in Bulgan County amounted to 50% and 54% of total numbers of sheep and goats counted in the end of 2009 (Statistical Department of Khovd Province, 2013). This confirmed local herders' notion that goats are most sensitive to cold, harsh weather conditions (own informal conversation with herders), which is opposed to the notion of Saizen et al. (2010) that goats are less sensitive to winter disaster due to their browsing behaviour. This disagreement can be explained by a different availability of woody plants and shrubs on pasture, since Saizen et al. (2010) considered the whole territory of Mongolia where the share of woody plants and shrubs is higher than in our study area. Begzsuren et al. (2004) argued that the most important factor causing adult animal mortality is weather condition rather than shortage of forage; which is only partly true because in a "white *dzud"* such as in 2009/10 (Middleton et al., 2015), a thick snow layer is of course impeding the access to forage on rangelands.

4.4.3 Current and alternative herd management approaches

Previous studies (Dickhoefer et al., 2012; Riedel et al., 2014; Feldt, 2015) reported that the PRY Herd Life model is a suitable tool to assess, in a virtual or *ex-ante* manner, the reproductive and monetary performance of different livestock species under different management options. According to the outcome of the present modelling endeavour, scenario IF showed the highest herd expansion and offtake rates, which seemingly resulted in the highest revenues per animal and year for both small ruminant species, mainly due to increased animal numbers. Especially increasing goat numbers (scenario IF) yields higher (20.8%) revenues from cashmere sales, whereas in sheep this strategy increased the monetary output per animal by 14.8% in comparison to SQ, due to a higher meat output that is positively correlated to better winter feeding of breeding females and thus higher reproductive performance (Togtokhbayar et al., 2015). On the other hand, to produce this output, sheep and goats require 0.57 kg and 0.44 kg DM per day of supplement feed, which costs 16.5 € and 12.8 € for the 4 months supplementing period, respectively. Therefore the calculated annual net revenue per sheep and goat unit was lowest for scenario IF. In order to decrease the annual mortality rate to <5% as proposed in IF, an average herder with 22 sheep and 78 goats would have to spent 1365 € on supplementary winter feeding (Annex 4.2), which is 20.9% higher than his/her average cash income from annual livestock sales (see Chapter 2). Moreover, increasing the herd size may not be a suitable management option as the mountain-steppe pastureland is very vulnerable to high grazing pressure (Saizen et al., 2010; Khishigbayar et al., 2015), which would be an inevitable consequence of increased herd sizes. The IF strategy with its slightly shortened parturition intervals and lowered mortalities was suggested at herder's level by Batsaikhan et al. (2007), who also suggested that offspring should be sold or slaughtered at 8 - 9 months of age in order to limit herd size and avoid overgrazing. In reality, the strategy was not (widely) implemented, most probably due to the high feed costs and, in our study region as well as in many other remote rural areas, the lack of attractive marketing opportunities for live animals.

The MC scenario accounts for this set of problems and aims at limiting herd expansion while at the same time increasing the annual revenue by selling more surplus young as well as old-age breeding animals. In this case, the total economic output for goats was not improved because of the high contribution of cashmere for the revenue per animal. Since cashmere is a yearly harvested product and its yield increases linearly with the animals' body surface and thus age and weight, culling many adult goats is avoided by local herders. However, since the cashmere yield of Mongolian native goat breeds ranges between 250 and 500 g per year (Nadmid, 2009), the respective sales revenue per animal is only 7 € - 15 €, which is opposed to an increasing risk of production in case of herd expansion and enhanced land degradation (Addison and Brown, 2014). Inversely, culling sheep at 48-72 months of age rather than at earlier or later ages shows more economic benefit, resulting the highest annual revenue (33.7 €) from a single sheep only due to a slightly higher (9%) yearly offtake rate without any supplement feed cost. The MC strategy thus potentially increases the annual revenue per sheep unit by 24.9%, 45.7% and 36.3% in comparison to strategies SQ, IF and MC+IF, respectively. The MC strategy would contribute to solve problems of increasing grazing pressure (Saizen et al., 2010; Khishigbayar et al., 2015) and pasture degradation (Akiyama and Kawamura, 2007; Bat-Oyun et al., 2010; Shinoda and Nandintsetseg, 2011) and could have a positive long-term impact on sustainable pasture utilization. Even if the pasture is not degraded (Wesche and Retzer, 2005), this strategy is definitely helpful to ensure the livelihood of herder families in remote areas of the country, as it bears potential to better overcome periods of dzud given its timely and more rigid culling of surplus animals. Yet, market options need to be present or established in order to realistically implement this strategy.

5. Conclusions

The reproductive performance of Mongolian native sheep and goat breeds as assessed in the current study was low, yet the herds performed relatively well in view of the very harsh environmental conditions and the extensive transhumant livestock husbandry system. Even though the prevailing small ruminant management with its minimal inputs in animal health care and winter feeding seems profitable at present, it might reach its limits in the near future due to the restricted carrying capacity of the region’s pasture areas. In this situation, increasing livestock offtake will allow herders to increase their yearly economic benefit without compromising herd development or enhancing their ecological footprint on pasture resources. Therefore a modified culling strategy, in the present chapter termed scenario MC, is strongly recommendable to herders. Yet, for its successful and lasting implementation this strategy requires preconditions such as granted accessibility of regional markets, stable and attractive market opportunities for live animals, or alternatively slaughtering and meat processing facilities and other institutional support, such as timely information on live animal prices and feed prices. International marketing opportunities for Mongolian livestock and livestock products in high demand countries such as China, Russia, and Pakistan as well as in some other Asian countries also need to be tapped. This does however require a successful abatement of epidemic diseases such as foot-and-mouth disease through, for example, regular vaccination and clear culling strategies in case of disease outbreak as well as effective control of adherence to such regulations.

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Annex

Annex 4.1. Input parameters for the PRY Herd Life Model and their sources.

Parameters	Unit	Source for goats	Values	Source for sheep	Values
Mortality, male	% of population per year	Survey Begzsuren et al. (2004)	See results	Survey Begzsuren et al., (2004)	See results
Mortality, female	% of population per year	Survey	See results	Survey	See results
Culling rate	% of population per year	Survey	See results	Survey	See results
Age at first parturition	Months	Survey	27.43	Survey	See results
Parturition interval	Months	Survey	12.74	Survey	See results
Litter size	Number of lambs/kids per parturition	Survey	1.07	Survey	See results
Feed energy content	MJ ME per kg of feed DM	Togtokhbayar (2006)	9.0	Togtokhbayar (2006)	9.0
Energy efficiency lactation	Quotient	Drochner et al. (2003)	0.63	Drochner et al. (2003)	0.63
Energy efficiency gestation	Quotient		0.33		0.33
Litter weight gain from milk	kg for total litter	Luo et al. (2004)	3.0	Torres-Hernandez and Hohenboken (1980) Chiba (2009)	4.0
Milk energy content	MJ ME per kg milk	Drochner et al. (2003)	3.5	Chadraabal et al. (2011)	4.4
Metabolic exponent for live weight (LW)	Exponent		0.75	Drochner et al. (2003)	0.75
Price per kg LW gain	Euro (€)	Survey, model specification		Survey, model specification	
Energy intake per kg LW gain	MJ/kg		6.3-23.1[1]	Chiba (2009)	7.5-31.0[1]
Maintenance energy requirements	MJ ME per kg metabolic weight	Drochner et al., (2003)	0.45	Chiba (2009)	0.43
Energetic efficiency coefficient	quotient		0.43[2] 0.51[3]	Nie et al. (2015)	0.43[4] 0.50[5]
Fibre yield	kg/per year/animal	Yokhama et al. (2009) Mandakh et al. (2011)	0.30	Chadraabal et al. (2011)	1.50

[1] The lowest value for LW 3.0 kg, the highest value for 51 kg, intermediate values for LW classes in between 20 kg to 38 kg for goats. The lowest value for LW 4.2 kg, the highest value for 66 kg, intermediate values for LW classes in between 30 kg to 60 kg for sheep.
[2] For LW 3.0 kg. [3] For LW range of 12 kg to 51 kg for goats. [4] For LW range of 36 kg to 55 kg. [5] For LW range of 4.3 kg to 25 kg for sheep.

Annex 4.2. Feed requirements for small ruminants, pasture vegetation and hay grass quality and their prices as well as annual monetary outputs of small ruminants in the Mongolian Altai Mountains

Scenarios	Required DM feed (kg/an/year)	Average live weight (kg)	Summer grass		Winter grass		Supplement hay grass		Supplement feed			Annual output (€/an/year)
			ME (MJ/kg)	Price (€/kg)	ME (MJ/kg)	Price (€/kg)	ME (MJ/kg)	Price (€/ton)	ME (MJ/kg)	Price (€/ton)	Yearly feed cost (€/an)	
For sheep herd												
Status quo (SQ)	740	47.53	8	0	5.6	0	6.9	14	0	0	0	23.79
Modified culling (MC)	715	47.53	8	0	5.6	0	6.9	14	0	0	0	31.70
Improved feeding (IF)	626	46.80	8	0	5.6	0	6.9	14	9.6	120.3	16.5	33.69
Combination of MC & IF	606	46.80	8	0	5.6	0	6.9	14	9.6	120.3	14.9	35.07
For goat herd												
Status quo (SQ)	551	38.35	8	0	5.6	0	6.9	14	0	0	0	26.33
Modified culling (MC)	548	38.35	8	0	5.6	0	6.9	14	0	0	0	26.45
Improved feeding (IF)	504	36.95	8	0	5.6	0	6.9	14	9.6	120.3	12.9	31.82
Combination of MC & IF	377	36.95	8	0	5.6	0	6.9	14	9.6	120.3	12.8	32.56
Reference	PRY model	Logistic & Bertalanffy regression	Togtokhbayar (2006)		Togtokhbayar (2006)		Nergui et al. (2011)	Own calculation	http://www.altantaria.mn/			PRY model

DM = Dry matter, an = animal, ME = Metabolizable energy, MJ = Mega joule.

Chapter 5

General discussion, conclusions and recommendations

5 General discussion, conclusions and recommendations

The design of proper strategies to cope with environmental constraints and socio-economic challenges induced by political aspects in livestock husbandry requires accurate enough and applicable assessments of current management practices. To assess current livestock management in the study region, the pastoral livelihood strategies, pasture use practices and performances of small ruminants were determined and the obtained results allow us to contribute to the assessment of overall effects of policies and the economic development of the country on its livestock sector as a backbone of the livelihoods of a majority of people (Asian Development Bank, 2013; Sharma and Davaakhuu, 2015; Undargaa and McCarthy, 2016).

5.1 Effect of recent country's developments on rural livelihoods

The political and socio-economic changes mostly referred to as democratic revolution in Mongolia in the early 1990s have intensely affected the livelihoods of local people (Fernandez-Gimenez, 2006; Oyungerel, 2016). The most important effect of the democratic revolution was that every citizen gained the right to own private property (Janzen, 2005; Johnson et al., 2006), meaning that herders can own livestock as many as he/she can manage. Subsequently, the new political and economic situation forced or encouraged each citizen to do his/her own business, and the world and global economy was opened to all Mongolians equally, who until then had been isolated from the non-Soviet countries (Swift and Mearns, 1993; Lkhagvadorj et al., 2013b). After the hold on aids and credits from the Soviet Union, western developed countries and international donor organizations such as the World Bank, the Asian Development Bank and the International Monetary Fund became interested the country and started investments in the trading, servicing and mining sectors with both partnership to national government and to private companies (Bulag, 2010; Undargaa and McCarthy, 2016). Additionally, the opening of remote border posts connecting Mongolia with China and Russia since 1991 brought considerable possibilities to import a variety of goods into Mongolia, and, in the study region, lead to the creation of many small local shops where herders can buy their daily needs easily (termed as an asset in Chapter 2). Also, herders are now able to access up-to-date information through television and mobile internet to market their marketable livestock products in a smart manner. More recently, infrastructure development, especially completion of the road between Bulgan county and the province center (Khovd city), as well as between Bulgan county and the Chinese border allows easier transportation of goods to and from major market points and to other counties or provinces within Mongolia. Despite of all these developments, the contribution of the livestock sector to the national economy dropped from over 40% in 1980 (Upton, 2010) to 20% in 2014 (NSOM, 2014); at the same time the role of livestock for rural livelihoods of increased and the number of livestock keepers remained constant or even slightly increased (Ykhanbai et al., 2004; Addison and Brown, 2014). Particularly in remote areas such as in the Mongolian Altai Mountain region where general infrastructure and market development is weak, the subsistence of households still strongly depends on livestock. Despite the open border point that gives access to import common goods from China into Mongolia (Chapter 2), exporting agricultural products from Bulgan county through that border point into China is not possible due to the lack of legislative agreements between the Mongolian and Chinese government. For this reason the border point does not have a clear advantage with respect to livestock production. The per kilogram prices for livestock products such as mutton, beef, and crops (potato and carrots) in Khovd city (the nearest national market for people in our study area) were 7%, 14% and 41-75% cheaper than the prices in Ulaanbaatar (capital city), while the per kilogram prices for common food items such as flour, rice and sugar, as well as petrol (per litre) were 6-58 times and 18 times higher in Khovd than in Ulaanbaatar (Statistical Office of Khovd Province, 2012; NSOM, 2012; Lkhagvadorj et al., 2013a). These statistics indicate that remoteness from central markets or the capital city, along with poor infrastructure development increases the expenditure of local people and decreases the prices of locally produced goods (Ykhanbai et al., 2004; Maytsetseg and Riichiro, 2006). Lkhagvadorj et al. (2013b) also reported that herders in the Mongolian Altai Mountains (Dayan county, Bayan-Olgii province) rarely sold their livestock and hardly sold milk due to the remoteness of their area and the poor road system. This is exactly the case the present study area, where only 20% of the surveyed households sold live animals and none sold milk because of the low demand for livestock products (Chapter 2) and a lack of market access (Addison et al., 2012). The present developments passively force herders to stay nearby the county center because of the availability of social services such as schools, hospitals and markets (Lkhagvadorj et al., 2013a; Sugita et al., 2015). As concerns of herders, agricultural management and environmental perceptiveness are being neglected in the recent governmental policy, major problems such as overgrazing and land degradation result from the dependence on services (Sternberg, 2008; Sugita et al., 2015) and incapability of herders to fully secure their livelihoods through their herds. NSOM (2015) reported that only 10% and 37% of all herders (290,000) in the country are covered by a social insurance and health insurance, respectively, due to their remoteness and irregular and insufficient (monthly) income. This lack of social security was also lamented by Smith (2015) who argued that the current absence of human development policies or their very poor execution contributes to an increase in poverty in Mongolia, especially among the rural inhabitants.

5.2 Pasture regulation and animal feeding

The pasture land is government property, but the central government has authorized county and sub-county governors to regulate pasture utilization (Fernandez-Gimenez and Batbuyan, 2004). However, 40% of the interviewed herders stated that pasture regulation is still done by herders today. During the interviews, 69% and 64% of the respondents mentioned problems of pasture utilization such as availability of a water point at pasture and pasture quality, especially in winter, spring and summer season. Lack of water availability at pasture does not allow herders to use all available pasture efficiently; as herds concentrate on pastures that provide sufficient drinking water, their quality has declined in comparison to the previous two decades (discussed in Chapter 3). This is not only the case for western Mongolia but also for other regions in the country where limited water availability at the pasture concentrates livestock around watering points (streams, rivers and wells). The resulting pasture degradation seems to continue in the future since both herders and government have limited possibilities to build/rebuild wells and there is no clear identified policy to solve the problem of water scarcity at pasture (Bedunah and Schmidt, 2004; Ykhanbai et al., 2004; Sternberg, 2008; Sugita et al., 2015). The quality of the studied summer pasture vegetation covered small ruminants' requirements of maintenance and growth. However, this study was conducted only during the peak season of pasture vegetation growth, whereas for other seasons of the year no insights were gained. Earlier studies stated that pasture yield decreases by 48%, 65% and 77% of summer pasture values in autumn, winter and spring, respectively, while the CP concentration in pasture vegetation declines by 29%, 49% and 69% across Mongolian pastures (Togtokhbayar, 1995; Nergui et al., 2011).

Consequently, daily intake of small ruminants on winter pasture decreased up to 36% compared to peak season (Li et al., 2015) and provided only 37-59% of their feed requirements during the winter season under the traditional Mongolian livestock husbandry system (Nergui et al., 2011). Such a feed gap can hardly be filled with supplementary feed during the spring and winter seasons, especially not in the Altai region (Chapter 2) which is characterized by insufficient hay stocking and lack of cash to buy concentrate feeds (Togtokhbayar et al., 2015). As discussed in Chapter 2, only weak small ruminants receive a bit of hay grass at the homestead in winter, and feed intake of the rest of the herd fully relies on pasture vegetation. If in consequence small ruminants lose 20-34% of their live weight (Bynie, 2002), this may reduce their ability to survive crises (drought, dzud) and leads to livestock mortality and in consequence further loss of income sources and wealth (Middleton et al., 2014; Bertram-Huemmer and Kraehnert, 2015; Rao et al., 2015). The possible policy options to reduce livestock mortality and help the recovery of livelihoods by the Mongolian government and other donor organizations were reviewed in Chapter 1. Even though technical solutions to improve the nutritive value of locally available cheaper forages or crop residues and by-products are available (Togtokhbayar, 2006; Zhang and Shao, 2006; Togtokhbayar et al., 2015), their adaptation is low, mostly because of lack of information of herders about such options, and lack of knowledge on how to apply such technologies and feedstuffs (Ben Salem and Smith, 2008). An alternative option, namely an intensified culling of infertile females and surplus males and females has been discussed in Chapter 4. Even though this strategy reduces overall feed needs and thus leaves more feed for the remaining animals, there is currently no very large regional market to absorb these livestock products (as specified above).

5.3 Small ruminants' performances and possible management options

As a consequence of lack of feed in winter and spring when animals give birth, reproductive performances of ewes and does and possible cash income originating from a single sheep and goat per year are very low (Chapter 4) under the current extensive livestock management in the Mongolian Altai Mountains. Since output of a single animal is low, a large herd size is economically desirable in order to generate more income (Lkhagvadorj et al., 2013b); in view of pasture degradation and feed scarcity, this strategy makes livelihoods of herd owners environmentally more vulnerable. The increasing number of livestock (see Chapter 1) renders current livestock husbandry marginally profitable, especially if feed and feeding costs are not considered. However, income generated from livestock is for a majority of families insufficient to sustain the basic needs, because 88% of the interviewed household in this study and 57% of all herder households in the country herd less than 200 animals (NSOM, 2012). With this number of animals it is not possible to secure a life above the national poverty line (Nixson and Walters, 2006; Mongolian Government, 2013). Our scenario analysis in Chapter 4 showed that a slight change of the current management (higher offtake rate of goats and supplementary feeding pregnant ewes and does in winter and spring) has the potential to increase the output per ewe and doe, and to stabilize herd size and composition. This livestock production strategy can play a major role in the successful implementation of the above-mentioned sustainable herd and pastureland management strategies. Once better marketing options for live animals, or possibilities to regionally transform carcasses into saleable meat products are installed, the recommended management options will offer more possibilities for both rural poverty reduction and landscape conversation (Addison and Brown, 2014). In other words, intensified culling together with well-functioning markets can be an efficient means to buffer the consequences of harsh winters and natural hazards rather than post-shock help support (Turner and Williams, 2002).

5.4 Conclusions and recommendations

The social and economic development in Mongolia since the 1990s has changed the lives of rural communities from a true nomadic system to more sedentary lifestyles. However, the livestock herding practices still follow the traditional transhumant mode, fully relying on natural pasture. This renders both animal feeding and livelihoods of herders very vulnerable to the highly variable climatic conditions. Small ruminants, and especially goats, are the main important species securing economic viability of their owners' livelihood, and they are well adapted to the harsh continental climate and the present low input livestock husbandry system. It is likely that small ruminants will keep their vital role for the rural community in the future, since the weak local infrastructure and slow market developments currently do not allow many income diversification options. Since the profitability of a single animal is low, animal numbers tend to increase, whereas the herd management does not change. From a simplistic and somewhat superficial point of view the present developments, the economic setting and the current policy measures cannot be considered as suitable for a sustainable development of the livestock sector in Mongolia. The very traditional rural livestock husbandry system has not yet adapted to the changing socio-economic (and environmental) conditions, and strategies are mostly left to herders while the national government is not actively supporting the economic development of the livestock sector in remote rural areas.

Therefore, to improve the present livestock husbandry system and to implement an intensified culling strategy, the following recommendations are derived from this study for local herders and governors, national policy makers and other stakeholders related to livestock and pasture management:

1. Water points/supply at the pastures need to be improved through fixing old wells in order to reduce grazing pressure in certain areas (around water points) and spread grazing to so far little or ungrazed pastures.
2. Considerable attention should be paid to transfer traditional herding knowledge to the younger generation, especially on selecting daily grazing areas, skilful herding at pasture, and seasonal herding approaches.
3. Institutional and technological support need to be provided to herders to use more frequently and efficiently locally available biomass as supplementary feed (silages, mineral blocks, straws) beyond grass hay during the spring and winter seasons.
4. A better controlling system should be promoted by local administration officers with respect to the implementation of supply and acceptance of veterinary services by private companies. At the same time, the quality of these veterinary services and their performances must be improved and herders need to be encouraged to pay attention to animal health care.
5. Stable and attractive market opportunities for live animals and their products must be established through rural infrastructure development.

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