Opportunities and constraints of transhumant small ruminant production in the Chinese Altay Mountains

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Abbreviations

ADF	Acid detergent fibre
ADFI	Acid detergent fibre intake
ANOVA	Analysis of variance
BW	Body weight
$BW^{0.75}$	Metabolic weight
C	Carbon
C/N	Carbon nitrogen ratio
°C	Celsius
Ca	Calcium
Ca/P	Calcium phosphorus ratio
CATPCA	Categorical principal component analysis
CL	Commercial crop farming plus subsistence livestock keeping
cm	Centimeter
CP	Crude protein
CPI	Crude protein intake
Cv	Commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping
d	Day
DM	Dry matter
DMI	Dry matter intake
DOM	Digestible organic matter
E	East
exp	Exponential function
FM	Fresh matter
g	Gram
GIS	Geographic information system
GPS	Global positioning system
ha	Hectare
HH	Household
IC	Improved culling
IF	Improved feeding
kg	Kilogram
km	Kilometer

Lcv	Commercial livestock keeping plus subsistence crop farming and vegetable cultivation
LW	Live weight
ME	Metabolisable energy
MJ	Mega joule
N	Nitrogen
N	North
n.a.	Non applicable
n.s.	Non-significant
NDF	Neutral detergent fibre
NDFI	Neutral detergent fibre intake
NIRS	Near-infrared reflectance spectroscopy
OM	Organic matter
OMD	Organic matter digestibility
OMI	Organic matter intake
P	Phosphorus
PCA	Principal component analysis
QGIS	Quantum geographic information systems
R	A language and environment for statistical computing
R^2	Coefficient of determination
RMB	Renminbi (the currency of China)
SD	Standard deviation
SECV	Standard error of cross-validation
SEM	Standard error of mean
SQ	Status quo
SU	Sheep unit
UTM	Universal transverse mercator
¥	Chinese Yuan
€	Euro

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Summary

Population growth, urbanization and increasing incomes have resulted in a rapid increase in the demand for livestock products in China. An increasing demand for small ruminant products, especially meat, creates opportunities and challenges for livestock keepers in the remote pastoral regions of the country's northern and highland regions. Presently, many of these systems suffer from limited forage production on the natural rangelands, and from a progressive degradation of rangelands due to continued overgrazing. High climate variability or climate change effects are also threatening the biomass production on rangelands, further limiting feed availability and in consequence herd productivity. An insight into the current livelihoods of livestock keepers, their animal nutrition and herd and rangeland management strategies is therefore important for devising, together with the involved stakeholders, sustained improvement of rangeland and herd productivity and household income. These were the objectives of the present thesis, which analyzes the current livelihood strategies of different ethnic groups in a rural area situated at the border of the Chinese Altay Mountain region and the Dzungarian Basin. The study provides first insights into the grazing behavior and feed intake of small ruminants on seasonal pastures in this region, and into the quantitative and qualitative biomass offer on natural rangelands. It analyses the current reproductive performance and annual herd expansion of the local sheep and goat herds, and, by modelling improved feeding and culling strategies, tests alternative herd management options that potentially improve the monetary output per female herd animal without further compromising the natural resources.

Through structured interviews in 258 rural households distributed along an altitudinal gradient of 1100 to 2500 m a.s.l. across five locations in Qinghe County, Xingjian Uyghur Autonomous Region, the current socio-economic situation and agricultural practices of agro-pastoralists were characterized. Based on categorical principal component analysis and two-step clustering, three main livelihood strategies were identified, namely (i) commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping (Cv, 24.0%), (ii) commercial crop farming plus subsistence livestock keeping (CL, 39.5%) and (iii) commercial livestock keeping plus subsistence crop farming and vegetable cultivation (Lcv, 36.4%). The importance of the different agricultural activities differed between clusters, ethnic groups and study locations. The Kazakhs were mainly livestock keepers and focused on small ruminants rather than large herbivores; they adhered to a traditional way of livestock husbandry with regular movements between seasonal pastures. Cropping and vegetable gardening were dominated by sedentary Han Chinese and Hui people.

In order to determine the interaction between qualitative and quantitative biomass production on the seasonal pastures and the animals' grazing behavior, feed and nutrient intake as well as performance, the grazing behavior (2013) of five goats and five sheep, selected from a representative herd, was observed in June, July and August, and the amount of feces excreted daily was quantified (2013 and 2014) using fecal collection bags attached to the animals during periods of five days. Three of these animals per species were equipped with a GPS collar to measure daily track length and calculate the size of the grazed area (2013 and 2014). The amount and quality of herbaceous biomass along the animals' grazing itineraries was determined at the same time (2013 and 2014) by destructively sampling herbal mass in 0.25 m^2 frames placed every 500 m along the animals' daily itineraries. The collected samples of biomass and feces were analyzed for dry matter (DM), organic matter (OM), nitrogen (N), calcium (Ca), phosphorus (P) and carbon (C) concentration as well as for the concentrations of cell wall constituents (NDF, ADF) following standard protocols. Diet digestibility was derived from the fecal N concentration.

The grazing behavior of goats and sheep was strongly affected by the seasonal variation in amount and quality of the pasture biomass. Both goats and sheep covered longer distances in spring 2013 (goats: 13.9 ±0.56 km, sheep: 15.6 ±0.47 km) and spring 2014 (goats: 12 ±0.09 km, sheep: 13.6 ±0.08 km) than in summer 2013 (goats: 9.6 ±1.11 km, sheep: 8.2 ±1.21 km) and summer 2014 (goats: 7.5 ±1.20 km, sheep: 8.9 ±1.01 km). The size of the area visited for grazing was positively related to the distances covered daily. Precipitation was confirmed as a key variable for forage availability: while in 2013 the herbaceous biomass yield (biomass on average: 2320 ±384.8 kg^{-1} ha DM; rainfall: 188 mm) did not vary much between seasonal pastures, it decreased significantly in 2014 (biomass on average: 1106 ±708.2 kg^{-1} ha DM; rainfall: 133 mm). The nutritive value of the vegetation (2013: CP, ADF, Ca, P and Ca/P, $p \leq 0.05$; 2014: OM, NDF, ADF, Ca and Ca/P, $p \leq 0.05$; between the year: CP, NDF, ADF, Ca, C/N and Ca/P, $p \leq 0.05$) and the digestibility of the ingested diet (within and between year, $p \leq 0.05$) varied between the seasons and years, while the quantitative intake did not show significant differences (except for the seasonal differences in ADF intake in 2014 and NDF intake in spring 2013 and 2014; $p \leq 0.05$).

Growth and reproductive performance of grazing goats and sheep in the local transhumant grazing systems were quantified through extensive animal weighing and a progeny history survey conducted on 120 ewes and 73 does of 15 pastoral households. The data was analyzed using the PRY Life Herd Model to simulate herd expansion, test offtake rates and the effects of supplementary feeding, and estimate monetary gain from traditional and alternative goat and sheep husbandry.

The age at first parturition was 20.9 ±5.48 months for sheep and 18.6 ±7.41 months for goats. The parturition interval was 12.6 ±3.45 months and 13.4 ±4.67 months for sheep and goats, mainly due to the harsh winters with limited feed supply. The reported offspring mortality was low, with 1% of sheep and 5.4% of goats dying before weaning. The monetary revenue per animal was higher in sheep, for which an annual contribution margin of 50.6 € per sheep unit was calculated under present management, while for a goat unit only 43.7 € were obtained. The simulation of improved culling and / or feeding strategies indicated that, under the current economic situation, herders' actual flock management appears to be most profitable for sheep, whereas an improved culling strategy could be adopted to increase annual revenues from goat herds. These results thus call for a species-specific culling strategy of the two jointly herded species.

Taken together, the results of this thesis indicate that, despite an increase and intensification of cropping and vegetable gardening in the region of Qinghe, livestock rearing is still the major livelihood strategy both in terms of prevalence and relative importance. However, livestock keeping is challenged by low biomass production on rangelands, due to the combined impact of climate variability and climate change, and highly localized grazing pressure on the seasonal pastures. Though government regulations try to tackle the latter aspect, their implementation is sometimes difficult. Alternatives to strict regulation of grazing periods and animal numbers on seasonal pastures are, in the case of goats, more rigorous culling strategies and, in the case of sheep and goats, strategic supplementation of the animals in the winter and spring season. However, for the latter strategy to become economically viable, an improvement of live animal and meat marketing options and an investment in local meat processing facilities that add value to the carcasses is needed. As the regional cities, and especially the city of Urumqi, grow rapidly, the potential market to absorb diverse and good quality meat products is there, along with the road network connecting Qinghe County to the regional capital. Such governmental measures will not only create new job opportunities in the region but also benefit the cash income of pastoralists in this westernmost region of China.

Zusammenfassung

In der Volksrepublik China haben anhaltendes Bevölkerungswachstum, Verstädterung und gestiegene Durchschnittseinkommen in den letzten Jahren zu einer zunehmenden Nachfrage nach tierischen Erzeugnissen geführt. Dies betrifft selbst die entlegenen Hochlandregionen im Nordwesten des Landes, wo die Haltung kleiner Wiederkäuer, insbesondere mit Blick auf Fleischproduktion, zunehmende Bedeutung erfährt und so einerseits neue Möglichkeiten aber auch Herausforderungen für dort ansässige Tierhalter schafft. Viele dieser Systeme zeigen mittlerweile jedoch Anzeichen verringerter Produktivität sowie zunehmender Degradierung ihrer natürlichen Weidegebiete infolge anhaltender Überweidung. Schwer vorhersehbare klimatische Schwankungen als spürbare Folge des globalen Klimawandels wirken sich ebenso negativ auf die Biomasseproduktion der Weiden aus und führen zu einer weiteren Verringerung der Futterverfügbarkeit und damit der Herdenproduktivität. Unter diesen Umständen scheint es notwendig, mehr über die Lebensverhältnisse pastoraler Tierhalter in dieser Region, ihre Fütterungsstrategien sowie das Weide- und Herdenmanagement zu erfahren, um auf Grundlage dieser Erkenntnisse, und in Zusammenarbeit mit beteiligten Akteuren, einen nachhaltigen Beitrag zur Verbesserung der Weidequalität sowie der Herdenproduktivität zu leisten und damit zur Erhöhung des Einkommens pastoraler Haushalte beizutragen. Dies sind auch die Ziele der vorliegenden Studie, welche sich inhaltlich mit der Analyse der aktuellen Unterhaltsstrategien verschiedener Volksgruppen in einer ländlichen Grenzregion des chinesischen Altaimassivs und Dzungarischen Beckens befasst. Die Arbeit gibt dabei erste Einblicke in das Weideverhalten sowie die Futteraufnahme kleiner Wiederkäuer auf saisonalen Weiden innerhalb dieser Region und untersucht das qualitative und quantitative Biomasseangebot der natürlichen Weideflächen. Darüber hinaus werden die Reproduktionsleistung und die jährliche Expansionsrate lokaler Schaf- und Ziegenherden untersucht und, basierend auf der Modellierung verbesserter Fütterungs- und Keulungsstrategien, alternative Managementansätze getestet. Diese haben das Potential, den monetäre Gewinn pro Muttertier im Rahmen der natürlichen Ressourcenverfügbarkeit zu erhöhen.

Zunächst wurden in 258 agro-pastoralen Haushalten strukturierte Interviews durchgeführt; die Haushalte waren in fünf ländlichen Ortschaften entlang eines Höhengradienten von

1.000 m bis 2.500 m ü.N.N. innerhalb des Distrikts Qinghe (im Uigurischen Autonomen Gebiet Xinjiang) angesiedelt. Auf der Grundlage der gewonnenen Daten wurden diese Haushalte zunächst hinsichtlich ihrer sozioökonomischen Ausrichtung sowie ihrer landwirtschaftlichen Praktiken charakterisiert. Basierend auf der Durchführung kategorialer Hauptkomponenten- und zweistufiger Clusteranalysen wurden drei Unterhaltsstrategien unterschieden: (i) kommerzieller Ackerbau mit angeschlossener subsistenzorientierter Gemüseproduktion und Nutztierhaltung (Cv, 24,0%), (ii) kommerzieller Ackerbau mit angeschlossener subsistenzorientierter Nutztierhaltung (Cl, 39,5%) und (iii) kommerzielle Nutztierhaltung mit angeschlossenem subsistenzorientiertem Acker- und Gemüsebau (Lcv, 36,4%). Die Bedeutung der unterschiedlichen landwirtschaftlichen Aktivitäten variierte hierbei zwischen den Clustern, Ethnien und Untersuchungsstandorten. Mitglieder der kasachischen Volksgruppe sind zumeist Viehzüchter und vornehmlich auf die Haltung kleiner Wiederkäuer spezialisiert. Sie pflegen bis heute eine traditionelle Art der Tierhaltung mit regelmäßigen Wanderbewegungen der Herden zwischen ihren saisonalen Weidegründen. Getreide- und Gemüseanbau werden dagegen in erster Linie von sesshaften Han-Chinesen und Angehörigen der Hui betrieben.

Um Aussagen über die Wechselwirkungen zwischen der qualitativen und quantitativen Biomasseproduktion der saisonalen Weiden und dem Weideverhalten der Tiere, ihrer Futter- und Nährstoffaufnahme sowie ihrer Leistung treffen zu können, wurden jeweils von Juni bis August 2013 und 2014 monatlich fünf Ziegen und fünf Schafe aus repräsentativen Herden bei ihren täglichen Weidegängen beobachtet (nur 2013). Die von den Tieren ausgeschiedene Dungmenge wurde an fünf aufeinanderfolgenden Tagen unter Verwendung von Kotsammelbeuteln erfasst (2013 und 2014). Jeweils drei Tiere pro Tierart wurden darüber hinaus mit GPS-Halsbändern ausgestattet, um so die Länge ihrer täglichen zurückgelegten Wege messen und die Fläche der von ihnen genutzten Weidegebiete berechnen zu können (2013 und 2014). Parallel dazu wurde entlang der täglichen Weiderouten der Tiere die Menge und Qualität der pflanzlichen Biomasse erfasst (2013 und 2014). Hierzu wurde die Vegetation in 500 m-Abständen auf einer Beprobungsfläche von 0,25 m² vollständig geerntet. Sowohl die Vegetations- als auch die Kotproben wurden anhand von Standardverfahren auf Trockenmasse (TM), organische Substanz (OS) sowie auf ihren Gehalt an Stickstoff (N), Calcium (Ca), Phosphor (P), Kohlenstoff (C) und Zellwallbestandteile (NDF, ADF) untersucht. Die Verdaulichkeit des aufgenommenen Futters wurde aus dem Stickstoffgehalt im Kot ermittelt.

Die Ergebnisse dieser Untersuchung zeigen deutlich, dass das Weideverhalten beider Tierarten durch die jahreszeitlichen Schwankungen in Menge und Qualität der auf den Weiden verfügbaren Biomasse beeinflusst wird. Sowohl Ziegen als auch Schafe legten im Frühjahr (Juni) 2013 (Ziegen: 13,9 ±0,56 km, Schafe: 15,6 ±0,47 km) und im Frühjahr 2014 (Ziegen: 12,0 ±0,09 km, Schafe: 13,6 ±0,08 km) jeweils längere Weidestrecken zurück als im Sommer (Juli, August) 2013 (Ziegen: 9,6 ±1,11 km, Schafe: 8,2 ±1,21 km) und im Sommer 2014 (Ziegen: 7,5 ±1,20 km, Schafe: 8,9 ±1,01 km). Die Größe der von den Tieren aufgesuchten Weideflächen korrelierte dabei positiv mit den täglich zurückgelegten Distanzen. Die Futterverfügbarkeit auf den Weiden hing vornehmlich von der Niederschlagsmenge ab. Während 2013 zwischen den saisonalen Weiden nur geringe Unterschiede in der Menge des Biomasseertrages festzustellen waren (durchschnittliche Biomasse: 2320 ±384,8 kg^{-1} TM ha; Niederschlagsmenge: 188 mm), nahm dieser 2014 im Jahresverlauf signifikant ab (durchschnittliche Biomasse: 1106 ±708,2 kg^{-1} TM ha; Niederschlagsmenge: 133 mm). Sowohl der Nährwert der Weidevegetation (2013: N, ADF, Ca, P und Ca/P, $p \leq 0{,}05$; 2014: OS, NDF, ADF, Ca und Ca/P, $p \leq 0{,}05$; interannuelle Unterschiede: N, NDF, ADF, Ca, C/N und Ca/P, $p \leq 0{,}05$) als auch die Verdaulichkeit des aufgenommenen Futters (intra- und interannuelle Unterschiede: $p \leq 0{,}05$) unterschieden sich zwischen den Monaten und Jahren, während bei der quantitativen Futteraufnahme – mit Ausnahme saisonaler Unterschiede bei der Aufnahme von ADF im Gesamtzeitraum 2014 sowie von NDF im Frühjahr 2013 und im Frühjahr 2014 ($p \leq 0{,}05$) – keine signifikanten Unterschiede festgestellt werden konnten.

In einer dritten Teilstudie wurden schließlich Wachstums- und Reproduktionsparameter der Ziegen und Schafe des lokalen, transhumanten Weidesystems erfasst. Hierzu wurde das Gewicht von 120 weiblichen Schafen und 73 weiblichen Ziegen aus insgesamt 15 pastoralen Haushalten bestimmt und ihre Besitzer zur Quantifizierung reproduktiver Leistungsparameter dieser Tiere befragt. Die so erhobenen Daten wurden unter Verwendung des PRY-Herdenmodells analysiert. Auf diese Weise wurde die Wachstumsrate der Herden simuliert, verschiedene Keulungs- und Fütterungsszenarien modelliert sowie der monetäre Gewinn aus traditioneller und alternativem Management von Ziegen und Schafen verglichen.

Das ermittelte Erstlammalter betrug bei Schafen 20,9 ±5,48 Monate und bei Ziegen 18,6 ±7,41 Monate. Mit 12,6 ±3,45 Monaten bei Schafen und 13,4 ±4,67 Monaten bei Ziegen wiesen beide Tierarten lange Zwischenlammzeiten auf, was als Folge harter Winter sowie der in dieser Jahreszeit begrenzten Futterversorgung zu werten ist. Mit lediglich 1,0% bei Schafen und 5,4% bei Ziegen wurden von den Tierhaltern äußerst geringe Sterblichkeitsraten für Lämmer von der Geburt bis zum Absetzen angegeben. Der ermittelte Deckungsbeitrag pro Muttertier fiel bei Schafen höher aus als bei Ziegen. Für das derzeitige Management wurde für Schafe ein jährlicher pro-Kopf-Deckungsbetrag in Höhe von 50,60 € ermittelt, während dieser bei Ziegen lediglich 43,70 € betrug. Ein Vergleich mit der Simulation optimierter Keulungs- und/oder Fütterungsszenarien ergab, dass unter den derzeitigen ökonomischen Verhältnissen ein Beibehalten des gegenwärtigen Schafhaltungsmanagements am profitabelsten ist, während die Umsetzung einer erhöhten Entnahmerate bei Ziegen den Deckungsbeitrag pro Tier steigern würde. Diese Ergebnisse sprechen somit für eine artspezifische Entnahmerate für diese beiden in der Untersuchungsregion wichtigsten Nutztierarten, obwohl sie gemeinschaftlich geweidet werden.

Zusammenfassend lässt sich sagen, dass trotz der gestiegenen Bedeutung und Intensivierung von Ackerbau und Gemüseanbau in der Region Qinghe die Tierhaltung noch immer die bedeutendste Aktivität der ländlichen Bevölkerung ist, sowohl hinsichtlich ihrer Verbreitung als auch ihrer relativen Bedeutung für das Haushaltseinkommen. Allerdings ist die lokale Tierhaltung heute großen Herausforderungen ausgesetzt: einerseits dem Rückgang der Futterproduktion in den saisonalen Weidegebieten infolge des Einflusses von Klimavariabilität und –wandel, andererseits durch örtlich sehr hohen Beweidungsdruck. Obwohl durch staatliche Regulierungen versucht wird dem letztgenannten Aspekt entgegenzuwirken, erweist sich deren Umsetzung in der Praxis als schwierig. Eine konsequentere Entnahme von jungen männlichen und weiblichen Ziegen sowie von unfruchtbaren Muttertieren und eine verbesserte Futterversorgung für beide Tierarten, insbesondere im Verlauf des Winters und Frühjahrs, wären daher denkbare Ergänzungen zu den bisherigen strengen staatlichen Beschränkungen der Weidezeiten und Tierzahlen auf den saisonalen Weidegebiete. Allerdings bedarf eine erhöhte Entnahmerate zunächst verbesserter Vermarktungsmöglichkeiten sowie eine höhere Inwertsetzung sowohl der lebenden Tiere als auch ihres Fleisches und seiner Verarbeitung. Der Markt und die diesbezügliche Infrastruktur hierfür sind in der Region durchaus vorhanden, insbesondere in den stetig wachsenden städtischen Agglomerationsräumen und in der Provinzhauptstadt Urumqi. Entsprechende staatliche Maßnahmen würden somit nicht nur neue Arbeitsmöglichkeiten im strukturschwachen Nordwesten Chinas schaffen, sondern gleichzeitig auch einen wichtigen Beitrag zu den Einkommen der pastoralen Haushalte in dieser Region leisten.

List of publications:

Publications related to present study:

Greta Jordan, **Alimu Shabier**, Tsevegmed Munkhnasan, Sven Goenster, Andreas Buerkert and Eva Schlecht. 2016. Cross-border analysis of biomass availability and stocking densities on seasonal pastures in the Chinese-Mongolian Altay-Dzungarian region. In: *X International Rangeland Congress, Saskatoon, Saskatchewan, Canada, 16-22 July, 2016.*

Greta Jordan, Sven Goenster, Tsevegmed Munkhnasan, **Alimu Shabier**, Andreas Buerkert and Eva Schlecht. 2016. Spatio-temporal patterns of herbage availability and livestock movements: A cross-border analysis in the Chinese-Mongolian Altay. *Pastoralism*, 6(1): 1-17.

Alimu Shabier, Tsevegmed Munkhnasan and Eva Schlecht. 2015. Reproductive Performance of Small Ruminants in the Transhumant Grazing Systems of the Chinese - Mongolian Altay Mountains. In: *Tropentag 2015, September 16-18, Berlin, Germany. "Management of land use systems for enhanced food security - conflicts, controversies and resolutions". Available from:* http://www.tropentag.de/2015/abstracts/links/Schlecht_L1PncTpF.php.

Chapter 1 General introduction and research objectives

1.1. Importance of livestock keeping

Livestock keeping is critical for poor people in the developing world (Kruska et al., 2003; Randolph et al., 2007). The majority of the world's estimated 1.3 billion poor people living in developing countries directly or indirectly depend on livestock for their livelihoods (World Bank, 2008; FAO, 2009). In Asia, livestock owners account for 42-82% of the total rural households (Zezza et al., 2008). Globally, livestock contribute about 40% to the agricultural gross domestic product (GDP) and constitute about 30% of the agricultural GDP in the developing world (World Bank, 2009). It is thus obvious that the role of the livestock sector cannot be underestimated. Livestock play multiple roles in the livelihoods of people in developing communities (Kristjanson et al., 2007; Herrero et al., 2013); animals not only aid the lives and livelihoods of the world's most vulnerable and marginalized citizens directly (Heffernan, 2004), but also contribute to the world's food supply, family nutrition, incomes, employment, soil fertility, transport and sustainable agricultural development (Ashley et al., 1999; Thornton, 2002; Perry & Sones, 2007; Randolph et al., 2007). Especially in the arid areas of the world, livestock are often the only source of livelihood (World Resources Institute, 2005), and people's diets are predominantly based on animal products (Swiss Network for Livestock in Development, 2006). Thus, the overall contribution of livestock to household livelihood security is greater for poor households than for those who are comparatively betteroff (Heffernan, 2004).

Population growth, urbanization, and most importantly, increasing incomes have resulted in a rapid increase in demand for livestock products (Swanepoel et al., 2010; Thornton, 2010; Cao and Li, 2013). Moreover, the demand for livestock products is even predicted to rise by 50% from current levels by the year 2020 (Delgado et al., 1999). The growth of the livestock sector presents both enormous opportunities and challenges (Swanepoel et al., 2010). The rapidly changing needs and demands of both the poor and the expanding global population have been increasing the pressure on livestock development (Heffernan, 2004). The demand for livestock produce is met by even faster growing and industrialized animal production systems (Swiss Network for Livestock in Development, 2006). In the past, increases in livestock productivity in developing countries have largely been the result of increased livestock numbers (Heffernan, 2004). However, land availability limits the continued growth of livestock numbers (Steinfeld, 2003; Heffernan, 2004). Furthermore, in many countries, human population expansion is eroding large areas of rangeland, which were traditionally reserved for livestock grazing (Heffernan, 2004). The production increases will thus increasingly depend on greater productivity per animal (Heffernan, 2004; Garg, 2012), which means that livestock producers will have to adopt practices to enhance productivity. The livestock-keeping systems practiced by the poor have a lower productivity per animal or land unit than those in the industrialized countries (Randolph et al., 2007). There are many reasons for lower productivity of livestock (Lamy et al., 2012). Smallholder management systems are typically low or no-input, letting animals forage for themselves, feeding on plants or waste that otherwise would not be used (Randolph et al., 2007). However, there are opportunities for livestock keepers to increase their returns through improved management, increased productivity and better marketing of their livestock and livestock products (ILRI, 1998; Moyo & Swanepoel, 2010).

Therefore, a well-managed livestock system has the potential to improve the livelihood of households, and can enhance the ability of livestock to contribute to human well-being in the developing world (World Bank, 1997; Randolph et al., 2007; Tara, 2010). Development interventions may have a greater impact if there is a better understanding of the needs and requirements of livestock keepers as a target group (Heffernan, 2004; ILRI, 2007).

1.2. Ecological setting and population in north-western China

There are about 17 million herders and agro-pastoralists in China (Editorial Committee of Chinese Animal Husbandry Yearbook, 2009), grazing on 400 million ha of pastoral land; China is thus 2nd in the extent of rangeland resources worldwide (Hua & Squires, 2015). The pastoral lands are distributed in the drier and higher altitude regions of northern and north-western China. They cover approximately 40% of the country and are mostly inhabited by various ethnic minorities (Squires, 2009; Squires et al., 2010; Fan et al., 2014). It has been reported (Longworth & Williamson, 1993) that there are 266 pastoral or agro-pastoral counties in China, of which 120 are purely pastoral with 190 million ha of rangeland, mainly located in six provinces. Since 1960, China has suffered from serious land degradation (Ci & Yang, 2010; Zhou & Tan, 2011), which has progressed at a rate of 15% per decade until 2006 (Wang & Han, 2000). Land degradation is particularly obvious on the rangelands (Hua & Squires, 2015), leading to a decrease in rangeland resources (Heshmati & Squires, 2013) and deepening the rural poverty in ethnic minority areas (Nelson, 2006).

Xinjiang Uyghur Autonomous Region (XUAR) as one of the major pastoral regions in China (Banks, 1999; Chen et al., 2013; Buerjin et al., 2014), is located in the northwest of the country and covers an area of 1.6649 million km^2 (Liao et al., 2014a). Xinjiang is China's largest autonomous region and constitutes one-sixth of China's total land area (Banks, 1999; Chen et al., 2013). Xinjiang has a 5,600 km border with eight countries from northeast to southwest: Mongolia, Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, and India (Chen et al., 2013; Liao et al., 2014b). There are three mountain ranges (the Altay Mountains, the Tianshan Mountains and the Kunlun Mountains) and two desert basins (Dzungarian basin and Tarim basin) in Xinjiang (Banks, 2001; Li et al., 2011; Chen et al., 2013), and the whole area can be described as typical semi-arid to arid (Li, 1991; Li et al., 2011; Xu et al., 2013). The total population in Xinjiang is about 21.8 million (Xinjiang Statistics Bureau, 2012) and there are 40 ethnic minorities which account for 59.9% of the total population of XUAR (Chen et al., 2013). According to Banks (2001) there are about 1.2 million pastoralists in Xinjiang, especially concentrated in the northern part of the region and dominated by ethnic minority groups, particularly Kazakh. The province is known as the land of sheep, and the number of sheep in Xinjiang accounts for 23 percent of nation's total (130 million) sheep population (Simpson et al., 2003).

The study area, located in Altay Prefecture, is a border area in the north of XUAR, situated at the southern end of the Altay Mountains and north of the Dzungarian basin, adjacent to Russia, Mongolia, and Kazakhstan (Reynolds, 2001; Fu et al., 2015). The area of Altay Prefecture covers 118,000 km^2 and the population is 668,900 (Xinjiang Statistics Bureau, 2012). Located in the central part of mainland Asia, it lies in the semi-arid and arid climatic belt of the Temperate Climate Zone (Li et al., 2011). The mean annual temperature is 1.1°C and the annual sum of precipitation is 362.8 mm, 73% of which falls during the growing season from April to September (Chen et al., 2012). In the mountains, however, annual precipitation ranges from 400–600 mm (Fu et al., 2015). The winter is long and cold, and the summer is short and moderate in temperature. The area of pastoral land in Altay Prefecture is more than 9.8 million ha (81% of total land area) and more than half of the population is engaged in livestock production. Dominated by transhumant pastoral systems, animal husbandry contributed about 60% of the value of the prefecture's agricultural production at the beginning of the present millennium (Reynolds, 2001). The main livestock species are cattle, sheep, goats, horses and camels, with sheep and cattle being the most important. The total number of livestock in 2012 was 2,733,700 and the proportion of sheep was 61%, cattle 20% and goats 14% (Xinjiang Statistics Bureau, 2012). Despite a rapid increase in the Han population since 1949, Kazakhs still account for some 52% of Altay's total population (Xinjiang Statistics Bureau, 2012). Pastoralism is still an important source of livelihood in Altay Prefecture, where most Kazakh herders follow a transhumant way of life and the annual transhumance route of 180 to 200 km reaches from the desert plains to the high mountain summer pastures (Reynolds, 2001).

Qinghe County is located in the eastern part of Altay Prefecture, at the northeast edge of the Dzungarian basin. The distances from Urumqi (capital city of XUAR) and Altay (capital of Altay Prefecture) are 530 km and 320 km. Along its eastern and northern side the county borders Mongolia for a 280 km distance. The county's topography includes mountains, hills, plains and part of the Gobi desert, and elevation ranges from 900 to 3659 m a.s.l. (Wang et al., 2015). There are seven administrative townships covering 52 villages, and the total population reported in 2011 was 64,273, with Kazakh (76.5%) and Han Chinese (18.6%) accounting for 95% of the total population (Xinjiang Statistics Bureau, 2012). Qinghe County is situated in the metalorganic strip of the well-known Altay Mountains with rich mineral resources. There are proven reserves of gold, copper, chrome, iron, nickel, beryl, mica and coal (Zhaojin Mining Industry Company Limited, 2010). The economic development in Qinghe has been quite rapid in recent years, for example, in 2013 the GDP (1.3 billion RMB), annual revenue (0.3 billion RMB), investment (2.7 billion RMB), local fixed assets (2.8 billion RMB) and industrial added value (0.2 billion RMB) had increased by 18.9%, 102.5%, 32.9%, 38.7% and 78.9% compared to 2012, respectively. Also, the per capita net income for farmers and herders was reported to have increased by 1100 RMB (total 6221 RMB) compared to 2012. Despite this rapid development in socio-economic terms, similar to the other pastoral regions in China (Editorial Committee of Chinese Animal Husbandry Yearbook, 2009), in Xinjiang (Banks, 2001) and Altay (Reynolds, 2001) the rangelands still play an important role in the livelihoods of pastoralists. The latter represent more than one third (22,378) of the total (64,273) or more than half of the rural (39,253) population (Xinjiang Statistics Bureau, 2012).

1.3. Causes of regional rangeland degradation

Despite their importance, China's rangelands are degrading seriously, and the country's rangeland managers face many challenges (Miller, 2002). The livestock sector has been developed rapidly in China and the total meat production quadrupled over the last two decades, but this development caused prominent environmental problems that have similarities with other rapidly growing economies (FAO, 2016).

There are both environmental and anthropological reasons for rangeland degradation. The environmental factors include climate change (Chen et al., 2013), desertification (State Forestry Administration, 2011) and plagues of insects and rodents (Hua & Squires, 2015). For example, the effects of climate change felt in the region are significant and reported to be more severe than at the national and global level (Chen et al., 2013). According to Cao and Ge (2009), the average rate of temperature increase from 1955 to 2000 was 0.13°C per decade in southern and 0.36°C per decade in northern Xinjiang. In terms of desertification, Xinjiang is the most desertified region in China, with an estimated 1.07 million km^2 of land affected in 2009, which accounts for 64.3% of Xinjiang's total surface and for 40.8% of the total desertified area in China (State Forestry Administration, 2011). It has been reported (Li, 2010) that 92% of the cities and counties, 68.6% of farmers, and 12 million people in Xinjiang are suffering from the effects of desertification. This is mainly caused by wind and water erosion, physical, chemical and biological processes of soil degradation, economic activities, as well as climate change (FAO, 1997). The anthropological factors include overgrazing (MOA, 2013), unreasonable development, industrial pollution, and illegal collection of plants (Hua & Squires, 2015). The rapid increase in population over the past two decades is further putting pressure on Xinjiang's limited natural resources (Scull, 2008). In 2009, the population reached 21.5863 million, which was nearly four times the population of XUAR in 1949 (Chen et al., 2013). The current intense mining activities are also damaging the grasslands in Xinjiang: according to Zhou and Yang (2004) 90,734 ha of land have damaged by mining activities, (this also includes farmland, woodland, as well as rangeland). Especially gold mining can cause extreme damage on rangelands - the desert shrubs in the Dzungarian basin have decreased by about 68.4% due to mining over the past 50 years (Chen, 2014). Reclamation of (degraded) land for farming purposes is another reason leading to rangeland degradation; the area of farmland in Xinjiang was about 1.21 million ha in 1949 and has increased by a factor 2.41 to about 4.12 million ha by the year 2010 (Wang & Shen, 2011; Xinjiang Statistics Bureau, 2011). Most of this farmland expansion took place on (cultivated) grasslands and in wetlands (Chen et al., 2013). During 1996 to 2007, due to land reclamation and construction requisition, about 100 million ha of natural grasslands were lost (Wang & Yang, 2010). Through such developments, the area of natural rangeland in Xinjiang decreased from 57.3 million ha in 1980 to 48.1 million ha in 1999 (Wu et al., 2005). By 2007, the area of deteriorated rangeland had expanded by more than 10 times (45.8 million ha) compared to 1980, and the pace of degradation had increased 15 times (Dong & Li, 2009). As a consequence, the quantity and quality of rangeland vegetation affected the region-wide forage production, whereby the dry grass yield decreased by 11.91 million tons within five (2004-2008) years (Zhang, 2010). At the same time, the number of livestock in Xinjiang increased to 57 million head, which exceeded the theoretical carrying capacity of the rangelands by two thirds as compared to 1949 (Huang, 2010). The average rate of overstocking on rangelands across China is about 34%, but in some areas of Xinjiang it is up to 70% (Han et al., 2008; Jin & Zhu, 2009). According to Buerjin et al. (2014), livestock numbers in Xinjiang have almost tripled since the middle of the last century, whereas pasture areas were reduced by about 10.7% and high quality herbage production decreased by 30% - 70% since 1980. Other statistics also showed that natural grasslands in Xinjiang are being degraded at an annual rate of 0.5% (Wang & Yang, 2010). At present, 85% of Xinjiang's natural grasslands are suffering from desertification and salinization, while 37.5% of them are already severely degraded (Wang & Yang, 2010).

The intensification of animal husbandry, responding to an increased demand for animal products throughout China, has accelerated this development; the livestock sector today accounts for 27% of the agricultural output value in Xinjiang (The Information Office of the State Council, 2009). The meat output had reached 1.8 million tons in 2008 and had thus increased by about 95% compared to 2000 (The Information Office of the State Council, 2009).

In supporting the grazing-based regional livestock industry, the rangelands in Xinjiang play a very important role for the local economy and are considered as a key component in providing herders' income (Hua & Squires, 2015). Most rangeland areas in Xinjiang are home to semi-nomadic people from ethnic minorities (Hua & Squires, 2015) and are thus an important source of livelihood for herders (Suttie, 2003). But the above-described declining availability and quality of livestock feed restricts the ability of resource-poor farmers to increase their livestock production (Devendra & Sevilla, 2002; Liu et al., 2012). Yet, since livestock are the most important source of income for (agro-) pastoral livelihoods (Martin et al., 2014), herders are reluctant to reduce their animal numbers to maintain or improve rangeland production and quality even though they would benefit in the longer run (Simpson et al., 2003). High livestock numbers that are not paralleled by an establishment of viable feed sources (or changing herd and rangeland management) can increase feed deficits, reliance on external feed markets (Brown & Waldron, 2013; Komarek et al., 2012) and ultimately resource degradation.

1.4. Study objectives and structure

The regional and local governments have taken various measures to solve the problem of rangeland degradation, such as trying to balance annual biomass production of rangelands and animal numbers, permanently settling nomadic people and reducing stocking rates (Hou et al., 2004; Peng, 2005) as well as fencing (Chai et al., 2010). Still, how to face the challenge of environmental deterioration and resource scarcity and allow for sustainable economic development is a main concern of Chinese policy makers and stakeholders (FAO, 2016).

Against this background and the illustrated constraints, the present study analyses the traditional transhumant grazing system of Kazakh herders, who, for centuries, have moved with their livestock from winter pastures in low altitude desert areas to high altitude summer pastures in the Altay Mountains. Departing from an assessment of the current socio-economic status and livelihood strategies of herder families in Qinghe county (Figure 1.1), in particular their pasture management and livestock grazing practices (Chapter 2), a more in-depth analysis of seasonal pasture management and the interdependency of pasture vegetation (quantity and quality) and livestock (small ruminants) grazing behavior as well as intake was undertaken (Chapter 3). In addition, the current performance of small ruminants, especially in terms of live weight gain and reproduction, was analyzed and compared to possible alternative herd management strategies (scenarios; Chapter 4).

The study was motivated by the following research objectives:

- Understanding herders' current livelihood strategies,
- Capture the seasonal variability of forage availability and quality and its impact on small ruminant grazing behavior and feed intake,
- Assess the present reproductive performance of small ruminants against possible improvement strategies.

A better understanding of the currently practiced livestock husbandry system, its constraints and flexibilities should contribute to the development of sustainable livestock and rangeland management strategies for the transhumant grazing system in China's Altay-Dzungarian region.

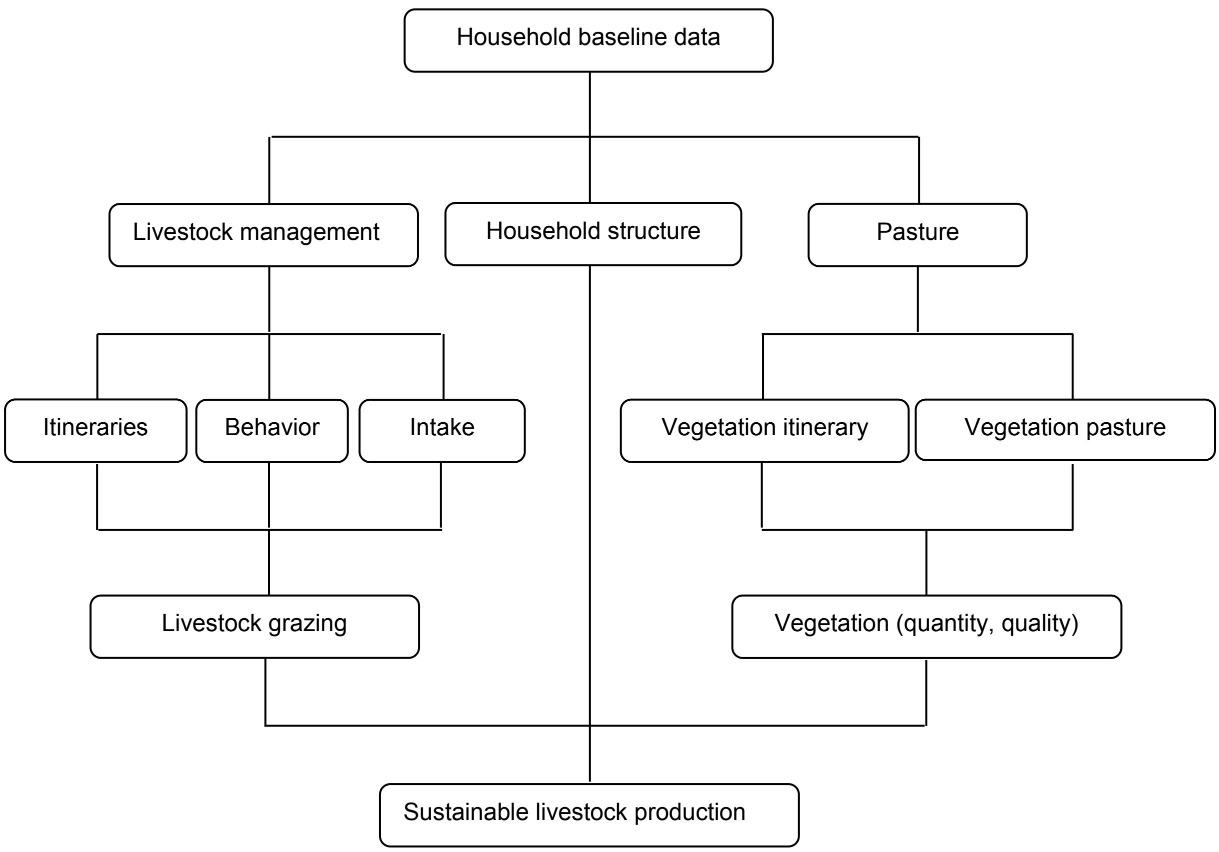

Figure 1.1. Methodological approach of the study.

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Chapter 2 Rural livelihood strategies in the Altay-Dzungarian region of Xinjiang province, China

Summary: Grassland degradation and low incomes have long been major problems in remote pastoral regions of China. Low incomes force pastoral households to increase livestock numbers, leading to grassland degradation and fuelling a downwards spiral of marginal agricultural production and low income generation. Pastoralism and agro-pastoralism are still important forms of livelihood in the Chinese Altay-Dzungarian region. In Qinghe County of Xinjiang Province where the present study was conducted, farmers tend to intensify their livestock production systems and also engage in crop farming and vegetable gardening. Through structured interviews in 258 rural households distributed across five locations near Qinghe, the current socio-economic situation and agricultural practices of agro-pastoralists were characterized. Based on categorical principal component analysis and two-step clustering, three main livelihood strategies were identified, namely (i) commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping (Cv, 24.0%), (ii) commercial crop farming plus subsistence livestock keeping (CL, 39.5%) and (iii) commercial livestock keeping plus subsistence crop farming and vegetable cultivation (Lcv, 36.4%). The importance of each livelihood strategy differed between clusters and study locations. The Kazakhs were mainly livestock keepers and, in terms of livestock species, these households kept more small ruminants than large animals, enabling a traditional way of life with easy movements between seasonal pastures. Cultivation of both cash crops and vegetable gardening was dominated by sedentary Han Chinese and Hui people. However, there are other socio-economic and ecological drivers that influence the current livelihood diversification, which are further elaborated in the following.

2.1. Introduction

According to Bruinsma (2003), livestock production contributes 40% of agricultural gross production globally and more than 50% in industrial countries. In many developing countries, crop farming households have adopted livestock production as part of a diversification strategy to increase household incomes (Abdulai & CroleRees, 2001; Block & Webb, 2001; Ellis, 1998). According to FAO (2009), around 987 million poor people in the world are depending on livestock for their livelihoods. This number increased to one billion in 2014 (Eisler & Lee, 2014), equivalent to 71% of the world's 1.4 billon "extreme poor". Martin (2004) described livestock keeping as one of the main livelihood options for landless or very small-scale farmers, as well as women, who, in the beginning of this millennium, represented 70% of the world's poor (DFID, 2000). The livestock sector is rapidly growing in developing countries due to a rising demand for livestock products driven by population growth, urbanization, and most importantly, increasing incomes (Delgadao et al., 1999); there are thus in principle ample opportunities for the sector's development and fruitful involvement of poor people. Given China's longstanding commitment to reducing rural poverty, increasing rural people's incomes is a fundamental goal for Chinese policy makers (Park et al., 2002).

Animal production is a major component of the agricultural economy in Asia. Livestock provide income and increased economic stability, and animals are often the most important source of income in small-scale mixed farming systems. In China, the demand for livestock products has increased rapidly over the past decades, driven primarily by rising incomes and rapidly increasing urbanization of the population, accompanied by a change of dietary habits (Hansen & Gale, 2014). A report by NSB (2007) states that the annual output of the livestock sector grew more rapidly (8.9%) since 1990 than the country's gross agricultural output value (GAOV; 6.2%). Thus livestock's share in the GAOV increased from almost 26% in 1990 to 32% in 2006 (NSB, 2007). According to Tian (2007), the output of livestock products in China increased massively between 1996 and 2006 (beef 111%, mutton 160%, poultry 81%, eggs 68%, pork 65%, and milk 650%).

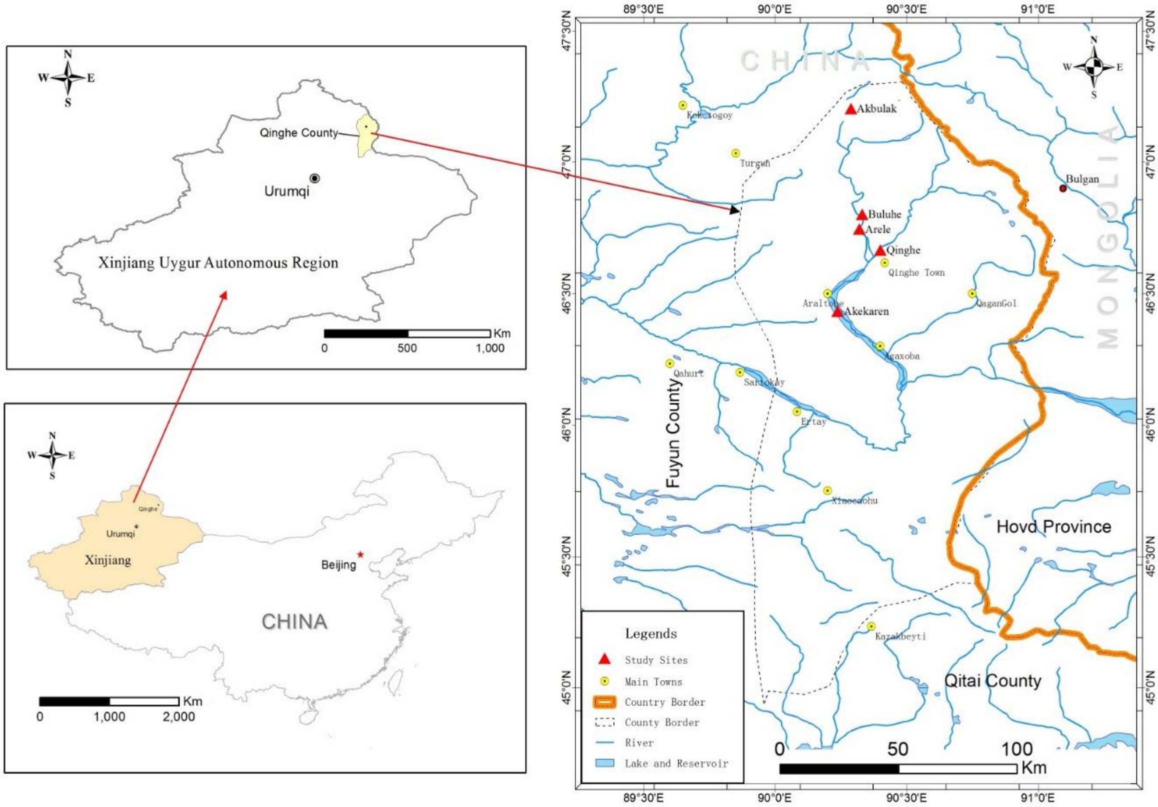
In the semiarid and arid grasslands of Inner Asia, long distance migration of livestock herds is the traditional, ecologic and economic livelihood strategy of pastoralists who have to cope with high variability of climate (especially precipitation and temperature) and as a consequence, plant biomass production on natural pastures (Fernandez-Gimenez & Le Febre, 2006; Conte, 2013, 2015). Despite government support of commercial pastoralism, most herders continue to use rangeland resources in ways that resemble their traditional lifestyles and economies (Hu & Zhang, 2003), especially in the marginal areas of Inner Mongolia and along the border regions of China in the north-western province of Xinjiang. Altay Prefecture in Xinjiang province is bounded in the north by high mountains and cut off from southern Xinjiang by a large expanse of desert and semi-desert (Reynolds, 2006); most people in this region belong to the ethnic groups of Kazakhs, Mongols, and Uyghurs. The remote rangelands within these areas are utilized by transhumant agro-pastoralists who depend on herding for their livelihood; they contribute nearly 60% of the value of agricultural production in the region (Reynolds, 2006). Livestock production is often just one part of a wider portfolio of these households' activities and mainly delivers non-marketed products such as meat and milk for home consumption, manure for household subsistence cropping, vegetable production and fuel, and animal labour for field work and transport, as well as intangible benefits including household financing, security, and status (Moll et al., 2007; FAO, 2009; Pica-Ciamarra et al., 2011).The livestock operation is totally based on grazing of natural pastures and only to a very limited extent makes use of non-marketed inputs (mainly crop residues used as feeds). Since the productivity of local pastures is said to have been gradually declining for about 10-15 years (Banks, 1997; Hu & Zhang, 2003; Brown et al., 2008; Williams, 2010; Zheng & Yin, 2010), this study departed from the hypothesis that households' exclusive reliance on livestock is too risky, whereas diversified farming activities will provide more income security and thus also more options to households. To test this hypothesis, structured interviews were conducted in order to (i) characterise the current socio-economic status of agro-pastoral households in the Altay-Dzungarian region of Xinjiang, (ii) analyse their cropping and livestock activities, and (iii) assess the relative importance of the various activities for household income.

2.2. Materials and methods

2.2.1. Research area

Five study sites (Akekaren, Qinghe, Arele, Buluhe, and Akbulak) were selected along a decreasing temperature gradient from lowland winter pasture to high altitude summer pasture alongside the Qinghe River (Figure 2.1) within Qinghe County of Altay Prefecture in Xinjiang Uyghur Autonomous Region, People's Republic of China. Agro-pastoralism is the predominant form of land use; the purely pastoral population constitutes 22% of the County's total population, and rangeland accounts for 82% of the total area of Altay Prefecture (Xinjiang Statistics Bureau, 2013).

Qinghe County (46°43' N, 90°24' E, 900 - 3659 m a.s.l) is located at the south-eastern range of the Altay Mountains, bordering Mongolia in the east and northeast. It is situated in the semi-arid and arid climatic belt of the Temperate Climate Zone characterized by long and cold winters, dry and hot summers, low precipitation (rainfall and snow) and high temperature fluctuations (Batima et al., 2005; Fu et al., 2015). The average minimum temperature for January is -26°C and the average maximum for July is 30°C. Precipitation, which mainly falls as snow, ranges from less than 100 mm per annum on the plains to more than 600 mm per annum on the high altitude pastures, where strong winds, snowfall, and spells of extreme cold, with temperature extremes below -40°C, are encountered (Reynolds, 2006). The county contains seven towns and is inhabited by 16 ethnic groups with a total population of 61,443 and a minority population of 49,941 (ADB, 2010). The county is renowned as a cradle of wheat and the production of corn is also quite substantial in the region. Both crops are irrigated throughout their growth period with water from the Qinghe River and its tributaries. The local livestock herds are comprised of cattle, sheep, goats, horses, and camels (ADB, 2010).



No	Locations	Coordinates (N, E)	Altitude (m)	Description
1	Akekaren	46°25'53.74", 090°14'20.10"	1131	Winter home base
2	Qinghe	46°39'53.60", 090°24'05.35"	1223	County center
3	Arele	46°44'39.60", 090°19'14.00"	1283	Agricultural village (township center)
4	Buluhe	46°48'01.83", 090°19'55.38"	1374	Agro-pastoral village
5	Akbulak	47°12'23.62", 090°14'58.20"	2418	Summer pasture

Figure 2.1 Map of study locations (above) and main characteristics of the five study locations (below) in Qinghe County, Altay-Dzungarian Basin, China, as in 2012.

2.2.2. Data collection

All households encountered within a 5 km radius of each location were selected for the present study. Pre-tested structured interviews were conducted with 258 households from the five locations in the summer of 2012. After introducing the purpose of the study and asking for the interviewees' consent, the coordinates of the households were recorded with a hand-held GPS (HOLUX M-241 wireless GPS logger, HOLUX Technology Inc., Hsinchu, Taiwan; accuracy ±3 m). Subsequently questions were asked to the household head regarding household characteristics (ethnicity, sex and age of family members, educational background, and employment status of adults), household assets (transportation assets such as car, motorcycle, bicycle, and cart; other equipment such as radio, television, kerosene cooker, electric or gas cooker, heater, solar panel, water pump, and sewing machine; agricultural machinery such as tractor, plough, seeder, and grass mower), agricultural surface area, crop and vegetable cultivation, crop management (fertilisation, pesticide use), livestock ownership, herd size, livestock species, age and sex composition, herding activities, use of livestock products (family consumption, marketing), and cash revenues from live animal sales. The number of livestock owned were converted to sheep units (SU)[1] (Hu & Zhang, 2006). The questions were asked in Kazakh language with the help of a Kazakh master student, otherwise in Chinese or Uyghur. All answers were translated into English.

2.2.3. Statistical analysis

After the removal of incomplete household data sets, a categorical principal component analysis (CATPCA) was employed, followed by a two-step cluster analysis (Dossa et al., 2011). Blasius and Greenacre (2006) described the CATPCA as a multivariate technique that is intermediate between standard (linear) PCA and nonlinear multiple correspondence analysis. One main advantage of CATPCA is that this tool, in contrast to linear PCA, can handle variables of different data scales (nominal, ordinal, and numerical) simultaneously (Sodede & Vrooman, 2008). The CATPCA approach was used to reduce the initial set of 22 variables considered relevant for household characterisation (Table 2.1) to a smaller set of variables that held the most relevant information among the initial variables. Variables with component loading values higher than 0.5 (Appendix 2.1) in either of the two principal dimensions (Appendix 2.2) were selected and correlated variables were excluded. The cluster goodness was evaluated based on the silhouette measure of cohesion and separation (≥0.6) following Rousseeuw (1987), Jain and Koronios (2008), and Dossa et al. (2011). The variables used for the final two-step cluster analysis were livestock keeping (yes/no), cropping activities (yes/no), vegetable

[1] A Sheep Unit (SU) is defined as a ewe of 40-kg live weight and its nursing lamb(s) with a daily forage consumption of 5 to 7.5 kg of dry matter. The conversion factors of other grazing species into SU are given in Appendix 2.3.

gardening (yes/no), total number of livestock (sheep units) and revenues from livestock sales (Euro).

Prior to comparative statistical analysis the residuals of continuous variables were checked for normal distribution using the Kolmogorov-Smirnov test. As all variables were found to be non-normal distributed, differences between clusters were explored using non-parametric tests depending on the data structure (Chi-square test for categorical variables; Mann-Whitney-U or Kruskal–Wallis test for continuous variables). All data were analysed with SPSS for Windows, Version 20 (IBM Corporation, 2011). Significance was declared at $p \leq 0.05$. The standard deviation (SD) was used to express variability. All monetary values were calculated in Euro based on the World Bank exchange rate between Chinese Renminbi (RMB) to Euro for the years 2007 and 2013, depending on the context.

Table 2.1 Naming, coding and description of variables used in the Categorical Principal Component Analysis.

Variable name	Description of variable and coding
ETHNICITY	Ethnic group (Kazakh=1, Han Chinese=2, Mongolian=3, Hui=4, Uyghur=5)
AGE	Age of household head (in years)
SEX	Gender of interviewed person (male=1, female=2)
HOUSING	House type (tent/yurt/ger=1, house=2, both=3, other=4)
HHSIZE	Number of family members permanently living in the household
ADULTS	Number of adults in the household
ADULT_EMP	Number of adults in the household employed in a formal job
EDU	Educational level of household head (none=1, attended primary=2, completed primary=3, attended secondary=4, completed secondary=5, university=6)
ASSET	Cumulative value of property (Euro)
CROP	Household owns crop field (yes=1, no=0)
GARDN	Household owns garden (yes=1, no=0)
VEGTBL	Household grows vegetables (yes=1, no=0)
ALFA	Household grows alfalfa (yes=1, no=0)
FIELD SIZE	Size of land cultivated by the household (ha)
WIN_SPRI	Distance from winter pasture to spring pasture (km)
SPRI_SUM	Distance from spring pasture to summer pasture (km)
LIVH	Household owns livestock (yes=1, no=0)
TLIV	Total number of livestock owned (sheep units)
LIV_ST	Total number of status animals (= horses and camels; in sheep units)
LIV_LA	Total number of large animals (= cattle, horses and camels; in sheep units)
LIV_SML	Total number of small ruminants (= sheep, goats; in sheep units)
INC_LIV	Income from live sales of livestock (Euro)

2.3. Results

2.3.1. Major livelihood strategies

The clustering procedure suggested a three-cluster solution for the 258 interviewed households; these three different livelihood strategies could be defined as (i) commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping (Cv, 24.0%), (ii) commercial crop farming plus subsistence livestock keeping (CL, 39.5%), and (iii) commercial livestock keeping plus subsistence crop farming and vegetable cultivation (Lcv, 36.4%). Whereas in all three clusters at least some households were involved in both livestock keeping (see below) and crop farming, vegetable gardening was not found in cluster CL.

In cluster Cv the average area of farmland owned was 1.2 ±0.76 ha (n=62). With 37.1%, the share of households involved in vegetable gardening was highest in this cluster as compared to 20.2% in Lcv and 0% in CL. On the other hand, livestock keeping was not important in this cluster, since only 8.1% of Cv households owned livestock with an average herd size of 86.4 ±37.22 SU for these 5 households (and an overall average for the cluster of 7.0 ±27.73 SU).

In cluster Lcv, livestock keeping was more important than in cluster Cv and all households kept animals. The total average number of sheep units per household (n=94) was 138.4 ±89.39 and thus highest among all three clusters. In contrast to livestock keeping, only a few Lcv households were involved in crop farming (6.4%, n=6), alfalfa fodder cultivation (38.3%, n=36) and vegetable gardening (20.2%, n=19). Furthermore, with an overall average of 0.3 ±0.52 ha the total field area was smallest for this cluster, yet field size was 0.8 ±0.58 ha for those households actually owning farm land (n=39).

All households in cluster CL were involved in crop farming and in livestock husbandry, while vegetable gardening was not practiced. With 1.3 ±0.77 ha per household (n=102) the size of the cultivated area was largest among all three clusters. Compared to cluster Lcv, the average number of livestock (in sheep units) per household was lower, being 81.0 ±48.79.

The identified livelihood systems were present at all locations except for Akeharen, which only harbored Lcv and CL households (Figure 2.2). However, the proportion of households belonging to each cluster differed by location. The Cv cluster was mainly present in Qinghe (46.8%) and Arele (38.7%), while more than half of all Lcv households (59.6%) were located at Akbulak compared to 30.9% at Akeharen and less than 10% at each of the other three locations. CL households were mainly found at Buluhe (40.2%), followed by Akeharen (21.6%), Qinghe (15.7%), Arele (13.7%), and Akbulak (8.8%).

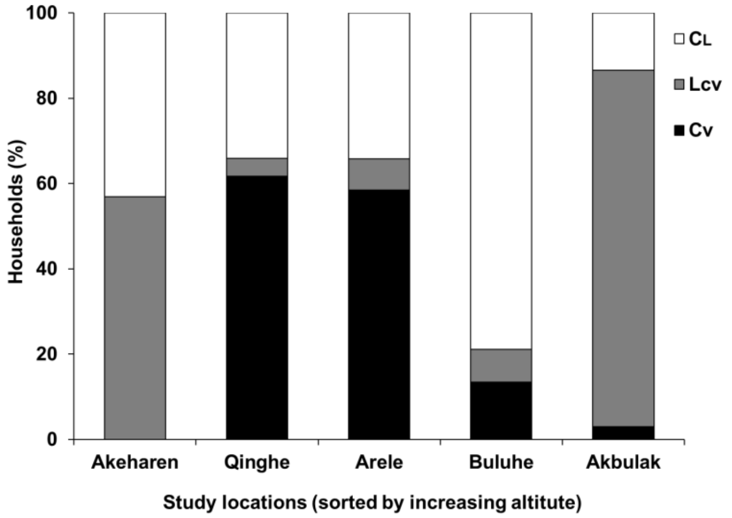


Figure 2.2 Distribution of three major livelihood strategies across the five study sites in Qinghe County.

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping.

2.3.2. Household characteristics

Of the 258 households, 84.9% were Kazakhs, 11.2% Han Chinese, 1.9% Hui, 1.2% Mongols, and 0.8% were Uyghurs. The Kazakhs were also the main ethnic group in each cluster, accounting for 48.4% 98.9% and 94.1% of the households in Cv, Lcv, and CL, respectively. The Han Chinese and Hui, being the second and third largest ethnic group in our study area, were distributed across clusters Cv (45.2% Han, 3.2% Hui) and CL (11.2% Han, 1.9% Hui). The Mongols were found in clusters Lcv (1.1%) and CL (2.0%), and Uyghurs were only found in cluster Cv (3.2%).

The average age of the household heads and the average number of adults per household were not significantly different between the three clusters (Table 2.2). However, the average household size was significantly lower ($p \leq 0.05$) in cluster Cv compared to the other two clusters, along with the number of both males and females ($p \le 0.05$) (Table 2.2). In cluster CL, the number of members of both sexes was higher but not significantly different from cluster Lcv ($p > 0.05$). The average number of adults employed in an off farm job was lower in clusters Cv and Lcv ($p < 0.05$) than in cluster CL (Table 2.2). Formal education levels of household heads were different among the clusters (Table 2.3); whereas most of the interviewed household heads were educated, 5.4% had never attended school. About 48% had completed primary school and 33% had attended junior high school.

2.3.3. Household assets

Households owned different types of assets that could be categorized as means of transportation, electronics or agricultural machinery. The number of assets differed by categories and cluster (Table 2.4). The total number of assets was highest ($p \le 0.05$) in cluster CL (5.0 ±1.83) and lowest ($p \le 0.05$) in cluster Cv (3.8 ±1.37) with Lcv being of intermediate position (4.2 ±1.85). Households in cluster CL also owned more ($p \le 0.05$) transportation assets (1.4 ±0.63) and agricultural machinery (0.9 ±0.92) compared to households in cluster Cv (transportation: 1.0 ±0.59; machinery: 0.4 ±0.55) and Lcv (transportation: 1.2 ±0.64; machinery: 0.5 ±0.73). The average number of family electronics and other equipment was not differed between the clusters ($p > 0.05$).

Table 2.2 Main characteristics of households (HH) in the three distinguished clusters. Values are means and standard deviations.

Cluster	Households (n)	Age of HH head (years)	Total members (n)	Adults (n)	Adults with formal employment (n)	Gender	
						Male	Female
Cv	62	47.0 ±14.20	3.2^{b} ±0.97	2.6 ±0.82	2.3^{b} ±0.74	1.7^{b} ±0.72	1.5^{b} ±0.74
Lcv	94	42.0 ±13.09	3.9^{a} ±1.19	2.8 ±1.11	2.4^{b} ±0.89	2.0^{ab} ±0.86	1.9^{a} ±0.94
CL	102	43.5 ±14.61	4.2^{a} ±1.06	3.0 ±1.05	2.8^{a} ±0.98	2.0^{a} ±0.78	2.2^{a} ±0.92

$^{a, b}$: Within columns, means with different superscripts are significantly different ($p \leq 0.05$, Kruskal-Wallis test).

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping.

Table 2.3 Formal education level of household heads (% per cluster) in the three distinguished clusters.

Cluster	Household heads (n)	Educational level					
		E1	E2	E3	E4	E5	E6
Cv	62	12.9	4.8	46.8	33.9	0.0	1.6
Lcv	94	3.2	16.0	45.7	34.0	1.1	0.0
CL	102	2.9	8.8	51.0	31.4	3.9	2.0
Total	258	5.4	10.5	48.1	32.9	1.9	1.2

E1: Never attended a school; E2: Attended primary school; E3: Completed primary school; E4: Attended junior high school; E5: Completed junior high school; E6: Attended senior high school.

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping.

Table 2.4 Number and cumulative value of major household assets possessed in the three distinguished clusters. Values are means and standard deviations.

Variable	Cluster		
	Cv	Lcv	CL
Total assets (n)	3.8[b] ±1.37	4.2[b] ±1.85	5.0[a] ±1.83
Transportation means (n)	1.0[b] ±0.59	1.2[b] ±0.64	1.4[a] ±0.63
Electronics, other equipment (n)	2.4 ±0.93	2.5 ±1.03	2.8 ±1.09
Agricultural machinery (n)	0.4[b] ±0.55	0.5[b] ±0.73	0.9[a] ±0.92
Cumulative value of all assets (€)*	1605[b] ±1822	2173[ab] ±2236	2535[a] ±1865

[a, b]: Within rows, means with different superscripts are significantly different ($p \leq 0.05$, Kruskal-Wallis test).

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping.

* The cumulative value of assets was calculated according to the price of purchase and converted into Euro based on the World Bank exchange rate in 2012.

2.3.4. Livestock husbandry

As already mentioned above, the possession of livestock significantly differed between the clusters (Table 2.5). The number of both large animals (horse, cattle, camel) and small ruminants (sheep, goat) per livestock-keeping household was high in cluster Lcv. As a consequence, cash earned from selling livestock was also highest in cluster Lcv (Table 2.6). In Cv, the total yearly revenue from livestock sales was lowest (307 ±33.6 €) and originated mainly from the sale of goats (250 ±400.7 €) and some sheep (57 ±126.7 €). In Lcv, livestock-related annual cash revenues exceeded 4600 € with the highest contribution from sheep sales (4053 ±4358.7 €) followed by cattle sales (338 ±508.6 €) and minimal contribution from camel sales (12 ±84.6 €). In CL again sheep (944 ±1544.3 €) and cattle (332 ±527.3 €) sales were most important, whereas camels were not sold.

Table 2.5 Livestock ownership in the three distinguished clusters. Values are means and standard deviations.

Cluster	HHs with livestock (n)	Livestock numbers (in sheep units)		
		Total	Large animals	Small ruminants
Cv	5	86.4[ab] ±56.15	57.9 ±34.74	28.5[ab] ±24.78
Lcv	94	138.4[a] ±89.39	63.0 ±43.68	75.4[a] ±63.60
CL	102	81.0[b] ±48.79	52.8 ±23.36	28.2[b] ±32.41

[a, b]: Within columns, mans with different superscripts are significantly different ($p \leq 0.05$, Kruskal-Wallis test).

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping.

Table 2.6 Annual cash income from livestock sale per household (HH). Values are means and standard deviations.

Cluster	Cv	Lcv	CL
HHs with livestock (n)	5	94	102
Total sales revenues (€)	307[b] ±433.6	4664[a] ±4695.2	1418[b] ±1773.0
Goat sales (€)	250[ab] ±400.7	236[b] ± 394.2	114[a] ± 246.4
Sheep sales (€)	57[b] ±126.7	4053[a] ±4358.7	944[b] ±1544.3
Cattle sales (€)	0	338 ± 508.6	332 ± 527.3
Horse sales (€)	0	25 ± 108.4	28 ± 193.6
Camel sales (€)	0	12 ± 84.6	0

[a, b]: Within rows, means with different superscripts are statistically different ($p \leq 0.05$, Kruskal-Wallis test).

Cv (n=62): commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv (n=94): commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL (n=102): commercial crop farming plus subsistence livestock keeping.

* Income from livestock was calculated according to the actual price when the livestock was sold and converted in Euro based on the World Bank exchange rate in 2012.

As far as livestock management is concerned, in addition to daily grazing on the rangelands, the animals were offered supplemental feed, mainly in the winter season. The order of livestock species to which supplements were most frequently offered was cattle (draught animals, dairy cows), riding horses (in Cv and CL) and small ruminants (sheep and goats). Particularly dairy cows were supplemented more frequently (some households fed them up to three times a day) and received higher quantities of feed than other animals. To camels, only very few CL families offered supplements such as grain (3.9%) and hay (4.9%). Practicing supplementation thus depended on animal species, orientation of production as well as cluster (Figures 2.3 & 2.4). Supplements included self-produced feed such as crop residues, grass hay and alfalfa hay, purchased feed (corn, cereal brans and salt) and other components (meal leftovers). The frequency of households using different supplements also differed among the clusters. In Lvc, corn was offered more frequently than other supplements, given mainly to cattle, small ruminants and horses. Households in CL also offered corn most frequently, followed by hay. In Cv, cattle were again fed more frequently than horses and small ruminants.

Since 4-10 households jointly own one hay field and use stones or trees to depict borders, it was not possible to collect the precise data on hay field sizes. Furthermore, hay yields were always given in tractor or cart loads per field, but loading volumes also differed between households. Therefore, it was difficult to reliably estimate a household's annual hay yield and stock. Based on the limited plausible data collected in the survey, 40.3% (Cv 5%; Lcv 44%; CL 51%) of all interviewed households (n=258) managed hay fields, which ranged from 10.7 ha to 83.3 ha in size, with a median per household of 33 ±16.7 ha.

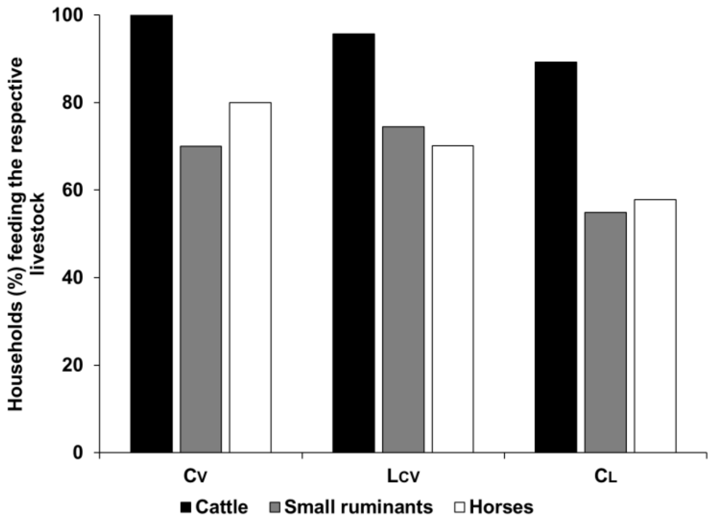


Figure 2.3 Percentage of livestock-keeping households in clusters Cv, Lcv and CL that offer supplement feeds to their livestock during winter.

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping. Livestock keeping: Cv=5, Lcv=94, CL=102.

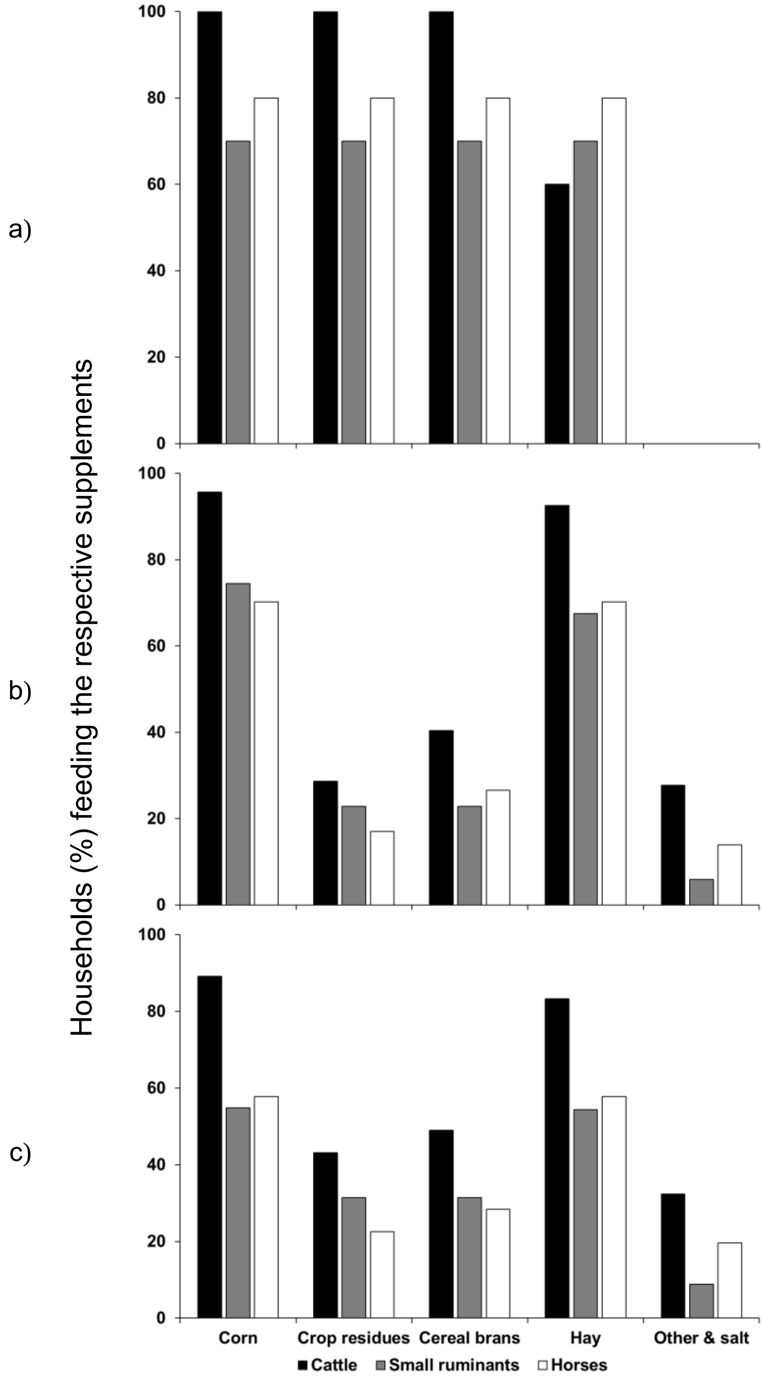


Figure 2.4 Percentage of livestock keeping households in cluster Cv (a), cluster Lcv (b) and cluster CL (c) offering various types of supplement feeds to their different livestock species during winter time.

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping. Livestock keeping: Cv=5, Lcv=94, CL=102.

2.3.5. Crop farming and vegetable gardening

Households from all three clusters were involved in crop farming, but field size, crop species and crop management approaches differed. In cluster Cv the average field sizes for the cluster (n=62) and those households owning fields (n=61), respectively, where the same (1.2 ±0.88 ha); in cluster Lcv (n=94) only 41.5% of households (n=39) owned fields, with an average size of 0.8 ±0.58 ha (compared to 0.3 ±0.55 ha being the average for the cluster). In cluster CL (n=102) all households owned fields with an average size of 1.3 ±0.86 ha.

The main crop cultivated in the region was wheat; vegetable gardening was only practiced if close to a market (city or town center), and households having more livestock were involved more in alfalfa cultivation (Figure 2.5). In cluster Cv, 77.4% of the households cultivated wheat, 37.1% grew vegetables and 6.5% alfalfa. Lcv households, for whom livestock is commercially important, mainly cultivated alfalfa (38.3%), followed by vegetable gardening (20.2%) and wheat (6.4%). In cluster CL every household involved in wheat cultivation, vegetable gardening was not found and 28.4% cultivated alfalfa.

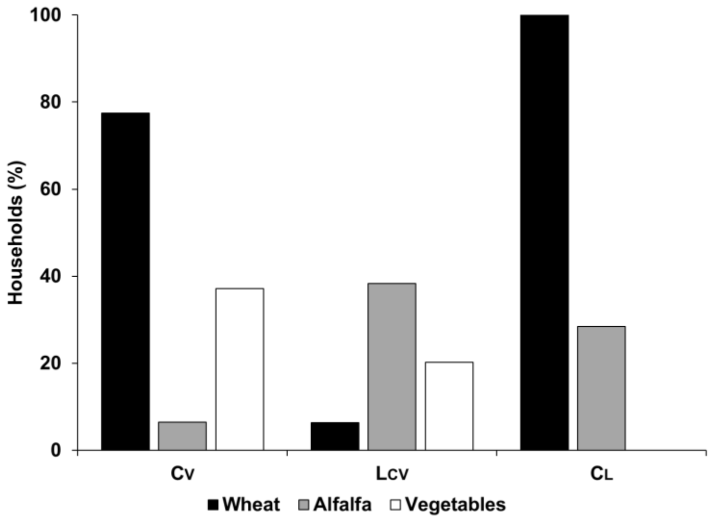


Figure 2.5 Involvement of households each of the three clusters (%) in cultivating wheat, alfalfa and vegetables.

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping.

In clusters Cv and CL, mineral fertilizers and pesticides were used by more than 90% of the households, but by only 79% (mineral fertilizer) and 87% (pesticides) of the Lcv households (Figure 2.6). In Lcv in contrast, compost was used by a higher share of farming households (38.5%) than mineral fertilizer (20.5%) and the combination of both (20.5%). In CL, 56% of the households used a combination of compost and mineral fertilizer and only 2% used compost only.

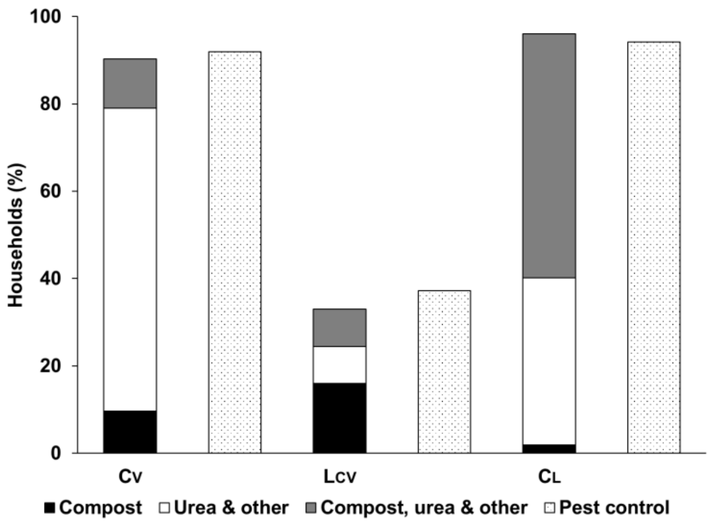


Figure 2.6 Share of crop farming households in each of the three clusters (%) using fertilizer and pest control for their crop cultivation.

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping. Crop farming: Cv=61, Lcv=39, CL=102.

The use of crop and vegetable yields (HH with crops) differed among the clusters (Figure 2.7). Most of the farming households (69% in Cv, 50% in Lcv and 82% in CL) used the yields for both their own consumption and for sale. About 13% of households from Cv, 38% from Lcv and 18% from CL used all yields for their own consumption, whereas 18% and 12% of households from Cv and Lcv sold their entire yields. The households' assessments of their own crop production (Figure 2.8) differed by cluster: In Cv and CL, 21% each of the interviewed households reported that their most recent crop yields were higher compared to five years before, while 47% (Cv) and 60% (CL) stated that crop yields were similar to previous years. In cluster Lcv 18% of households could not classify yield changes as higher, lower or similar compared to five years ago.

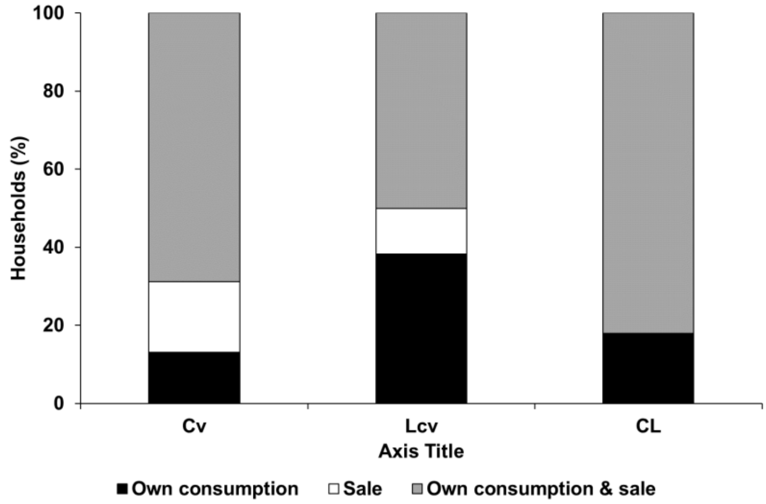


Figure 2.7 Utilization of crop yields by crop farming households in each of the three clusters (%).

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping. Crop farming: Cv=61, Lcv=39, CL=102.

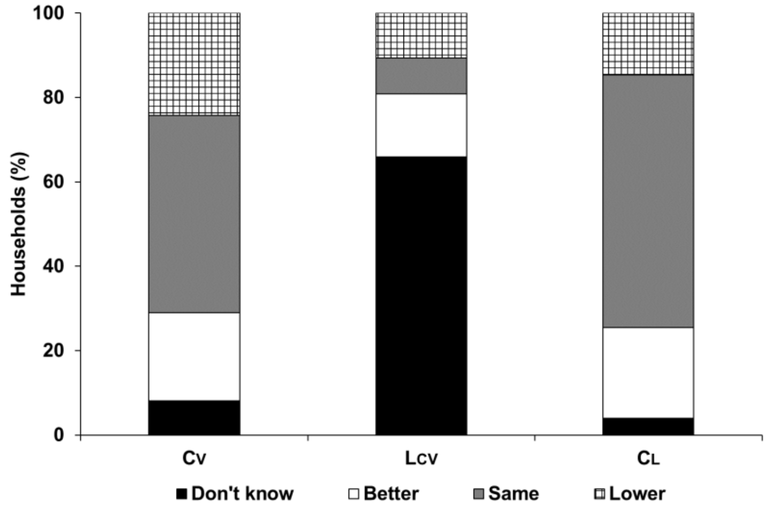


Figure 2.8 Evaluation of current crop yields as compared to those five years ago by crop farming households in each of the three clusters (%).

Cv: commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping; Lcv: commercial livestock keeping plus subsistence crop farming and vegetable cultivation; CL: commercial crop farming plus subsistence livestock keeping. Crop farming: Cv=61, Lcv=39, CL=102.

2.4. Discussion

2.4.1. Livelihood strategies

Sustainable livelihood strategies have been studied in many Asian countries such as China (Xu et al., 2015), Mongolia (Mearns, 2004), Pakistan (Urrehman & Rana, 2008), Kazakhstan (Kuleimenov, 2013), Kyrgyzstan (Eckhard, 2012) and Tajikistan (Chiranjeewee & Gulnaz, 2013). However, information on the current status of livelihood strategies and farming practices in rural areas of the Chinese Altay-Dzungarian border region is very rare. The insights presented here shed some light on the current situation and might thus be useful for endeavors towards the development of sustainable livelihood strategies in the area.

Subjecting the variables pre-selected by CATPCA to the two-step cluster analysis was useful to identify the three dominant livelihood strategies of rural people in the study region and may provide a basis for future research and planning. According to the present results, the prevalent production system in the Altay-Dzungarian region of Qinghe County is an agro-pastoral system including livestock production, crop farming and vegetable gardening. Such a system was also described by Squires and Limin (2010) for Northwest China (Gansu and Xinjiang provinces) and by the FAO (2006) for Mongolia (Arkhangai, Khentii and Bulgan provinces). However, the importance of each livelihood strategy differed between the five study locations and was governed by the proximity of rivers to access water for irrigated agriculture (the only way to cultivate crops and vegetables in the region), but also by the individuals', access to pasture resources. Pastures, for example, are allocated to livestock-keeping households on the basis of a 30 year contract, which means that despite changes in household size the pasture area will remain the same. Therefore, adult sons or daughters of herders, or newly migrated Han Chinese families, can in most cases not get access to pastures.

In all three clusters households kept livestock and cultivated crops, which reflects the importance of these activities in the study area. Particularly, Kazakhs have a long livestock herding tradition (Reynolds, 2006) in several regions such as Northwest China (Banks & Doman, 2001; Banks, 2003; Yongfa et al., 1984; Waldron et al., 2008; Cerny, 2008, 2010), Mongolia (Gil-White, 2002; Lkhagvadorj et al., 2013), and Kazakhstan (Robinson, 2000), and perceive livestock as a living bank with animal sales providing cash income (Liao et al., 2014a); this strategy was the one adopted in the Kazakh-dominated cluster Lcv. In addition to pastoralism, farmers in Qinghe were also involved in cropping wheat; in addition to feeding the family or using cash from wheat grain sales, this allowed them to feed their livestock with wheat straw and bran. This was also reported from Tajikistan (Kerven et al., 2012). However, cultivation of both cash crops and subsistence crops, i.e. vegetables and wheat, respectively, was dominated by sedentary Han Chinese and Hui people who were mainly found in the Cv cluster. Similar observations were made in other parts of the Altay and the Tianshan Mountains of Xinjiang (Liao et al., 2014a). Nevertheless, some home gardens were also owned and managed by Kazakh households for subsistence purposes, mainly to grow potatoes and carrots (Zukosky, 2008). Liao et al. (2015) observed that an increasing number of mobile pastoralists are adopting a sedentary lifestyle and start to cultivate vegetables, paralleled by similar endeavours of the newly arrived Han Chinese from the East of the country, who are, for their main income, mostly involved in non-agricultural sectors.

Among the interviewed households, vegetable gardening was not practiced on a large scale. The fact that no CL household was involved in this activity highlights the difficulty of combining two spatially differing and temporarily strongly overlapping activities. At the time of interview, most livestock producers were either located in Akeharen (low altitude winter home base) or Akbulak (high altitude summer pasture), and in both places there is insufficient water available for larger scale irrigated vegetable production. Secondly, vegetable production requires up to 10 times more labour than cereal crops (Ali, 2000), and herders who are seasonally moving with their livestock to different pastures can therefore not engage in this activity. Lastly, the cultural background (Liao et al., 2015) along with lack of information and storage facilities also limit vegetable cultivation of the rural population in Qinghe County. The majority of the interviewed households were involved in crop farming and livestock activities, but we were not able to collect reliable data on revenue from crop farming and off-farm activities. However, livestock keeping was quite important in all clusters, and was the principal occupation of most Kazakh households, contributing a considerable share of household income. As far as the income from livestock sales is concerned, households involved more strongly in livestock activities (cluster Lcv) also had the highest revenues from animal sales (up to 4600 € per year); in addition, the cumulative value of their assets was also higher than that of households with no animals who were mainly involved in crop farming (Cv).

2.4.2. Livestock husbandry

Households in the study area kept more small ruminants than large animals, which enables a traditional way of life with easy movements between the seasonal pastures throughout the year. Sheep were found to be the most important livestock species in the Chinese part of the Altay Mountains, with herders in our study keeping four times more sheep than goats. This is different in Mongolia, where herds in the steppe regions are dominated by goats (Johnson, 2009) since cashmere wool yields 63-70% of a family's yearly cash income (Lkhagvadorj et al., 2013). This pronounced difference between Xinjiang Province and neighbouring Mongolia might in part be due to the good transportation facilities for live animals (by truck on paved roads) in Qinghe County (good roads are still lacking in neighbouring Khovd Province of Mongolia), which greatly enhances herders' options for selling live animals (Shombodon & Williams, 2001) and their products (meat, milk, and skin) directly to regional markets rather than to local traders for a low price (Wang et al., 2013). In addition, a rising living standard and rapid urbanization even in Xinjiang Province (through government-supported settlement of Han Chinese) have increased the meat consumption in the region (as throughout China). Consequently, the price for mutton increased more than three times from 2007 (1.9 € /kg) to June 2013 (7.2 € /kg) and continues to rise (Yu et al., 2014).

Rangeland degradation (Novelly & Watson, 2007) and forage shortages (Makkar, 2012; Sundstol, 2013) are common problems in most of the pastoral and semi-arid regions of the world. Although rangelands account for 89% of the world's dryland areas, 73% were considered to be degraded in 1992 (Dregne & Chou, 1992). In Xinjiang, many pastures are overstocked at up to 1.7 times their carrying capacity (Jin & Zhu, 2009). According to Waldron et al. (2008) the summer-, winter-, and spring- /autumn- pastures in the Altay Mountains are overgrazed by 21%, 28%, and 138%, respectively. As a direct result of the high grazing pressure, the rangelands are degraded and seasonal feed shortages very regularly occur with major risks for livestock survival during winter and early spring (Reynolds, 2006). Winter feed conservation through irrigated hay production is one solution to improve the animal production system and reduce the pressures on winter and transitional pastures in the Altay region (Li et al., 1996). Therefore, the local authority (Xinjiang Animal Husbandry Bureau) developed 5,067 ha of artificial grassland and 4,800 ha of improved pasture between 1990 and 2000 in the neighbouring Fuyun County (Bedunah & Harris, 2005); however, up to date this strategy was not implemented in Qinghe County even though hay fields may reduce the grazing pressure on natural pasture land. However, according to Liao et al. (2015), hayfields alone are not enough to sustain livestock throughout the harsh winters in Altay. The lack of sufficient hay pushes herders to buy winter feed (Waldron et al., 2007), as has been reported for neighbouring Buerjin County (Banks & Doman, 2001). In the current study, 43% of the interviewed households stated to buy supplemental feed such as grains, cereal brans, salt, and sometimes even hay and crop residues. The frequency of feeding and type of winter supplement used differed between animal species, and only dairy cows and riding horses were fed with expensive grains, while small ruminants were perceived to be well-adapted to the poorly yielding winter pastures (Bailey, 2005; Putfarken et al., 2008). This was confirmed by the fact that in our study region small ruminants were grazed on the winter pastures during day time, whereas cattle were kept close to the settlements, which was also reported by Waldron et al. (2008) for the Altay, Tacheng and Yili regions. However, the presently observed low utilization of supplements is in sharp contrast to a study conducted on high altitude pastures in Nepal where nearly half of the animals' feed was provided by crop residues during winter time (Kreutzmann, 2012).

2.4.3. Crop farming

The main crop in the study region is wheat (although the government has in 2012 installed large irrigation systems where maize is grown), which is grown for dual-purposes (grain for human consumption and straw for animal feed) in Xinjiang, and the crop by-products are considered an important source of fodder in the agro-pastoral zones (Xia et al., 2010). In most of the agro-pastoral regions of Xinjiang more than 50% of total hervbivore forage comes from sown pastures or fodder crops (Squires & Limin, 2010). In our study area, the sedentary Han Chinese and Hui were advanced in their crop cultivation practices (Liao et al., 2015) and managed their fields more intensively than Kazakh herders; this can be ascribed to cultural background and language skills (Liao et al., 2014b). However, field management patterns and intensity also differed by location and cluster. In Cv and CL, the fields were managed more intensively and households practiced fertilizer application (both compost and mineral) and pest control more than in Lcv. In terms of fertilizer type, C_V and C_L households preferably applied mineral fertilizer and fewer used only compost or a combination of organic and mineral fertilizers. Use of composted manure was mainly related to livestock numbers, with households keeping more livestock (L_{CV}) using composted manure more frequently (38%) than households with fewer animals (C_V: 10%; C_L: 2%). Crop yields were reportedly better when mineral fertilizer was used (that is, in clusters CV and CL) and enabled the majority of households (about 68% in C_V and 80% in C_L) to sell all or part of the crop yields.

2.5. Conclusions

Our results indicate that the three agricultural livelihood strategies, namely crop farming, vegetable gardening and livestock keeping, are strongly associated with the ethnic/cultural background of a household and its spatial location within the Altay-Dzungarian border region of Xinjiang province. For reasons related to both resource endowment and Kazakh culture, pastoralism has historically been an integral part of the lives of the Kazakh people. All of the sedentary and newly arrived Han Chinese live near Qinghe city and dominate crop and vegetable farming. In addition to household characteristics, there are other socio-economic and ecological drivers that influence the currently ongoing livelihood diversification, such as access to land, livestock, pasture, water, animal health services, markets and education. Furthermore, changes in land tenure, agricultural policies and government initiatives towards sedentarisation also play a role. Next to the policies, the institutional as well as physical infrastructure is important and can affect a household's ability to use its productive capital to achieve a positive livelihood outcome. The inability to determine a household's overall farm and non-farm income is the main drawback of the current study, as it prevents insight into the question of whether and how the diversification of farming activities, particularly the combination of crop and vegetable farming with livestock keeping, improves a household's economic situation and overall welfare.

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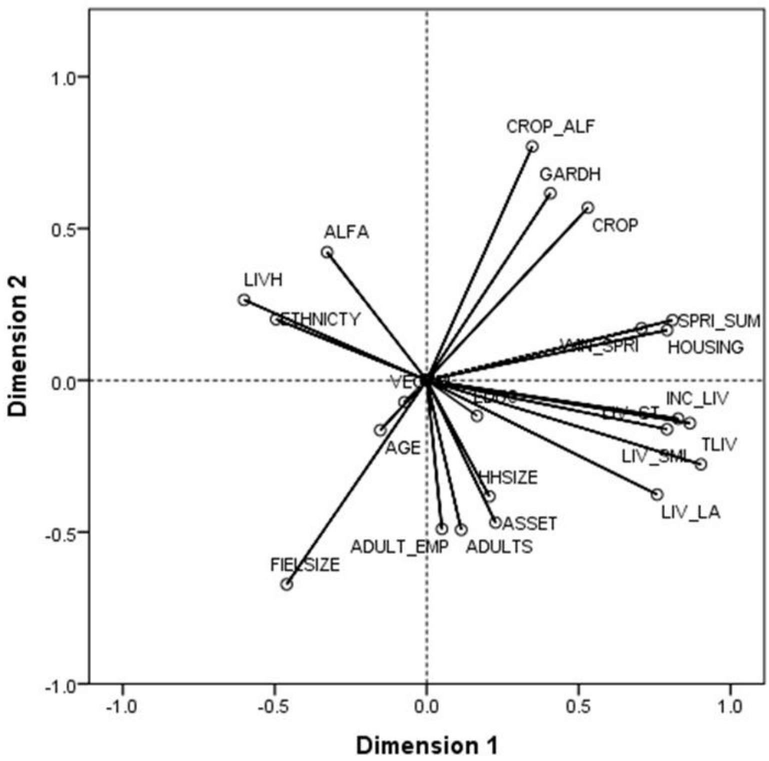
Appendix

Appendix 2.1 CATPCA model summary and component loadings.

Overall model	Parameter estimate	
Total Gronbach's Alpha	0.945	
Total Eigenvalue	10.195	
Explaining x% of total variance	46.341	
Two-dimensional model	**Dimension 1**	**Dimension 2**
Gronbach's Alpha	0.896	0.731
Total Eigenvalues	6.888	3.307
Explaining x% of total variance:	31.310	15.031
Component loadings		
AGE	-0.153	-0.164
ETHNICTY	-0.496	0.201
HOUSING	0.791	0.165
EDUC	0.166	-0.117
HHSIZE	0.206	-0.383
ADULTS	0.114	-0.492
ADULT_EMP	0.050	-0.490
ASSET	0.227	-0.469
CROP	0.531	0.569
GARDH	0.407	0.616
VEGTBL	-0.073	-0.072
ALFA	-0.328	0.422
CORP_ALF	0.347	0.770
FIELSIZE	-0.461	-0.672
WIN_SPRI	0.707	0.171
SPRI_SUM	0.809	0.198
LIVH	-0.601	0.265
TLIV	0.902	-0.277
LIV_LA	0.758	-0.377
LIV_SML	0.866	-0.141
LIV_ST	0.791	-0.161
INC_LIV	0.827	-0.126



Appendix 2.2 Plots of component loadings obtained from CATPCA describing the relationships among the major socio-economic characteristics of 258 rural households in Qinghe County.

Appendix 2.3 Conversion factors for sheep units.

Species	Description	Stock unit
Sheep	Breeding ewe and its nursing lamb	1
	Adult ram	1
	One-year old lamb	0.5
Goats	Breeding doe and its nursing kid	0.9
	Adult buck	0.9
	One-year old goat	0.4
Cattle	Adult cow	5
	Draught bull, medium working strength	5
	Fattened beef cattle	5
	6 to 12 month old cattle	2.5
	12 to 18 month old cattle	3.5
	18 to 24 month old cattle	4.5
Horse	Adult horse, medium strength	5
	Breeding mare and its nursing foal	5
	1 year old horse	2.5
	2 year old horse	3.5
	3 year old horse	4.5
Camel	Adult camel	7

Chapter 3 Grazing behavior and feed intake of small ruminants in the Chinese Altay Mountains

Summary: Grazing animals have a strong impact on rangelands through consumption and trampling of the vegetation, by their excreta deposit, and by their movements across the landscape. Meanwhile, forage availability and quality have a direct effect on animal performance, ultimately affecting productivity and health. Therefore, it is important to understand the interaction between qualitative and quantitative vegetation production and animal performances. Spatial movements (2013 and 2014) and daily grazing behavior (2013) and feed intake (2013 and 2014) of goats and sheep were studied on seasonal (spring and summer) pastures of the Chinese Altay Mountain region. Seasonal variation of vegetation quantity and chemical composition were measured.

The results showed that grazing behavior of goats and sheep differed between species, seasons and daytime. The daily grazing distances were longer ($p \leq 0.05$) in spring than in summer in both species. Correspondingly, the grazing area visited by both species was larger in spring. The amount of vegetation on offer (kg DM ha^{-1}) was similar between seasons but significantly higher in the first year (2013), whereas its chemical composition varied between seasons and years. Despite seasonal differences in forage quality, forage intake was not different between the seasons and years. The OM digestibility was significantly higher in the late summer of 2013 ($p \leq 0.05$) and the early summer of 2014 ($p \leq 0.001$), whereas total fecal excretion of goats (g DM day^{-1}) only varied slightly between seasons and years.

These results should now be linked to data on body weight development of the animals to assess the relationship between feed intake and performance during spring and summer season, which are very important for recovering from winter feed shortage and (re-)accreting body reserves.

3.1. Introduction

China has large area of rangeland covering 40% (400 million ha) of its land area (Miller, 2002) and being utilized by over 3.3 million pastoral households (Hua & Zhang, 2012). There are 260 pastoral counties, many of them hosting nomadic pastoralists, who are among the poorest people in China (Miller, 2002). The semi-arid pastoral areas in the north and west of China account for about 75% of China's total rangelands (Miller, 2002). Xinjiang Province is one of the major pastoral areas in China with 1.16 million pastoralists living in 275,800 households (Kreutzmann, 2013). The total grassland area of Xinjiang is about 32.6 million ha (Animal Husbandry and Veterinary Division / Ministry of Agriculture, 1996) which accounts for 28.8% of the national land area (Bu et al., 2014).

Natural grazing land is the predominant feed source for small ruminants (Yami, 2008). The over-stocking of grassland still poses a major challenge to sustainable grassland development in China (Li et al., 2014). The State Development Planning Commission (1996) and the State Environmental Protection Agency (1998) reported that at least 90% of China's grasslands are degraded at light to heavy levels with significant regional variation. The average overstocking rate on rangelands across China is about 34%, whereas the overstocking rate in Xinjiang reaches 70% in some areas (Han et al., 2008; Jin & Zhu, 2009) and livestock numbers have tripled since the last 50 years (Bu et al., 2014). Rangelands have historically supported the pastoral economy and wildlife populations in western China, but pastoralists have been affected by recent social, political and economic changes (Bedunah & Harris, 2002). The degradation of rangeland forces livestock to graze more fragile, less productive pastures which are not suited for high livestock numbers. Also, it decreases soil fertility and forage productivity, leading to poor animal productivity (Pardini, 2009).

Livestock production systems are facing challenges created by an increasing global food demand and environmental issues (Godfray et al., 2010; Pretty et al., 2010; Reynolds et al., 2010). Livestock farming is very important in Asia and the Pacific region as a source of livelihood, but livestock productivity in many countries is below the genetic potential because of inadequate and imbalanced feeds and feeding, and poor reproductive management (FAO, 2010). The nutrition of small ruminants is the most important factor affecting their performance. Poor nutrition results in low rates of production as determined by growth and reproduction (Yami, 2008). Forage quality influences the performance of grazing livestock and wildlife, and it is often assumed that, if forage quality meets animal nutrient requirements, animal performance will meet expectations (Lyons et al., 1995). Among the feeding systems of small ruminants, grazing natural or sown pastures is the most widespread practice (Pulina et al., 2013). In China, most grasslands are in the arid, semi-arid or alpine areas and vast areas of natural grasslands (Xinjiang and Gansu) are poor in quality (Hu & Zhang, 2003). One of the major constraints in balancing nutrient supply and nutrient requirements of small ruminants is to quantify what and how much grazing ruminants eat (Dove, 2010).

The performance of grazing small ruminants is very variable, depending on the type of soil and vegetation, time of grazing, location and altitude (Allison, 1985; Gudmundsson, 1993). Herbage intake is influenced by animal species, vegetation composition, location, plant growth stage, region, and environmental conditions (Laredo et al., 1991; Dove et al., 1996; Oliván & Osoro, 1999; Kelman et al., 2003). Also, animal gain and forage availability are not always positively related which can be due to differences in forage quality (Gudmundsson, 1993). The nutritive value and digestibility of the ingested forage are always difficult to determine because grazing animals select their diet from various combinations of plant species and plant parts (Allison, 1985; Huston & Pinchak, 1991; Dove & Farrell, 1993). In order to improve the performance of grazing small ruminants, it is essential to determine herbage intake, diet composition and digestibility on the rangeland.

3.2. Materials and methods

3.2.1. Study area

The study was conducted in the Qinghe County, Xinjiang Uyghur Autonomous Region of China, during the vegetation period of 2013 and 2014 (May-September). The spring pasture (Qianghan, 46°43'42.06" N, 90°14'19.57" E, 1500 m a.s.l) was located about 20 km west of Qinghe County, with the yearly grazing period lasting from late April to early June (about 50 days). The summer pasture (Akbulak, 47°12'23.62" N, 090°14'58.20" E, 2400 m a.s.l; see Figure 2.1) grazing period is early July to early September (about 60 days).

3.2.2. Data collection

Animal grazing itinerary and grazing behavior

To determine the daily grazing itineraries and grazing activities, five goats and five sheep were chosen from one herding family (cluster cLC, see Chapter 2). Three goats and sheep were monitored with GPS devices (GPS PLUS Globalstar, VECTRONIC Aerospace GmbH, Berlin, Germany; Buerkert & Schlecht, 2009; Schlecht et al., 2009) that were mounted on the first and removed on the last of five consecutive monitoring days per animal and period. The GPS registered date, time, altitude, latitude, and longitude at intervals of 64 seconds from May to September 2013 and 2014. The seasonal and species-specific variation in the spatial orientation of grazing was extracted, together with information on vegetation types visited by the animals and overall offer of biomass along the itineraries. All GPS raw data obtained from the tracked animals were corrected for outliers (GPS positions estimated from only 3 satellites) as well as failed GPS readings (GPS positions estimated from < 3 satellites) and were subsequently merged per season (spring and summer) and animal species (goat and sheep). All data were processed using the software packages ArcGIS 9.2 (ESRI Corp, Redlands, CA, USA) and QGIS; coordinates were converted to UTM grid projection (WGS 1984, 46°N). The horizontal distance covered in long distance transhumance movements was calculated using the Hawth's Analysis Tools extension for ArcGIS. To calculate the daily walked distances, the horizontal distance was divided by the total tracking time. A buffer with a 50 m width to both sides of the collared animal's itinerary was placed along the merged tracks. The surface of the resulting area was calculated and defined as theoretical utilized pasture area for the goat and sheep herd, respectively. The theoretical utilized pasture area was divided by the herds' duration of stay to determine the theoretical utilized pasture area per day.

During the GPS tracking, goats and sheep (three each) were followed three days (one day per animal) on spring pasture (May-June, 2013) and two times three days on summer pasture (July-Sept, 2013) from their departure until their return to the night resting place. Behavior was observed during day light grazing time (6 a.m. to 8 p.m.) and was grouped into morning (6 a.m. – 3 p.m.) and afternoon (3 p.m. onwards). The behavior of each goat and sheep was monitored by visual observation at 3 min intervals. Recorded activities included grazing, ruminating while standing, ruminating while lying, resting while standing, resting while lying, walking without grazing (walking), and other activities. Grazing was defined as biting, chewing, and swallowing herbage, or walking between feeding points. Resting was calculated as sum of ruminating while standing, ruminating while lying, resting while standing and resting while lying. Other activities included drinking water, ingesting soil and concentrate, social interactions between the peers as well as mother and kids, individual scrubbing or licking, urination, and defecation. The proportion of time an animal spent on each activity was calculated according to the frequency of each behavioral activity occurring during the daily observation time.

Biomass offer and quality along the itinerary

Biomass quantity along the animals' grazing itineraries was estimated on day four of each GPS monitoring period on spring and summer pastures (2013 and 2014). Plant material was completely harvested every 0.5 km along the itinerary within a frame of 50 cm x 50 cm by clipping all vegetation within the sampling frame at 1 cm height above ground. The geographical position of the frame was also taken. Plant samples were first weighed fresh, then put into a cotton bag and air-dried in the shade. When completely dry, each sample was weighed again, subtracting the weight of the bag.

Determination of feed intake and digestibility

To quantify the intake of feed and nutrients of grazing goats, in spring and summer 2013 and 2014, the total amount of feces excreted was quantified in parallel to the GPS tracking and behavior observation. Five male goats (3 with GPS and 2 additional ones) were fitted with fecal collection bags on day 1; the bags were left on the animals until day 5 and were emptied every 8-12 hours. At each emptying, fresh feces were weighed, put into cotton bags and dried in the shade. After samples were completely dry, they were weighed again and pooled into one composite sample per animal and period. Samples were milled to 1 mm particle size and analyzed in duplicate for their proximate composition.

3.2.3. Chemical analysis

Analysis of biomass and feces samples

All biomass samples were dried at 60°C until constant weight to determine the dry weight of aboveground biomass. Following grinding through a 1 mm screen (FOSS sample mill, CyclotecTM 1093, Haan, Germany), all samples were read with a XDS-Rapid Content Analyzer NIRsystem (FOSS NIRsystems, Hillerod, Denmark). The concentrations of dry matter (DM) after drying at 105°C (4 h), of organic matter (OM) after combustion at 550°C, of phosphorus (P) and calcium (Ca) were determined following standard procedures (Naumann & Bassler, 2004). The concentration of neutral detergent fiber (NDF) and acid detergent fiber (ADF) was measured (van Soest et al., 1991) by using a semi-automated Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY, USA) following the procedure of Schiborra et al. (2010). The carbon (C) and nitrogen (N) concentrations were determined by a CN-Analyzer (vario MAX CN; Elementar Analysensysteme, Hanau, Germany). On the basis of a calibration model (NDF: R^2= 0.87, standard error of cross-validation (SECV)= 43 g kg^{-1} DM; ADF: R^2= 0.90, SECV= 31 g kg^{-1} DM; N: R^2= 0.94, SECV= 1.5 g kg^{-1} DM; OM: R^2= 0.88, SECV= 21 g kg^{-1} DM; P: R^2= 0.72, SECV= 30 g kg^{-1} DM, Ca: R^2= 0.95, SECV= 25 g kg^{-1} DM) the concentration of the respective chemical fractions was predicted in the remaining samples (Reddersen et al., 2013). The concentration of crude protein (CP) was calculated based on the N concentration (CP= N x 6.25, Allen et al., 2011).

The fecal samples were processed in a similar manner as the plant samples. They were analyzed for DM, OM, NDF, ADF, N, and P. From the concentration of CP in fecal OM the organic matter digestibility (OMD) of the overall diet was estimated using the equation (1) established by Wang et al. (2009):

$$y = 0.899 - 0.644 \times \exp(\frac{-0.5774 \times faecal\ CP\ (g/kgOM)}{100}) \quad \text{(Eq. 1)},$$

where *y* is the OM digestibility (%) of the diet.

3.2.4. Statistical analysis

Differences in the respective share of feeding time (recorded as grazing and browsing activities, in % of total observations) spent by goats and sheep were analyzed across seasons (2013 spring and summer). The same was done (2013 and 2014) to determine variations in the average site- and season-specific concentration of OM, NDF, ADF, CP, P, and Ca of the diet as well as in the respective fecal OM, N, NDF, ADF, P, and OMD concentration. Data residuals were first checked for normal distribution, investigating the skewness and kurtosis z-values as well as the Shapiro-Wilk test p-value, before testing for homogeneity of variance. Pair-wise comparisons of means were then carried out using the independent t-test and one-way ANOVA for normally distributed as well as the Mann-Whitney U and Kruskal-Wallis test for non-normally distributed data sets in case of two and more than two independent variables, respectively. Welch's t-test was used for cases of unequal group variances or sample sizes. Statistical data analyses were performed in SPSS Statistics 22 (IBM Corp, 2013) with significance levels of 0.05, 0.01 and 0.001 to determine differences between subgroups.

3.3. Results

3.3.1. Quantity and quality of pasture vegetation

The average DM availability (Table 3.1) along the grazing itinerary was not differed between seasons ($p>0.05$) but significantly differed between years ($p\leq0.05$). The overall DM availability in different seasons of 2013 was significantly higher ($p\leq0.05$) than in the corresponding seasons of 2014. The altitude of the spring pasture visited in 2013 was significantly lower ($p\leq0.05$) than that of the early summer pasture but not different ($p>0.05$) from the altitude of the late summer pasture. In 2014, the altitude of the spring pasture was significantly ($p\leq0.05$) lower than the altitude of both early and late summer pasture.

The vegetation height was similar in the different seasons of 2013, but significantly higher ($p\leq0.05$) in early summer 2014 (20 ±8.8 cm) compared to spring and late summer 2014 (10 ±4.4 cm, 13 ±2.6 cm). The vegetation cover was similar ($p>0.05$) in different seasons of 2013; in 2014, the vegetation cover was significantly lower ($p\leq0.05$) in spring (0.25 ±0.10) compared to summer (0.73 ±0.97, 0.63 ±0.22). Comparing the same seasons between the two years, the vegetation cover was significantly higher ($p\leq0.05$) in spring 2013 (0.56 ±0.15) than in spring 2014 (0.25. ±0.10) but was not different ($p>0.05$) in the summer seasons. The stone cover was similar in the different seasons of 2013, but was significantly higher ($p\leq0.05$) on the 2014 spring pasture (0.17 ±0.20) compared to the two summer pastures. The stone cover on the 2014 spring pasture was furthermore about three times higher ($p\leq0.05$) compared to the 2013 spring pasture (0.06 ±0.16), whereas stone cover on the summer pastures was not different ($p>0.05$) between the years.

Table 3.1 Average altitude of seasonal pastures, dry matter (DM) biomass yield along small ruminants' grazing itinerary, vegetation height and cover as well as stone cover.

Year	Season	n	Altitude (m)	DM (kg/ha)	Vegetation height (cm)	Vegetation cover (%)	Stone cover (%)
2013	Spring	10	1506[b] ± 11.4	2420[A] ±429.9	14.5 ±10.53	55.5[A] ±14.80	5.7[B] ±15.59
	Early summer	6	2408[a] ±103.4	2219[A] ±358.0	13.5 ± 6.19	66.7 ±20.41	0.0
	Late summer	3	2275[B, ab] ± 24.2	2189[A] ±271.0	8.8[B] ± 1.67	83.3 ±14.43	7.3 ±11.01
2014	Spring	13	1502[b] ± 19.4	1029[B] ±364.3	10.2[b] ± 4.39	25.4[B, b] ± 9.67	16.9[A, a] ±19.81
	Early summer	8	2419[a] ± 81.8	1360[B] ±429.2	19.9[a] ± 8.83	72.5[a] ±19.27	3.1[b] ± 6.87
	Late summer	8	2418[A, a] ± 73.3	977[B] ±230.6	12.5[A, ab] ± 2.63	63.1[a] ±22.02	0.6[b] ± 0.74

Small letters ([a,b,c]) indicate differences between the seasons within a year; Capital letters ([A,B,C]) indicate differences for the same season between the two years. Significance was tested at 0.05 level.

Significant differences between the seasonal means ([a,b,c]) according to one-way ANOVA and between the years ([A,B,C]) according to independent t-test and Mann-Whitney U test.

The occurrence of different vegetation groups was different across seasons and years (Figure 3.1). The proportion of grass sampled on spring pastures (85% and 39%) was higher than on summer pastures (25% and 11%) in 2013 and 2014. Subshrubs were only found on spring pastures, while summer pastures were dominated by grass plus annual herbs (75% and 89%) in both years; only 8% of herbs were found on the 2014 spring pasture.

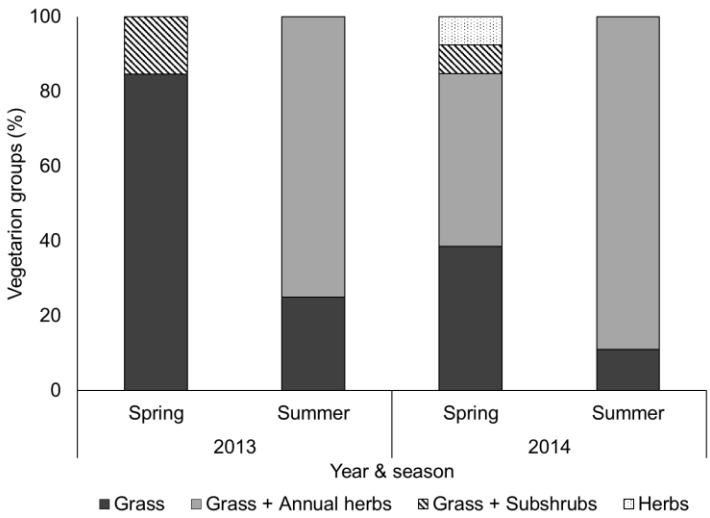


Figure 3.1 Frequency distribution of vegetation groups in different locations collected along the itinerary of small ruminants on spring and summer pastures in 2013 and 2014.

The nutritional quality of the vegetation (Table 3.2) collected on the spring and summer pastures along the animals' grazing itineraries varied between seasons and years. The DM (g kg^{-1}) concentration (in fresh matter) was different between the seasons with the lowest value in early summer of both 2013 ($p≤0.05$) and 2014 ($p≤0.001$). OM (g kg^{-1} DM) was similar in both years but was lower ($p≤0.01$) in spring 2014 than in summer 2014. CP content of the vegetation showed seasonal variation ($p≤0.05$) in 2013 and decreased significantly ($p≤0.01$) in late summer of 2014. The NDF was higher in spring 2014 than on summer pastures ($p≤0.001$) and was also higher compared to spring 2013 ($p≤0.01$). The highest ADF concentration was found in spring of both 2013 ($p≤0.05$) and 2014 ($p≤0.001$) and decreased in summer. Compared to the early summer of 2013, the ADF concentration in early summer 2014 was significantly lower ($p≤0.001$). The Ca was lower in both spring 2013 ($p≤0.01$) and 2014 ($p≤0.001$) than in the respective summer, and also was lower ($p \leq 0.001$) in spring 2013 than in spring 2014. P concentration only varied ($p \leq 0.001$) in 2013 with a high value in spring (2.3 g kg^{-1} DM), but was similar in 2014 and between 2013 and 2014. The C/N ratio of the vegetation was similar between the seasons in both 2013 and 2014, but was higher in spring ($p \leq 0.05$) and lower in late summer ($p \leq 0.01$) 2013 than in spring and late summer 2014. Ca/P ratio in spring of both 2013 (3.3) and 2014 (2.2) was significantly lower ($p \leq 0.01$, $p \leq 0.001$) than in early and late summer of 2013 and 2014. Comparing the years, only spring 2013 was higher ($p \leq 0.05$) than spring 2014, but early and late summer pastures were similar ($p > 0.05$) in their Ca/P ratio.

Table 3.2 Quality of pasture vegetation: concentration of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), carbon (C), calcium (Ca), phosphorus (P), C/N ratio and Ca/P ratio in forages along the grazing itineraries of small ruminants. Values are means and standard errors of the mean (SEM).

Year	Season	n	DM	OM	CP	NDF	ADF	C	Ca	P	C/N	Ca/P
			g/kg FM	g/kg DM								
2013	Spring	10	522^{a}	853	136^{a}	495^{B}	373^{a}	442	$7.5^{A, b}$	2.3^{a}	20^{A}	$3.3^{A, b}$
	Early summer	6	401^{b}	881	117^{b}	479	$327^{A, b}$	428	12.5^{a}	1.9^{b}	23	6.6^{a}
	Late summer	3	413^{ab}	891	$126^{A, ab}$	488	309^{b}	435	12.4^{a}	1.9^{b}	22^{B}	6.5^{a}
	SEM		21.6	8.1	3.5	8.3	10.4	4.0	0.67	0.06	0.58	0.45
	Effect of season		*	n.s	*	n.s	*	n.s	**	***	n.s	**
2014	Spring	13	518^{a}	858^{b}	126	$571^{A, a}$	388^{a}	448	$4.7^{B, b}$	2.1	23^{B}	$2.2^{B, b}$
	Early summer	8	382^{b}	905^{a}	110	470^{b}	$285^{B, b}$	443	10.1^{a}	1.9	26	5.3^{a}
	Late summer	8	465^{a}	900^{a}	114^{B}	461^{b}	292^{b}	441	11.0^{a}	1.9	24^{A}	5.7^{a}
	SEM		15.5	6.6	3.1	14.3	11.3	1.7	0.65	0.05	0.60	0.36
	Effect of season		***	**	n.s	***	***	n.s	***	n.s	n.s	***
Effect of year	Spring		n.s	n.s	n.s	**	n.s	n.s	***	n.s	*	***
	Early summer		n.s	n.s	n.s	n.s	*	n.s	n.s	n.s	n.s	n.s
	Late summer		n.s	n.s	**	n.s	n.s	n.s	n.s	n.s	**	n.s

FM = fresh matter, n = number of biomass samples.

Small letters (^{a,b,c}) indicate differences between the seasons within a year; Capital letters (^{A,B,C}) indicate differences for the same season between the two years. * p≤0.05, ** p≤0.01, *** p≤0.001, n.s. = non-significant. Significant differences between the seasonal means (^{a,b,c}) according to one-way ANOVA and Kruskal-Wallis test and between the years (^{A,B,C}) according to independent t-test and Mann-Whitney U test.

3.3.2. Length of grazing itinerary and size of areas visited

The length of the grazing itinerary varied by season and year (Figure 3.2a). The daily grazing distances covered by goat herds in 2013 was longer than in 2014 in both spring and summer. The longest distances were recorded in spring (13.9 ±0.58 km, 12 ±0.09 km), the shortest distances in late summer (8.7 ±0.18 km, 7.5 ±1.88 km) in both years. In 2013, the daily grazing distances were significantly different ($p \leq 0.05$) between seasons, but they were similar in early and late summer 2014. Comparing the same season across the two years, the daily grazing distances in spring and late summer were not different ($p > 0.05$), whereas daily grazing distances in early summer were longer ($p \leq 0.05$) in 2013 compared to 2014. In sheep, the longest grazing distances were also found in spring in both 2013 (15.6 ±0.47 km) and 2014 (13.6 ±0.08 km). In late summer 2013, the sheep herd walked further (9.2 ±0.31 km) than in early summer (7.1 ±0.16 km; $p \leq 0.05$), but there were no significant differences in summer 2014. Within each season, grazing distances of sheep did not differ between 2013 and 2014.

Correspondingly, the size of pasture areas visited by goat and sheep herds were larger when the animals walked longer, and differed by seasons (Figure 3.2b). In both species, the largest areas were visited in spring, whereby the size of the area visited was relatively larger in 2013 compared to 2014. In early summer 2013, goat herds visited larger ($p \leq 0.05$) areas (45.9 ±5.38 ha) than in late summer 2013 (29.7 ±0.47 km), whereas in 2014 larger areas ($p > 0.05$) were grazed in late summer (27.7 ±4.64 km) than in early summer (20.5 ±4.08 km). In contrast to the goat herd, the sheep herd visited larger areas in late summer 2013 (35.9 ±3.26 km) and early summer 2014 (24.8 ±2.42 km). The size of the areas visited by goat and sheep herds was only different ($p \leq 0.05$) in early summer 2013 and 2014 and otherwise was of similar size.

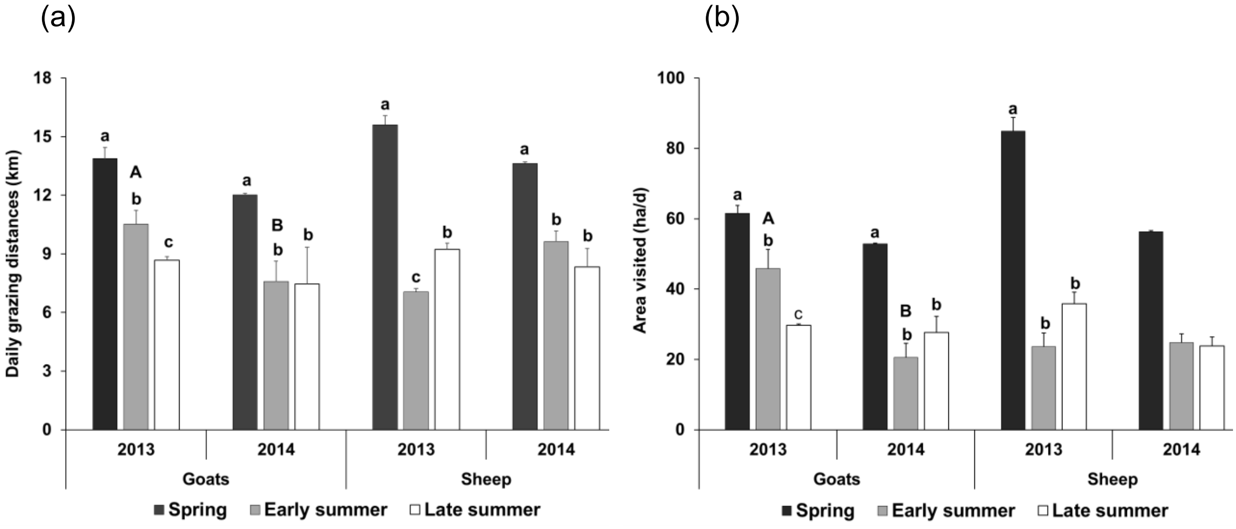


Figure 3.2 Small ruminants' daily grazing distances (a) and size of pasture area visited (b) in 2013 and 2014.

Small letters (^{a,b,c}) indicate differences between the seasons within a year; Capital letters (^{A,B,C}) indicate differences for the same season between the two years, p≤0.05.

3.3.3. Small ruminants' grazing behavior and feed intake

Grazing activities of goats (spring and summer) and sheep (only summer) were observed in spring and summer pastures in 2013 (Figure 3.3). The proportion of time spent grazing, resting, walking and doing other activities was different between seasons and species. In spring goats spent less time on grazing (47%) than in summer (60%) The resting time of goats decreased from 40% in spring to 37% in summer. The time spent on walking was also reduced from 12% in spring to less than 2% in summer. In summer, sheep spent less time on grazing in the morning (46%) than in the afternoon (72%), and also reduced the proportion of time spent walking from 12% in the morning to 3% in the afternoon.

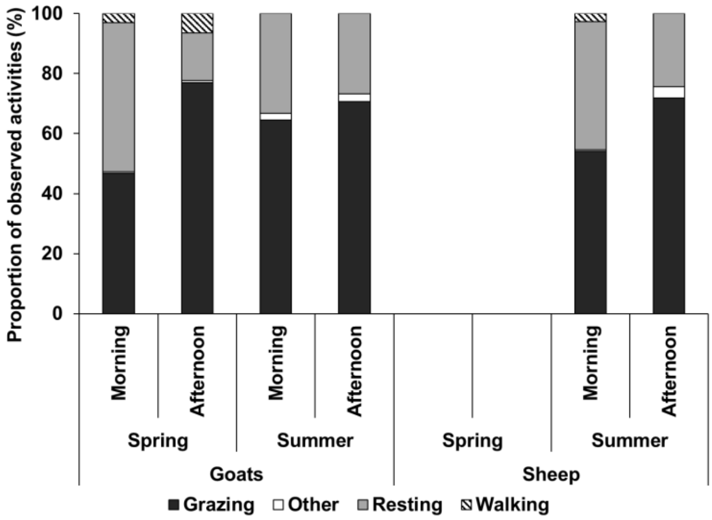


Figure 3.3 Share of major activities in daily grazing time of small ruminants during the spring and summer season 2013. No data was recorded for sheep in spring 2013.

The live weight (LW) of goats used for the intake study was similar ($p>0.05$) across seasons and years. The organic matter digestibility (OMD) of the selected diet as calculated from the fecal crude protein concentration was significantly differed between seasons and years (Table 3.3). In 2013, the OMD was high ($p\leq0.05$) in the late summer (72.3%) and significantly differed ($p\leq0.05$) from spring (69.8%); in 2014 OMD was significantly higher ($p\leq0.001$) in early summer (75.6%) than in spring (70.4%) and late summer (71.8%). Differences in OMD between the two years were only manifest for early summer (2013: 72.2%, 2014: 75.6%; $p\leq0.05$) but not for spring and late summer.

DM and OM intake (DMI, OMI) were not different ($p>0.05$) between seasons and years. The highest values for both DMI (80 g $kg^{-0.75}$ LW) and OMI (75 g $kg^{-0.75}$ LW) were found in early summer 2014, and the lowest (62.5 g DM $kg^{-0.75}$ LW, 59.5 g OM $kg^{-0.75}$ LW) in late summer 2013. CP intake (CPI) was also not different ($p>0.05$) between seasons and years. The highest CPI was determined in spring 2014 (9.5 g $kg^{-0.75}$ LW) and the lowest in late summer 2013 (7.9 g $kg^{-0.75}$ LW). NDF intake was similar for the various seasons in both years, but was significantly higher ($p\leq0.05$) in spring 2014 (43 g $kg^{-0.75}$ LW) than in spring 2013 (31 g $kg^{-0.75}$ LW), whereas no differences were found between summer seasons. The ADF intake was similar in the three seasons of 2013, but in 2014 was significantly higher ($p \leq 0.05$) in spring (29 g $kg^{-0.75}$ LW) than in early summer (21 g $kg^{-0.75}$ LW) and late summer (23 g $kg^{-0.75}$ LW).

Table 3.3 Live weight (LW) of goats, organic matter digestibility (OMD) of the ingested diet and intake of dry matter (DMI), organic matter (OMI), crude protein (CPI), neutral detergent fiber (NDFI), and acid detergent fiber (ADFI). Means and standard error of the mean, n=5.

Year	Season	LW	OMD	DMI	OMI	CPI	NDFI	ADFI
		kg	g/kg DOM	g/kg$^{0.75}$ LW				
2013	Spring	59	698^{b}	63	60	8.5	31^{B}	23
	Early summer	62	722$^{B, ab}$	76	71	9.0	37	25
	Late summer	66	723^{a}	63	60	7.9	31	19
	SEM	3.0	4.8	5.3	5.0	0.63	2.5	1.8
	Effect of season	n.s	*	n.s	n.s	n.s	n.s	n.s
2014	Spring	60	704^{b}	76	71	9.5	43^{A}	29^{a}
	Early summer	64	756$^{A, a}$	73	68	8.0	34	21^{b}
	Late summer	52	718^{b}	80	75	9.1	37	23^{ab}
	SEM	3.1	6.5	3.3	3.1	0.40	1.9	1.4
	Effect of season	n.s	***	n.s	n.s	n.s	n.s	*
Effect of year	Spring	n.s	n.s	n.s	n.s	n.s	*	n.s
	Early summer	n.s	*	n.s	n.s	n.s	n.s	n.s
	Late summer	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Small letters (^{a,b,c}) indicate differences between the seasons within a year; Capital letters (^{A,B,C}) indicate differences for the same season between the two years. * p≤0.05, ** p≤0.01, *** p≤0.001, n.s. = non-significant. Significant differences between the seasonal means (^{a,b,c}) according to one-way ANOVA and Kruskal-Wallis test and between the years (^{A,B,C}) according to independent t-test and Mann-Whitney U test.

3.3.4. Organic matter and nutrient excretion

The daily quantitative excretion (Table 3.4) of DM (g day^{-1} per animal and g $kg^{-0.75}$ LW) and fecal OM concentration (g kg^{-1} DM) was not affected ($p>0.05$) by year and season (only the daily DM excretion in early summer 2014 was less than in spring 2014, $p\leq0.05$). The N concentration of feces was significantly higher on summer pastures ($p\leq0.05$) of 2013 than in spring 2013, and in early summer ($p\leq0.001$) of 2014 than in spring and late summer of that year. However, the fecal N concentration in early summer 2014 was significantly higher ($p\leq0.001$) compared to the early summer 2013. The NDF content of feces showed a decreasing trend ($p\leq0.05$ in both years) over the time in both years with highest values in spring and lowest in late summer. Furthermore, the decrease in fecal NDF from spring ($p\leq0.001$) to early summer ($p\leq0.01$) 2013 was more obvious than in late summer ($p>0.05$), especially when compared to the respective season in 2014. There were no significantly differences ($p>0.05$) found in fecal C between the seasons and years, while the P concentration of feces was significantly lower in late summer of both 2013 ($p\leq0.05$) and 2014 ($p\leq0.01$) than in the other seasons of each year, whereas P concentrations in early summer 2014 were significantly higher ($p\leq0.05$) than in early summer 2013. The C/N ratio of feces was similar ($p>0.05$) across 2013 but significantly varied ($p\leq0.001$) in 2014, and the fecal C/N ratio in early summer 2013 was significantly higher ($p\leq0.01$) than in early summer 2014, whereas data from spring and late summer were not affected ($p>0.05$) by year.

Table 3.4 Daily fecal dry matter (DM) excretion, and fecal concentration of organic matter (OM), nitrogen (N), neutral detergent fiber (NDF), carbon (C), and phosphorus (P), as well as fecal C/N ratio. Values are given as means and standard errors of mean; n=5.

Year	Season	DM excretion		OM	N	NDF	C	P	C/N
		g/d per animal	$g/kg^{0.75}$ LW	g/kg DM					
2013	Spring	451	21	834	27^{b}	$619^{A, a}$	458	7.8^{a}	17.0
	Early summer	493	23	849	$30^{B, a}$	$546^{A, ab}$	461	$5.5^{B, ab}$	15.2^{A}
	Late summer	429	20	837	30^{a}	537^{b}	465	4.7^{b}	15.5
	SEM	26.7	1.6	5.1	0.6	10.5	3.5	0.40	0.34
	Effect of season	n.s	n.s	n.s	*	**	n.s	*	n.s
2014	Spring	527^{a}	25	852	28^{b}	$548^{B, a}$	469	7.7^{a}	16.7^{a}
	Early summer	427^{b}	19	858	$36^{A, a}$	$520^{B, ab}$	461	$7.0^{A, a}$	$12.9^{B, c}$
	Late summer	467^{ab}	25	853	30^{b}	506^{b}	459	5.1^{b}	15.3^{b}
	SEM	16.2	1.3	3.9	0.9	6.3	2.4	0.38	0.45
	Effect of season	*	n.s	n.s	***	**	n.s	**	***
Effect of year	Spring	n.s	n.s	n.s	n.s	***	n.s	n.s	n.s
	Early summer	n.s	n.s	n.s	***	**	n.s	*	**
	Late summer	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Small letters (^{a,b,c}) indicate differences between the seasons within a year; Capital letters (^{A,B,C}) indicate differences for the same season between the two years. * p≤0.05, ** p≤0.01, *** p≤0.001, n.s. = non-significant. Significant differences between the seasonal means (^{a,b,c}) according to one-way ANOVA and Kruskal-Wallis test and between the years (^{A,B,C}) according to independent t-test and Mann-Whitney U test.

3.4. Discussion

3.4.1. Quantity and quality of pasture vegetation on offer

One of the most important constraints to livestock production are seasonal variations in the quantity and quality of pasture vegetation (The International Center for Tropical Agriculture, 2015). Chemical composition of forages varies greatly from season to season (Wang et al., 1997; Yan & Fan, 2004). Those changes are due to variations in local climate, soil fertility, plant species composition and animal management factors (Van et al., 2005; Celaya et al., 2007). The altitude differences between spring and summer pastures in the present study did not show any positive or negative impact on aboveground biomass, which was reported by Li et al. (2007) for the Tianshan Mountain region of Xinjiang, China. The variation in dry biomass yield between the two years can be explained by differences in precipitation. According to the weather station records at each pasture site (installed by the WATERCOPE project), the cumulated annual rainfall received in 2013 reached 188 mm (average across the 3 altitudes), compared to 133 mm in 2014. According to various studies (Fay et al., 2000; Miranda et al., 2009; Kidron, 2014; Xu et al., 2014), biomass production shows a strong positive correlation to precipitation.

The quality of the plants growing on pastures is an important factor for livestock productivity (Ramirez et al., 2006; Ben Salem & Smith, 2008; Lugassi et al., 2015). The nutritive value of the vegetation depends on forage species, growing conditions, plant fraction and stage of maturity at sampling time (Wilson, 1977; Lambert et al., 1989; Papachristou & Papanastasis, 1994; Pearson & Ison, 1997). The vegetation quality is evaluated by indicators such as CP, NDF and ADF concentration and digestibility (Lugassi et al., 2015). The nutritional quality of the pasture vegetation in our study varied between different seasons and years – the latter may in part be due to the mentioned differences in rainfall between 2013 and 2014 (Cline et al., 2009). In both years the CP concentration in spring vegetation was higher than in biomass samples collected in summer, which can be ascribed to the high proportion of mature leaves and twigs in the latter samples (Boufennara et al., 2012). It has been reported that high temperature increases cell wall constituents and lignification but decreases CP and soluble carbohydrate concentration as well as digestibility (Pearson & Ison, 1997). This also shows in the present results where high CP concentration is paralleled by lower NDF and ADF concentrations. The Ca content of vegetation in the present study was lower than the average Ca content of pastures reported from Inner Mongolia (22.7 g kg^{-1} DM; Narisu et al., 2013) and Ningxia district, China (12.6 g kg^{-1} DM; Fujihara et al., 1995), but was higher than the Ca concentration of diets (1.5 to 2.6 g kg^{-1} DM) recommended by the Australian Agricultural Council (1990). Differences between the concentration of Ca in the present vegetation samples and values reported in literature may be partly explained by the botanical composition of the vegetation, plant growth, season, soil characteristics and grazing history (Khan et al., 2009). Phosphorus concentrations in the forage were higher in spring than in summer, with values decreasing throughout the grazing season, which can be mainly attributed to the increase in dead biomass (Bedia & Busqué, 2013). A high C/N ratio of forages reduces their digestibility and finally feed intake (Kumar & Soni, 2014), whereas a higher CP concentration positively influences diet digestibility (Al-Asfoor et al., 2013). Moretto and Distel (1997) reported that leaves of palatable grasses have a higher CP concentration and lower C/N ratio and lignin concentration than those of unpalatable grasses. A Ca/P ratio of 2:1 is usually recommended for ruminant diets (Kumar & Soni, 2014); since the Ca/P ratios of pasture vegetation in both years of study were higher than 2.00, this imbalance may lead to P unavailability / antagonism and thus decrease growth performance and the effectiveness of transformation of forage into animal products (Jacobson et al., 1972; McDowell, 1992).

3.4.2. Characteristics of animals' grazing itineraries

Livestock mobility is critical for local livelihoods, trade, and coping with climate change (Clifton & Louhaichi, 2015); it is practiced by pastoralists to cope with variability and unpredictability of limited forage resources (McAllister, 2012). The movement of livestock and their spatial distribution depend on many factors such as availability, distribution and composition of forage (Adler & Hall, 2005; van Beest et al., 2010). The length of daily grazing itineraries in this study varied between seasons, years and species. In spring season of both 2013 and 2014, the daily grazing distances were longer than in early and late summer in both goats and sheep, which may due to the favorable weather conditions and availability of sparse but highly preferred herbs in this season (Nording, 2008). Similarly Schlecht et al. (2009) reported that walking distances of goats in northern Oman were longer in spring than in autumn. They also reported that the distance was longer with higher forage availability, which matches our results that both species had longer itineraries in 2013 where the amount of biomass DM on pasture was twice that of 2014. Except for goats in the early summer season of 2013, the lengths of grazing itineraries of goats and sheep in the same season (in 2013 and 2014) were not different; this may be due to the fact that both species grazed in the same area in both years. The mean daily walking distances were 8,070 to 12,950 m in goats, and 8,780 to 14,620 m in sheep, respectively. These distances were shorter than the walking distances of Arbas Cashmere goats (8,200 to 14,000 m; Jin et al., 1998), and longer than the walking distances of sheep (4,700 to 6,400 m; Lin et al., 2011) in Inner Mongolia, China. Lu (1988) reported that goats travel longer distances than sheep to find desired forage, whereas studies from Switzerland (Leiber et al., 2009) and Greece (Evangelou et al., 2014) reported that goats prefered to graze nearby shrub lands while sheep extended the explored area in order to reach habitats dominated by Poacea, which resulted in longer distances travelled by sheep in comparison to goats.

3.4.3. Animal grazing behavior and feed intake

Grazing patterns of goats and sheep differed depending on day time, with the longest period of grazing realized in the afternoon and the shortest in the morning. These results are in agreement with studies from semi-arid India (Shinde et al., 1997), continental Australia (Lynch et al., 1992), steppe pastures of Inner Mongolian (Lin et al., 2011) and a mountain karst area in Slovenia (Bojkovski et al., 2014). The reason for this, on the one hand, is that ruminants tend to avoid the hottest part of the day for grazing (Bojkovski et al., 2014). On the other hand, the concentration of total nonstructural carbohydrates of the forage in the evening is higher than in the morning (Sauvé et al., 2009). The seasonal variation in grazing activities of small ruminants may be due to herbage availability and growth stage of vegetation (Wang, 1997; Animut et al., 2005), as well as (increasing) air temperature which has previously been recognized as the most important direct environmental factor that affects grazing behavior (Groberek et al., 2004; Fischer et al., 2008).

The voluntary feed intake of grazing ruminants is influenced by several factors (Decruyenaere et al., 2009); among others, sward characteristics such as leaf morphology, hair occurrence, leaf size (Barre et al., 2006) as well as stem physical properties are known to stimulate or limit animal foraging behavior (Provenza, 2005). The

OM digestibility of the diet, as assessed from the fecal nitrogen concentration (Wang et al., 2009) was low in spring of both years, and increased in summer (late summer 2013 / early summer 2014). Higher carbohydrate concentration in more mature plants in summer as compared to spring could be one explanation for the increase in OM digestibility (Decruyenaere, 2015). The daily OM intake of goats (g $kg^{-0.75}$ LW) determined in the present study (59 - 74) was lower than values (87 - 107) obtained for goats in Oman (Schlecht et al., 2008; Dickhöfer, 2009). The daily DM intake (g $kg^{-0.75}$ LW) determined in spring and late summer 2013 (62.8 and 62.5) was very close to the average DM intake requirement (62) recommended for goats by NRC (2007), and the values obtained for early summer 2013, spring, early and late summer 2014 were even 16-28% higher. The intake of CP, Ca and P (g $kg^{-0.75}$ LW) also exceeded goats' average requirements of 4.19, 0.11 and 0.09, respectively (NRC, 2007) by 0.9-1.2, 3-7 and 0.3-7.8 times. Except for differences in NDF intake between spring 2013 and 2014 and ADF intake between 2014 spring and summer, the intake of other proximate diet constituents did not differ between seasons or years. This may be explained by the herbage abundance on the seasonal pastures in both years, as a biomass yield above 1000 kg DM ha^{-1} does not limit feed selection and intake of grazing small ruminants (Animut et al., 2005). The goats may thus have had the possibility to select plant species or plant parts of higher nutritional quality than the average forage on offer. Similar results were reported by Zemmelink and t'Mannetje (2002), namely that an increasing level of feed allowance results in higher intake and better opportunities for selection and consequently a higher nutritive value of the diet consumed.

3.4.4. Organic matter and nutrient excretion

The most reliable method for calculating forage intake of grazing ruminants consists in the total quantification of fecal excretion (Kozloski et al., 2014). Despite of differences in the DM concentration of available forage on spring and summer pastures, the DM concentration of goats' feces was very constant across seasons and years, which was also reported by Wang and Li (1997). Utilizing the concentration of N in feces to derive diet digestibility and from there estimate forage intake is recognized as a direct and accurate method (Kozloski et al., 2014). Peripolli et al. (2011) reported that the correlation between fecal N concentration and OM intake is strong and significant for all types of diets. The significant variation in fecal NDF between the seasons indicates differences in the degree of digestibility or availability of feed, or a combination of both (Erasmus et al., 1978). In all seasons (both years) the fecal N concentration was higher than that of the biomass on offer; this might to some extent point to a high proportion of undigested dietary N (NDF-bound N) in feces, which resulted in relatively higher fecal N concentrations for situations with a high C/N ratio of the forage. This is in accordance with findings of Al-Asfoor (2010) that ruminal digestion decreases the high C concentration of low quality plant material to a larger extend than the relatively lower C concentration of high quality plant material, while fibre-bound N increases in feces, resulting in a narrower fecal C/N ratio especially with fibrous diets. The P concentration of feces was much higher than that of the feed on offer; as the only path of P loss in the adult ruminant is through feces (Kibria et al., 1997), the P-enrichment in feces relative to the consumable biomass points to an unavailability of P for the animals due to the above-mentioned (3.4.2) high Ca/P ratio of the forage.

3.5. Conclusions

This study provides some first insights into the grazing behavior and feed intake of small ruminants as well as into quantitative and qualitative biomass offer on natural rangelands in the westernmost part of the Chinese Altay. For a sustainable use of the natural rangelands in this region, it is important to understand the interactions between aboveground net primary production and animal performance. Grazing behavior of goats and sheep differed between seasons and species due to variable weather conditions, fodder availability and day length. Despite the variation in forage availability between the two years of study, the feed and nutrient intake of goats seemed to be unrestricted. However, drought spells or years and ongoing pasture degradation caution a too optimistic appreciation of the present findings. Regular monitoring of grazing patterns and intensity, and of vegetation quantity and quality on the natural rangelands would help the responsible governmental bodies in developing sustainable pasture use and management plans and controlling grazing pressure in the study region.

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Chapter 4 Reproductive performance and herd development of small ruminants under pastoral management in the Altay Mountains of Xingjian Province, China

Summary: Small ruminants play a very important role in the life of transhumant households in the Chinese Altay mountain region. Sheep and goats are socially, environmentally and economically preferred species and make a valuable contribution to household income. A progeny history interview on breeding female sheep (n=120) and goats (n=73) as well as their offspring (sheep=289; goats=185) was conducted. Based on the results, reproduction parameters were calculated and entered into PRY Herd Life model to simulate herd development under current management (status quo) and three alternative scenarios, namely (i) improved culling (IC), (ii) improved feeding (IF) and (iii) improved culling plus improved feeding (IC plus IF).

The average age at first parturition was 20.9 ±5.48 months for sheep and 18.6 ±7.41 months for goats. The parturition interval was 12.6 ±3.45 months and 13.4 ±4.67 months for sheep and goats whereas reported offspring mortality was low in sheep (1%) and higher in goats (5.4%). The scenario analysis showed that improved culling would stabilize livestock numbers and slightly increase (+3%) the monetary output per goat, but the annual monetary output per sheep would decline considerably (-25%). Improved feeding could increase herd expansion rate, offtake rate as well as the annual monetary output per animal, but extra feeding costs would exceeded the revenues.

From these insights it is concluded that under the current economic situation, herders' actual flock management (SQ) appears most profitable for sheep in terms of annual monetary output, whereas an improved culling strategy could be adopted to increase revenues from goat herds, calling for a species-specific culling management of the two jointly herded species.

4.1. Introduction

In the developing world, livestock are a key to livelihood security for many smallholder farmers (Owen et al., 2004; Upton, 2004) and are often used as indicators of wealth. Animals are often an important source of household cash income. Especially in poor families, safeguarding and increasing the returns from their livestock assets is expected to help them in their endeavour to escape poverty (Brown, 2003; Delgado, 2003; ILRI, 2003, 2007; Reist et al., 2007; Catley, 2008; Pica-Ciamarra, 2009). Around 987 million poor people (or about 70% of the world's 1.4 billon "extreme poor") depend on livestock for their livelihoods (Ashley et al., 1999; FAO, 2009). Small ruminants, especially indigenous breeds, are widespread and important to the subsistence, economic and social stability of numerous people in developing countries (Kosgey, 2004). These animals have lower feed and capital requirements than larger species, making them suitable for smallholder producers (Devendra & Thomas, 2002). Small ruminants also play a complementary role to other livestock in the utilization of available feed resources and provide a means of using vast areas of natural grassland in regions where crop production is not possible (Baker & Rege, 1994). Goats and sheep are also the preferred species in the so-called drylands of the world, in warm as well as in cold climates. Ranking of their major products milk, meat, fiber, manure and skins depends on local customs, preferences and demand, including that of the household, and access to markets.

In 2008, there were 353 million small ruminants in the dry areas of Caucasus (CAC), West Asia and North Africa and some countries of Latin America (FAO, 2010), and it was estimated that 82% of this population is owned and raised by smallholders. Between 2003 and 2008, the statistics (FAO, 2010) show an increase in sheep and goat numbers, respectively, in CAC of 54% and 98%.

The livestock revolution (Delgado et al., 1999) has occurred across most of the developing world but most obviously in China (Zhang, 1999; Fuglie et al., 2004; Waldron, 2007), where the demand for livestock products, particularly meat and milk, has been increasing rapidly. Rae (2008) reported that the consumption of dairy products and poultry between 1990 - 2006 increased by 296% and 144% in urban households, and by 392% and 179% in rural households, respectively. Verburg et al. (1999) stated that sheep and goats in China are also important for their wool, mohair and cashmere production. China has so far largely supplied this growth from domestic production - primarily from increases in animal numbers, although productivity growth has also been significant (Rae et al., 2006). Alone from 1995 to 1996, sheep numbers have increased by 4.3%, and goat numbers by 14.1%. According to Zhu et al. (1999) and Verburg et al. (1999), there are about 133 million sheep, and 171 million goats in China and these numbers are still increasing, with major implications for land use.

The area in which this study has been conducted is Altay Prefecture in northern Xinjiang Uyghur Autonomous Region, China. Pastoralism is the predominant form of land use and the area of rangeland accounts for 81.8% of Altay's total area. Small ruminants are widespread in Altay, accounting for 75% of the total livestock (more than 2.7 million head) in the region (Xinjiang Statistics Bureau, 2013). Therefore, pastoralism also forms an important source of livelihood in the region, and 50.2% of the total population (663,410) can still be characterized as agro-pastoralist (Xinjiang Statistics Bureau, 2013). The livestock farming is dominated by transhumant grazing systems and contributes nearly 60% of the value of agricultural production in Altay (Reynolds, 2006). Small ruminants here play a complementary role to other livestock species, especially in the utilization of feed resources available on vast areas of natural grassland in regions where crop production is impossible due to lack of water; in the whole area, crop farming is only possible on irrigated surfaces. Small ruminants are also important for the socio-economic wellbeing of people that is nutrition (meat, milk), income generation from live animal sales (see Chapter 2) and intangible benefits. However, overgrazing of rangelands by small ruminants is currently strongly discussed in China (El Aich & Waterhouse, 1999). The local herders practice seasonal grazing of low altitude pastures in the Dzungarian basin in winter, and of alpine meadows (at >1500 m altitude) in the Altay Mountains, especially in spring/autumn and summer (Jordan et al., 2016), and especially the mountainous grasslands are suffering from severe grazing damage (Fu et al., 2015). Waldron et al. (2008) reported that in Altay Prefecture, the summer pastures, winter pastures and spring/autumn pastures are exposed to a grazing pressure exceeding their carrying capacity by 21%, 28% and 138%, respectively. Apart from the ecological damage of such practice, this also threatens the productivity of the livestock herds. Therefore, management options must be identified which maintain the primary production and biodiversity of the lowland and high altitude pastures alike and by this sustain the productivity of livestock, in particular small ruminants, to meet the livelihood needs of their owners. Since sustainable rangeland and herd management are closely intertwined, highly flexible mobile grazing schemes and active herding (Jordan et al., 2016), along with a strict control of mating and annual herd expansion as well as adequate supplementary feeding of the herd during winter (Addison & Brown, 2014) are the key elements of sustainable rangeland and herd management practices in the study region and similar cold drylands in within China and the neighbouring countries of Mongolia and Central Asia.

Within this context, the objectives of the present study were to analyse the current reproductive performance and annual herd expansion of sheep and goat herds in Qinghe County and to compare these to three different options of supposedly sustainable herd management practices by using the bio-economic PRY Herd Life Model (Baptist, 1992). This model has been applied to evaluate herd management scenarios for goats in Oman (Dickhoefer et al., 2012), cattle in Niger (dos Santos Neutzling et al., 2010), camels in Kenya (Kaufmann, 2005; Olukoye et al., 2005), pigs in China (Riedel et al., 2014), and to various antelope species in Kenya (Fink & Baptist, 1992). Using the model for simulating possible developments of pastoral small ruminant flocks in the Chinese Altay Mountains should allow evaluating alternative management scenarios for small ruminant herds which improve their productivity without compromising the natural resources base they live off.

4.2. Materials and methods

4.2.1. Study location and animal species

The study investigated the transhumant pastoral system in the Altay Mountains, Qinghe County (46°43' N, 90°24' E, 1463 m a.s.l), Altay Prefecture, China. The prefecture is located in the northern part of Xinjiang Uyghur Autonomous Region, to the north of the Dzungarian basin, and borders Russia, Mongolia, and Kazakhstan. Within the prefecture, Qinghe County is directly bordering Mongolia on the east and northeast. Situated in the south-eastern range of the Altay Mountains, its complex landforms alternate between mountains and basin areas (Fu et al., 2015). The regional climate of this temperate continental semi-arid to arid zone is characterized as BWk / BSk (arid cold desert / steppe climate) according to the Köppen-Geiger system (Peel et al., 2007). In Altay prefecture, the mean annual temperature is 3.7°C, the annual temperature range spans over 30°C, the annual precipitation and evaporation are 171.5 mm and 1814.9 mm, respectively, and the frost-free period lasts for 131 days (Li et al., 2006).

Qinghe county governs seven towns and is inhabited by 16 ethnic groups with a total population of 61,443 and a minority population of 49,941 (Asian Development Bank, 2010). A lot of irrigated wheat and corn is grown in the county; livestock husbandry focuses on cattle, sheep, goats, horses and camels (Asian Development Bank, 2010).

The Altay breed of sheep is one of the Kazakh group and originated in the dry but cold mountain basins of China. It is one of the fat-rumped (or fat-tailed) sheep renowned for producing carpet wool. The Kazakh types are found in the desert and mountainous regions of China in west Xinjiang. Altay rams average 82 kg and ewes 69 kg. The height of the mature Altay varies from 72 to 76 cm depending on the sex. New born lambs weigh around 4.5 kg. The Altay sheep is grown primarily for meat with wool being a secondary product (Cheng, 1985).

4.2.2. Study design

In summer 2012, a five-month Participatory Rural Appraisal (PRA) was conducted with 258 rural households involved in various crop farming and livestock-keeping activities (Chapter 2). The households were selected at predefined locations following a decreasing temperature and increasing altitude gradient from low land winter pasture in the Dzungarian desert and at mountain foothills to high altitude summer pastures (see Chapter 2, Figure 2.1) along the Qinghe River. Each household was individually interviewed, whereby questions targeted household structure, animal management and pasture use (see Chapter 2). Based on the information provided by the 258 households, three major household activities were distinguished: (i) *commercial crop farming plus subsistence vegetable cultivation and occasional livestock keeping* (CV), (ii) *commercial crop farming plus subsistence livestock keeping* (CL), and (iii) *commercial livestock keeping plus subsistence crop farming and vegetable cultivation* (LCV).

4.2.3. Body weight development of small ruminants

In summer 2014, a total of 543 sheep were weighed. These animals were owned by seven LCV households who were selected based on the location of their high-altitude summer pasture (see Chapter 2, Figure 2.1). The size and composition of their small ruminant herd closely corresponded to the average number of livestock per household of 279 animals with about 90% thereof being small ruminants, in particular sheep. All approached households agreed to have their sheep weighed. The animals were grouped according to age classes (0-1, 1-2, 2-3, 3-4, 4-5, 5-6 years) and were weighed once by using a tripod-based battery-powered suspension balance (range 0–300 kg, accuracy 0.5 kg) to establish an age-for-weight curve. For goats, initial body weight development until the age of 6 months was adopted from Al-Nakib et al. (1996). Thereafter, body weight development was interpolated until the age of 24 months when goats normally reach 80% of their final body weight (Gall, 2001).

4.2.4. Market survey

The prices for live sales of small ruminants of different sex and age were obtained during the baseline survey in 2012 (Chapter 2). The obtained values were divided by the respective body weight (by sex and weight classes) to obtain the price per kg of body weight. The fiber yields and prices were obtained from similar studies in the region (see Appendix 4.3). All monetary values were calculated in Euro based on the World Bank exchange rate between Chinese Renminbi to Euro for the years 2007 and 2013, depending on context.

4.2.5. Reproductive performance and scenario analyses

Interviews on the progeny history (Kaufmann, 2005) of 120 breeding ewes and 73 breeding does were conducted to determine their age at first parturition, the frequency of abortions, of still, single and multiple births, the kidding intervals and the mortality of sheep and goats of different age. If a herder did not remember the exact month in which an event occurred, the season of the year was recorded and January, April, July, and October were taken as approximate dates for events occurring in winter, spring, summer, and autumn, respectively. In addition, culling of old or infertile breeding animals, offtake (sales and home-consumption) of surplus stock and general aspects of breeding as well as feeding management were recorded. Further on, the term “culling” is used to comprise any deliberate form of offtake of animals from the herd. The variables obtained in the progeny history survey were fed into the PRY Herd Life Model (Baptist, 1992) to describe the current productivity of sheep and goats, simulate herd development and test various breeding and culling management options. PRY simulates the development of the size and composition of livestock populations over time given a specific age at first parturition, kidding interval, prolificacy and mortality rate, thereby accounting for the proportion of breeding females that are culled due to sickness, low performance or old age. According to the specific culling and offtake ages of breeding females, males and surplus females, the potential annual animal offtake is calculated.

The reproductive performance of small ruminants depends on both genetic and environmental factors, whereby in the study region animals are particularly sensitive to the latter. To determine the productivity of the local sheep and goat population under current management and to compare this to simulated improved management approaches, a scenario analysis was conducted.

The first scenario, *improved culling* (IC) aimed to increase the herd output without compromising the reproductive performance. For this, the culling rate of older breeding females of both species was set to 80% at an age of 60 months (when the reproductive performance starts to decrease) and increased to 99% at 100 months of age for sheep and 90 months of age for goats. For younger breeding females, males, and surplus females the culling and offtake ages and rates determined in the progeny history interviews were chosen.

The second scenario, *improved feeding* (IF), represents a semi-intensive management system where small ruminants are predominantly grazing natural pastures but benefit from increased homestead feeding during four months in winter. While the feed energy was assumed to average 9 MJ of metabolisable energy (ME) per kg of feed dry matter (DM) across the year in the current setting (*status quo*, SQ) as well as in scenario IC, improved winter feeding (concentrate supplementation) was assumed to increase the annual average feed energy content to 10.5 MJ ME/kg DM (N. Togtokhbayar, Professor of Animal Nutrition, Research Institute of Animal Husbandry, Mongolia University of Life Sciences, Ulaanbaatar - personal communication). This is achieved by 4 months of winter supplementation to the breeding females, with a supplement feed intake (DM) for sheep of 1.2 kg DM/d and for goats of 0.78 kg DM/d. As compared to SQ, this improved nutritional situation was assumed to lower age at first parturition and parturition interval to 18 months and 12 months, respectively, for both sheep and goats, and increase litter size to 1.10 for sheep and 1.18 for goats (Table 4.1).

The third scenario assumed a concomitant implementation of *improved culling plus improved feeding* (IC+IF), in order to test whether the combination of the two management strategies would further increase the annual monetary output.

For the modelling exercises, the male mortality of both sheep and goats was taken from Begzsuren et al. (2004), and daily feed energy intake as well as the metabolisable energy (ME) concentration of the natural pasture vegetation was taken from Togtokhbayar (2006). The energy efficiency for lactation and gestation, as well as the metabolic exponent for body weight for both sheep and goats were taken from Drochner (2003). The litter weight gain from milk, milk energy content, energy intake per kg body weight gain, maintenance energy requirements and energetic efficiency coefficient values for goats were taken from Drochner (2003) and for sheep from Torres-Hernandez & Hohenboken (1980), Chiba (2009), Chadraabal et al. (2011) and Nie et al. (2015). The values for annual fibre yield were taken from Yokohama et al. (2009) for goats and Chadraabal et al. (2011) for sheep. Other values were obtained from the own survey (Appendix 4.3). The daily supplement feed intake (DM) on winter pasture for sheep (1.2 kg DM/d) were taken from Hu et al. (2014) and Li et al. (2015); for goats (0.78 kg DM/d) data of Sun et al. (2014) was taken. According to the interviews and official market price data, the price of hay and concentrate feed (mainly maize) was set at 0.8 ¥/kg DM and 2.2 ¥/kg DM, respectively (1 € = 7.95 ¥, World Bank Exchange Rate, 2012). Other fix and variable costs of small ruminant production, such as housing, veterinary care, pasture use and labour (for herding and hay making) was not considered.

Table 4.1 Reproductive performance of sheep and goats in transhumant grazing systems of Qinghe County, China, under current (SQ) and improved management regimes (IC, IF, IC+IF) as inputted into the PRY Herd Life Model.

Species	Parameter	Unit	SQ	IC	IF	IC+IF
Sheep	Age at first parturition	months	20.9	20.9	18.0	18.0
	Kidding interval	months	12.6	12.6	12.0	12.0
	Litter size	n parturition^{-1}	1.0	1.0	1.10	1.10
	Mortality rate	%	8.0	8.0	5.0	5.0
Goats	Age at first parturition	months	18.4	18.4	18.0	18.0
	Kidding interval	months	13.4	13.4	12.0	12.0
	Litter size	n parturition^{-1}	1.1	1.1	1.18	1.18
	Mortality rate	%	8.0	8.0	5.0	5.0

SQ: *Status quo,* parameters determined in progeny history interviews; IC: improved culling of old-age breeding females; IF: improved winter feeding of all animals in the herd; IC+IF: combination of IC and IF measures.

4.2.6. Statistical analyses

Sheep and goats were statistically compared for age of breeding females, number of offspring, age at first parturition, average parturition interval, parturition rate, mortalities, culling rate (includes offtake) and exit reasons.

Data were analysed with SPSS for Windows, Version 20 (IBM Corp, 2013). The results obtained for interval scaled data were specified as mean value ± standard deviation. The design-based Chi-squared test was applied to categorical data; comparison was done between species and between sexes within species. Pair-wise comparison of means was computed using the independent t-test for normally distributed and the Mann-Whitney U-Test for non-normally distributed data sets after normality was assessed by the Shapiro-Wilk test. Welch's t-test was used for cases of unequal group variances or sample sizes (Feldt, 2015).

To determine the body weight of sheep at the moment of sale and slaughter (see 4.2.5), growth curves for female and male animals were established separately. The Brody, Gompertz, Logistic, Bertalanffy and Richards models (Brown et al., 1976; Gbangboche et al., 2008) were compared to determine which model best described the growth curves, and the following Logistic model fitted best:

$$y = A * (1 + b * e^{-k*t}) \qquad \textit{Eq1}$$

Where y is the body weight (kg), A is the asymptote (=adult body weight), t is age in months, b and k are function variables, and e is Euler's number.

Due to goats accounting for only a very small proportion of small ruminants compared to the sheep (Appendix 4.1), it was not possible to weight enough animals to determine a growth curve for the local goats. Therefore, goat body weight data from neighbouring Bulgan county on the Mongolian site of the Altay Mountains were used (Sabir et al., 2015) in the PRY herd model. For adult goats, only non-pregnant females and castrated males were weighted. Von Bertalanffy's model (Von Bertalanffy, 1957) fitted best to the goat weight data:

$$y = A * (1 - b * e^{-k*t})^3 \qquad \textit{Eq2}$$

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

All model parameters were estimated by the Gauss–Newton iterative procedure (Brown et al., 1976), using the software R (R Core Team, 2014).

4.3. Results

4.3.1. Body weight development of sheep

The average body weight (Figure 4.1) of all male sheep (n=115) was 35.6 ±20.47 kg, whereas for all females (n=428) it was 52.5 ±14.36 kg, with significant differences between sexes ($p \leq 0.05$). The average body weight of adult male (n=19) and female (n=337) sheep was 71.1 ±14.66 kg and 58.7 ±6.36 kg, respectively. The maximum and minimum body weight was 84.3 kg and 6.5 kg in male sheep and 75.3 kg and 7.1 kg in female sheep. The average body weight predicted by the Logistic regression model for all male and female sheep was 34.4 ±18.90 kg and 52.5 ±13.32 kg, and 69.5 ±19.04 kg and 58.6 ±2.75 kg for adult males and females, respectively. The reason for the higher average body weight of female than male sheep was the different number of male and female sheep per age group kept in the herd (Figure 4.2). Herders used to keep only a few adult breeding males, so that the proportion of young animals (<24 months) was 83.5% for males and 21.2% for females, whereas the proportion of adults (≥24 months) was only 16.5% for males compared to 78.8% for females.

The average body weight across all male (n=208) and female (n=237) goats weighed in Bulgan county, Mongolia (T. Munkhnasan, pers. communication) was 46.1 ±13.63 kg and 37.4 ±8.27 kg, respectively with significant differences between the sexes ($p \leq 0.05$). The adult (male=191; female=213) and young (male=17; female=24) body weight was 48.7 ±10.93 kg and 39.3 ±5.91 kg, and 17.0 ±2.81 kg and 20.1 ±5.69 kg, respectively. The maximum and minimum body weight was 71.9 kg and 12.0 kg in males, 61.5 kg and 11.0 kg in females. The average body weight predicted from von Bertalanffy's model for all male and female goats was 46.3 ±11.29 kg and 37.0 ±6.75 kg, and 48.8 ±7.59 kg and 39.1 ±2.50 kg for adult males and females, respectively.

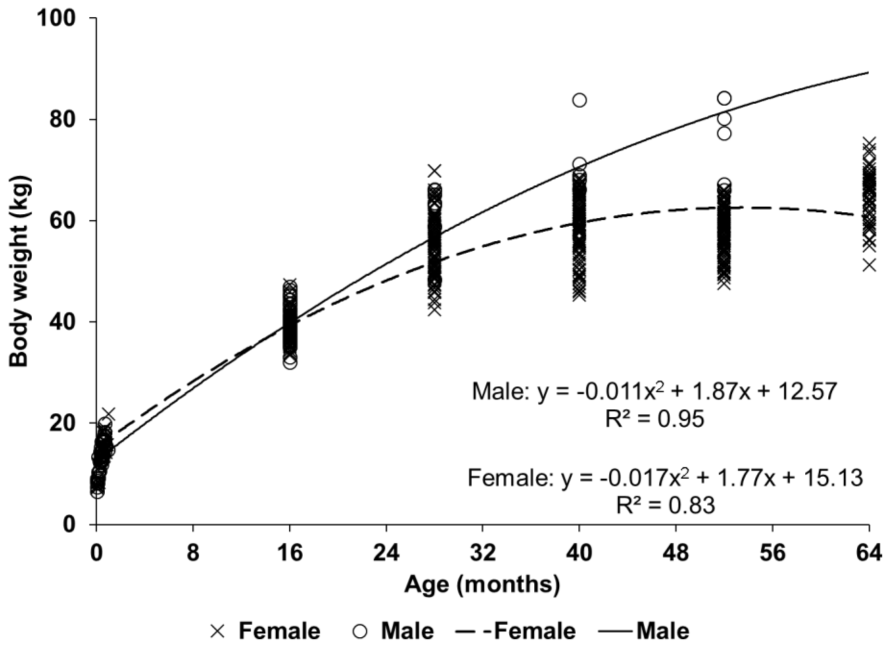

Figure 4.1 Body weight development of 115 male and 428 female sheep until 60 months of age as determined by weighing in summer 2014. Regression lines were computed by a Logistic function (4.4.1). Filled dots represent male and empty dots female weight data.

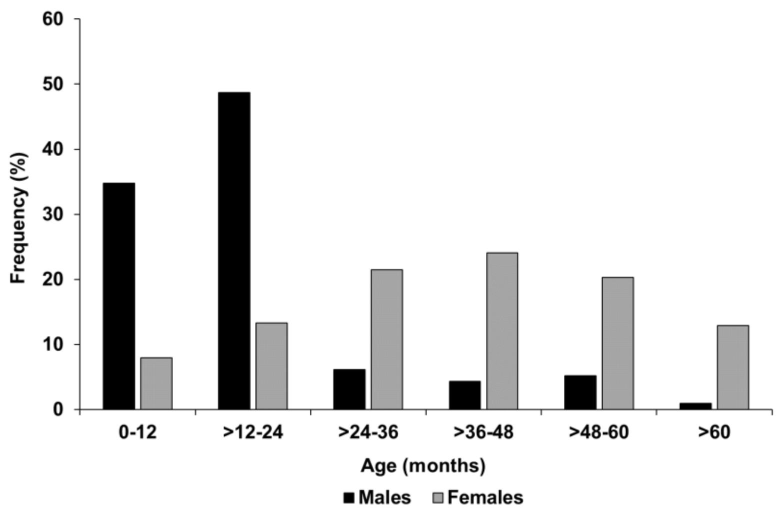

Figure 4.2 . Frequency distribution across pre-set age classes of the 115 male and 428 female sheep sampled for their body weight.

4.3.2. Reproductive performance

Age of breeding females

The age distribution for breeding ewes and does is shown in Figure 4.3. The average age of breeding goats was 40.2 ±17.81 months as compared to 41.8 ±19.47 months for breeding sheep ($p>0.05$). In both species, the youngest breeding female sampled was 16 months old. The maximum age was higher in sheep (100 months) than goats (90 months), but the age structure was the same for both species, with about 65% of breeding females younger and the rest older than 4 years.

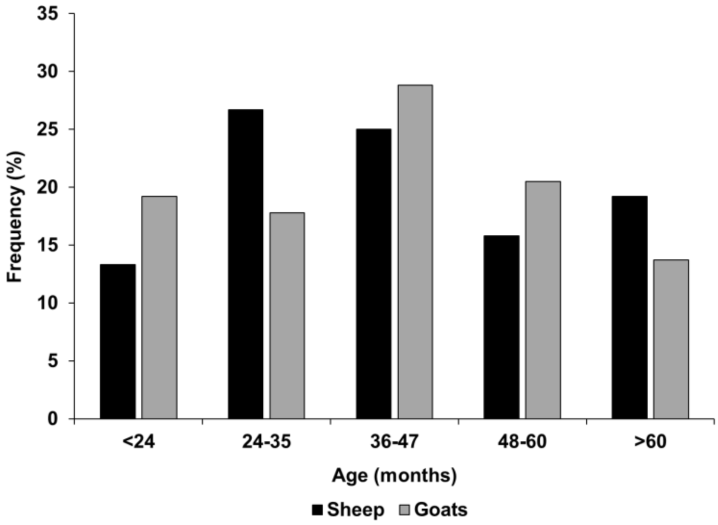

Figure 4.3 Age of sampled breeding ewes (n=120) and does (n=73) at the time of interview.

Number of parturitions, age at first parturition and parturition interval

The average number of parturitions in a breeding female's lifetime (Figure 4.4) was 2.5 ±1.62 for goats and 2.4 ±1.34 for sheep ($p>0.05$). The average age at first parturition (Figure 4.5a) was 18.4 ±7.41 and 20.9 ±5.48 months for goats and sheep, respectively ($p\leq0.05$). The largest proportion of breeding females gave birth for the first time at the age of 12 to 24 months in goats (49.3%) and 24 to 36 months (72.5%) in sheep. The earliest parturition age for goats and sheep was 9 and 12 months, respectively, the latest was 36.5 months in both goats and sheep.

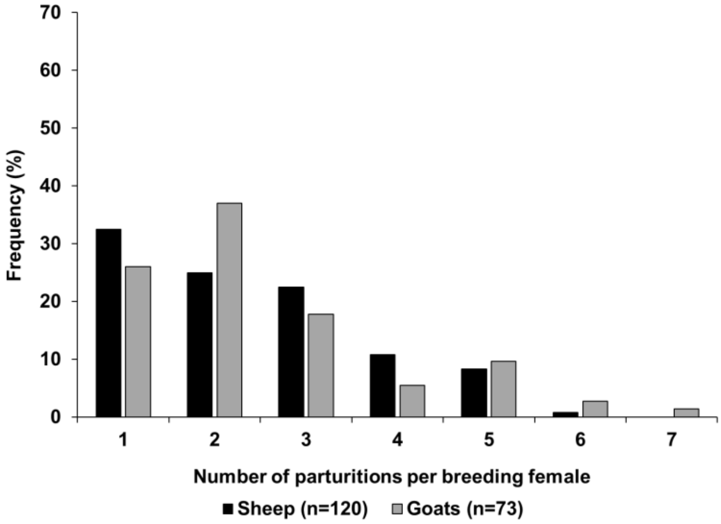

Figure 4.4 Number of parturitions per sampled female breeding ewe and doe.

The average length of a parturition interval (Figure 4.5b) for goats and sheep was 13.4 ±4.67 and 12.6 ±3.45 months, respectively ($p>0.05$). The largest proportion of breeding goats (71.4%) and sheep (92.1%) had an average parturition interval of 12 to 23 months, with this interval being significantly more frequent than others ($p\leq0.05$), and no differences in the frequency of longer parturition intervals ($p>0.05$). The minimum and maximum parturition interval was 6.4 and 36.5 months for goats, and 11.6 and 37.6 months for sheep.

a)

b)

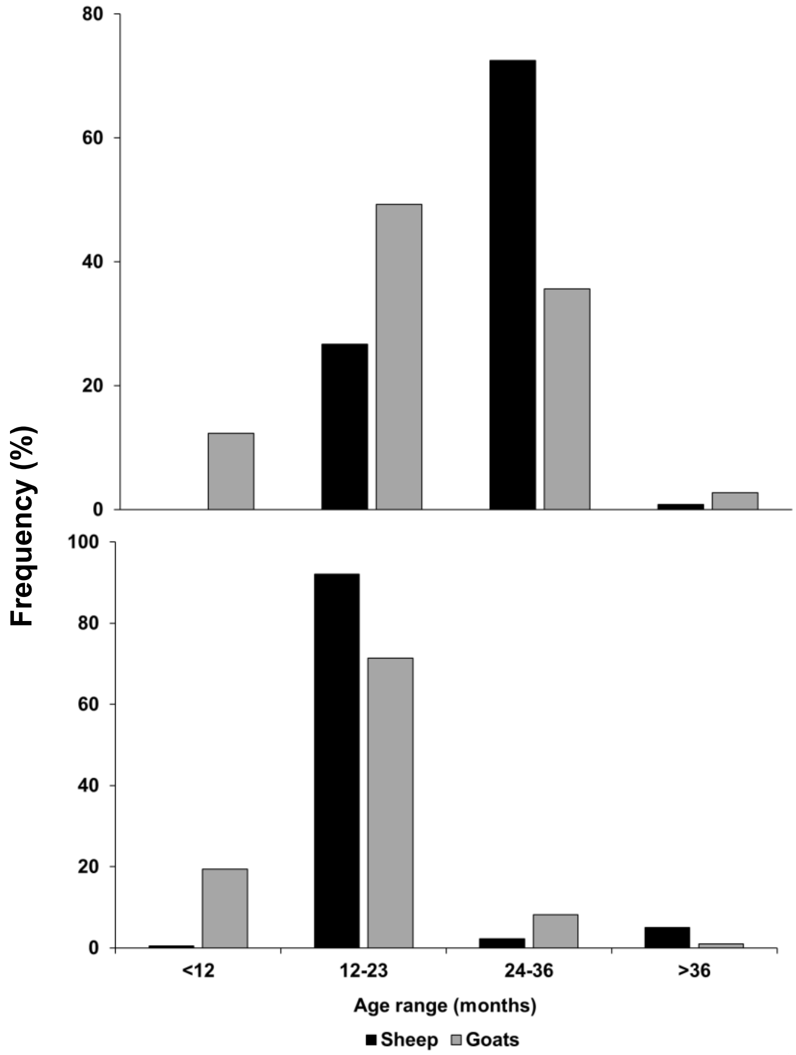

Figure 4.5 Frequency distribution for the age at first parturition (a) and the parturition interval (b) in the sampled breeding ewes (n=120) and does (n=73).

Parturition rate and litter size

The parturition rate of successfully delivering females (Figure 4.6a) was calculated for each year covered by the interviews, and was higher in goats (109.1%) than in sheep (100%). While for goats the lowest rate was observed in 2014 (106.6%) and the highest in 2011 (114.3%), no annual differences occurred in sheep. The average annual parturition rate across all breeding females - including female offspring reaching breeding age (Figure 4.6b) - was higher in goats (67.3%) than in sheep (55.3%), with the highest value for goats in 2013 (93.9%) and the lowest in 2010 (54.5%). In sheep, the highest value was 78.7% (2014) and the lowest 11.1% (2009).

The litter size was different between the two species, since no twins and triplets were reported for sheep. In goats, the single birth was most frequent (92.4%), twin births occurred with a frequency of 7.0% and triplets were very rare (0.6%). The proportion of male offspring in goats (51.9%) and sheep (56.4%) as determined from the interviews was higher than that of females.

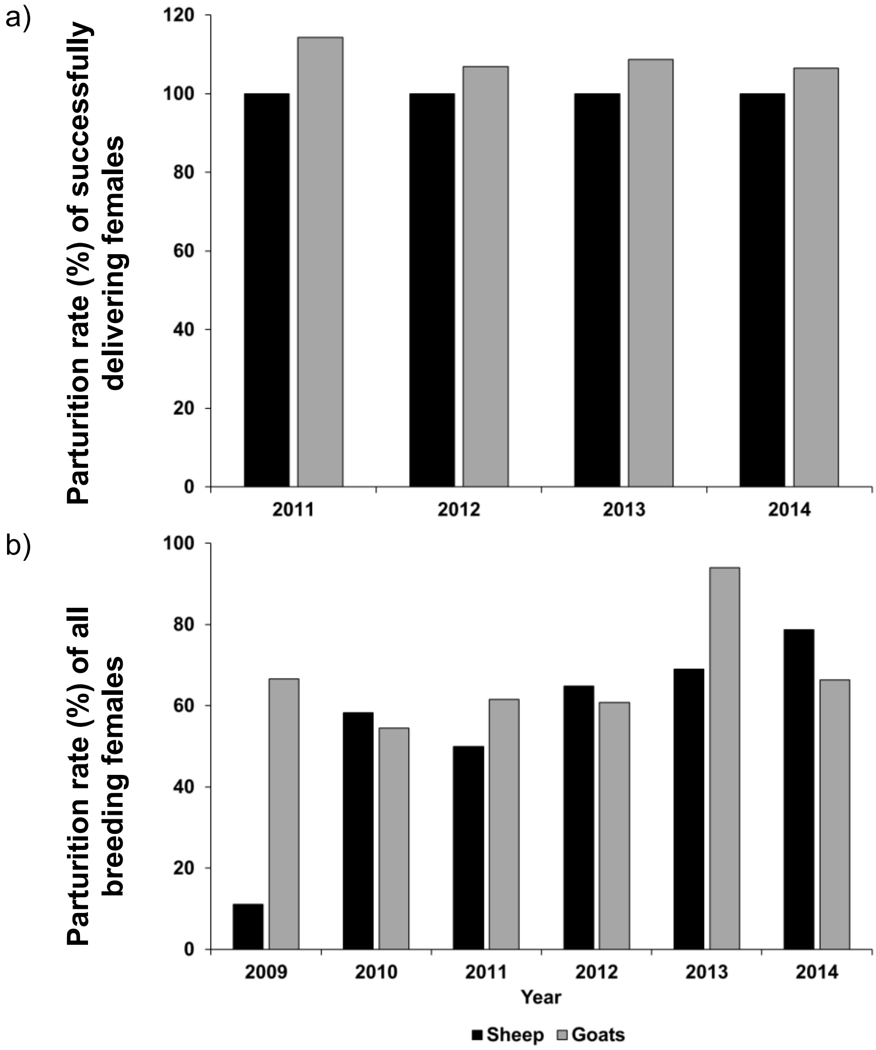

Figure 4.6 Frequency distribution for the annual rate of successful parturitions (a) and parturition rate of all females having reached breeding age (b) in the sampled sheep (n=120) and goats (n=73).

Culling rate, mortality and exit reasons

Due to the way progeny history interviews are conducted, breeding females included in the survey were still in the herd at the moment of interview; therefore mortalities and culling rates were only calculated for the offspring. Yet, the number of offspring that died at birth or was aborted was very low or not recordable for some years, therefore mortality could not be calculated in a reliable manner. The overall culling rate in goats and sheep was 14.6% and 30.5% (Figure 4.7). The culling rates tended to increase over time, with the lowest value found in 2009 for both goats and sheep (3.7% and 1.1%) and the highest in 2013 (40.7% and 46.6%). Except for 2009 and 2011, culling rates were always higher in sheep than in goats.

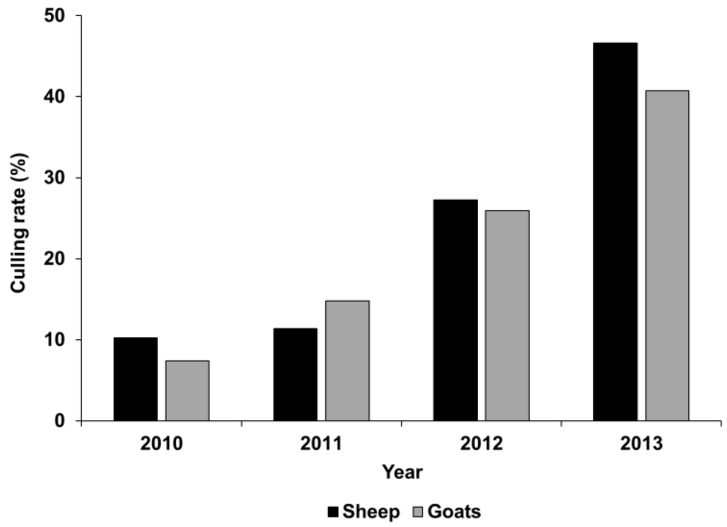

Figure 4.7 Annual culling rate in the sampled sheep (n=409) and goats (n=258).

The herd exit reasons for sheep and goats were summarized across sexes and age groups (Table 4.2). The main exit reason in goats was slaughter for family consumption (54.1%), followed by death (24.3%) and sales (16.2%). In contrast to goats, 93.4% of exiting sheep were sold and only 2.2% were slaughtered for family consumption. In terms of sex, males dominated among the exiting animals (goats 75.7%, sheep 95.6%). The average price for sold goats and sheep was different ($p \leq 0.05$), with a sheep yielding a higher price (84.0 ±12.39 €) than a goat (51.7 ±19.84 €).

Table 4.2 Exit reasons of small ruminants and prices for sold animals (period 2008-2012, total sheep=91, total goats=27).

Exit reason	Sheep		Goats	
	Male	Female	Male	Female
Died (%)	2.2	1.1	10.8	13.5
Slaughtered (%)	2.2	0.0	45.9	8.1
Gifted (%)	1.1	0.0	0.0	2.7
Stolen (%)	0.0	0.0	2.7	0.0
Sold (%)	90.1	3.3	16.2	0.0
Total (%)	95.6	4.4	75.7	24.3
Average (±SD) price (€)	83.7 ±12.49	92.7 ±3.76	51.7 ±19.84	n.a.

* Yearly average exchange rates (Chinese Yuan to €) from 2005-2013 used for the price calculation (Source: Foreign Exchange Services; http://www.oanda.com/currency/historical-rates/).

n.a.: not applicable.

Replacement of breeding females

The herders tended to keep most female offspring in the herd, yet the proportion of female offspring becoming a breeding animal differed by year and animal species (Figure 4.8). The average value of female offspring becoming breeding female was increasing in both sheep and goats. The total number of female offspring that became breeding females in sheep and goats (2010 to 2014) was 39 and 52. The lowest values in both sheep and goats were reported in 2010-2012 (10.3% and 15.4%), and the highest occurred in 2012-2014 (59% and 67.3%), respectively.

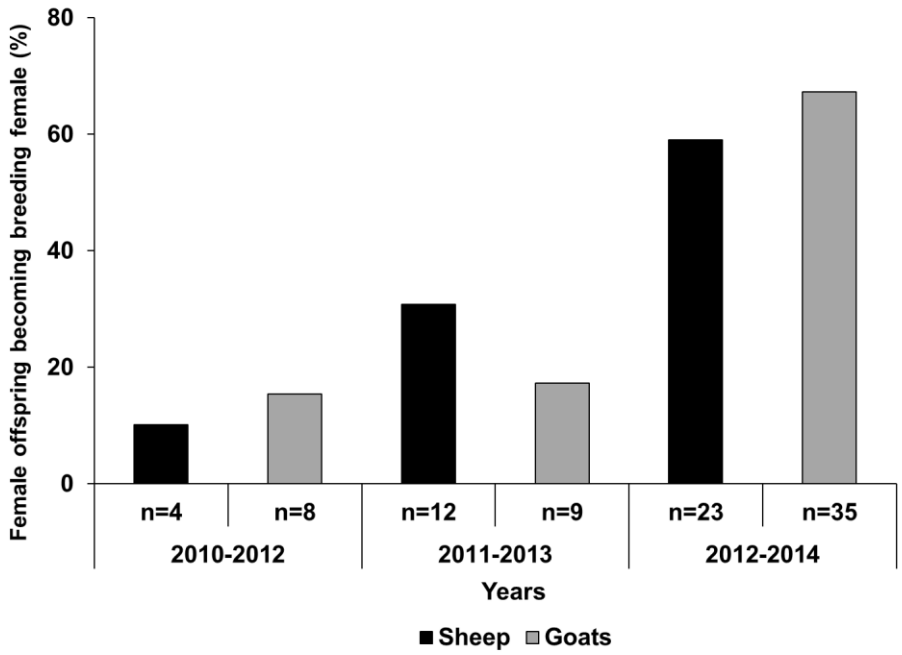

Figure 4.8 Yearly (2010-2014) percentage of female offspring of sheep (total n=39) and goats (total n=52) reaching breeding age*.

* The offspring reaching breeding age was determined according to the average age at first parturition (sheep 20.9 months; goats 18.4 months).

4.3.3. Scenario analysis

Under current management (SQ) the potential herd expansion rate and culls per year were slightly higher in sheep than in goats (Table 4.3). The annual culls for males were more than 60% in both sheep and goats, and the monetary output per average herd animal was 50.6 € for sheep and 43.7 € for goats, respectively.

In scenario IC, the annual herd expansion rate decreased by about 5% in sheep and 3% in goats (Table 4.3). Even though culling ages for breeding females, males and surplus females remained the same for both species, annual output per animal in sheep decreased by about 25% (12.8 €) in sheep and increased by about 3% (1.4 €) in goats. For scenario IF, at similar culling ages for growing males and surplus females, the decrease in age at first parturition from 20.9 (SQ) to 18 months in sheep and from 18.4 (SQ) to 18 months in goats, the shortening of the parturition interval from 12.6 (SQ sheep) and 13.4 (SQ goats) to 12 months and the increase in litter size by 10% in both species increased the annual herd expansion rate by about 7% in both sheep and goats.

Consequently, annual output per animal increased from 50.6 € (SQ) to 53.3 € (IF) in sheep and from 43.7 € (SQ) to 51.4 € (IF) in goats. The annual herd expansion rate for scenario IC+IF was 1.9% (sheep) and 3.5% (goats) higher compared to SQ, but 2% (sheep) and 3.4% (goats) lower than under scenario IF. The combination of improved culling and improved feeding did not increase the annual monetary output per animal above what was achieved under scenario IF.

Table 4.3 Production and output characteristics of sheep and goats under current (SQ) and improved management scenarios determined by the PRY herd model.

Output variable	SQ	IC	IF	IC+IF
Sheep				
Breeding females (in herd, %)	50	55	48	51
Surplus females (in herd, %)	23	18	26	22
Males (in herd, %)	27	28	26	26
Culls per year, total (%)	20	22	25	27
Culls per year, surplus females (%)	28	20	31	25
Culls per year, males (%)	68	63	61	58
Annual herd expansion rate (%)	17.5	12.8	24.4	19.4
Feed DM intake (kg/animal*year)	772	784	648	648
Output (€/animal*year)	50.6	37.8	53.3	53.2
Goats				
Breeding females (in herd, %)	41	44	36	39
Surplus females (in herd, %)	17	14	21	19
Males (in herd, %)	42	42	43	43
Culls per year, total (%)	18	19	21	21
Culls per year, surplus females (%)	27	21	30	27
Culls per year, males (%)	65	62	59	60
Annual herd expansion rate (%)	16.6	13.7	23.5	20.1
Feed DM intake (kg/ animal*year)	574	575	488	489
Output (€/animal*year))	43.7	45.1	51.4	51.0

SQ: *Status quo,* parameters determined in progeny history interviews; IC: improved culling of old-age breeding females; IF: improved winter feeding of all animals in the herd; IC+IF: combination of IC and IF measures.

DM: dry matter.

4.4. Discussion

The PRY Herd Life model is a species-independent herd model developed for the assessment of herd productivity in livestock systems (Kaufmann, 1998), and has been applied to goats in Oman (Neutzling et al., 2010; Dickhöfer et al., 2012) and Madagascar (Feldt, 2015). The model can generate live weight and fecundity tables to calculate the expected animal offtakes and population structure for one infinitely large population (Baptist, 1992). It thereby permits to compare herds reared under different kinds of management, and measures the overall productivity of an animal system by combining deterministic and stochastic procedures (Neutzling et al., 2010). The deterministic component of the model calculates population structure, offtake and life expectancies (Baptist, 1992; Kaufmann, 1998) and the stochastic model component simulates (by defining culling strategies) births, losses and culls over a certain time span for an initial livestock population, thereby allowing to analyze the development of population size, population structure and numeric offtake per animal category over time (Kaufmann, 1998). However, the model requires specified demographic inputs (Kaufmann, 1998) and feed-related calculations (feed energy intake). The demographic inputs such as the maximum biological age of animals, survival rate, age at first parturition and culling rate per parity can be specified referring to progeny history data. Progeny history surveys have been applied successfully in different studies with ruminants (Kaufmann, 1998; Neutzling et al., 2010; Dickhöfer et al., 2012; Feldt, 2015) and also in the present case provided sufficiently accurate data for evaluating the current productivity of small ruminants in the study region as well as potential measures for improvement. However, especially data related to feed quality, feed intake and feed metabolization, such as live weight gain, energy requirement for maintenance, growth, gestation and lactation, were not available for the study region and were therefore taken from publications on similar rearing systems wherever possible (Appendix 4.2).

4.4.1. Growth rates

For the studied transhumant grazing system, the average mature weight recorded during the weighing of sheep was 71.1 kg for males and 58.7 kg for females. These values are differed from weights reported for other sheep breeds and even for the same breeds in the study region (Xia et al., 2010). For example, the present average adult body weight was much higher than the weight of Kazakh sheep breeds (rams: 60 kg; ewes 46 kg) kept in a similar pastoral (mountain) grazing system (Xia et al., 2010). On the other hand, the weight of male Xinjiang fine wool sheep was 17 kg higher (88 kg) and that of females 10 kg lower (49 kg) than our results (Xia et al., 2010). The average body weight of adult Dolang sheep from the hot and arid plain of southern Xinjiang (Kashgar) was higher in both rams (98.4 kg) and ewes (68.3 kg; Xia et al., 2010). Furthermore, Xia et al. (2010) reported on the average body weight of the same breed (Altay sheep) and their results were higher than our results in both rams (93 kg) and ewes (67.6 kg). Such differences may be due to different breeds, management and breeding systems and environmental conditions (Malhado et al., 2009).

Growth is one of the most important features of livestock; it is defined as increase in live weight or body dimension against age (Hossein-Zadeh, 2015) and is depicted by growth curves (Keskin et al., 2009). These provide insights into growth patterns over time and allow for the estimation of the expected body weight of animals at certain ages (Lupi et al., 2015). The analysis of the animal’s growth performance throughout its life span is helpful to establish appropriate feeding strategies and the best slaughter age (Hossein-Zadeh, 2015; Jannoune et al., 2015). Nonlinear models have been reported to represent the body weight changes of sheep better than linear models (Topal et al., 2004; Hamouda & Atti, 2011; Tariq et al., 2013). Within a set of well-established growth functions, the decision for one particular model is mainly depending on how accurately it fits the data. For example, the Richards function was reported to excellently fit the weight-age data of Karagouniko sheep in Greece (Goliomytis et al., 2006), and the Brody model showed the best fit in African Dwarf sheep (Gbangboche et al., 2008). The Gompertz and Von Bertalanffy models showed the best fit in Morkaraman and Awassi lambs in Turkey (Topal et al., 2004). In the present data set, the recorded average adult body weight of rams (71.1 kg) and ewes (58.7 kg) was very close to the body weight predicted by the Logistic model (rams: 69.5 kg; ewes: 58.5 kg), which indicates that the Logistic model is suitable to explain the growth of Altay sheep in the study region. Likewise, the Logistic model was selected for its accuracy of fit in Bergamasca sheep in Brazil (McManus et al., 2003). Yet, as reported for goats in Oman (Dickhöfer, 2012) and cattle in the USA (Brown, 1970), the asymptotic value of the Logistic regression curve, that is maximum animal weight, may underestimate the real mature weight if no or only few actual weights at full maturity are included in the dataset.

4.4.2. Reproductive performances

Most of the livestock breeds encountered in Xinjiang Province are well adapted to the harsh climate and ecological conditions of the region and show excellent productive performance (Xia et al., 2010). In the current study, reproductive data were collected using the progeny history interview technique that relies on the remembrance of livestock keepers of fertility traits of their breeding females and destiny of the offspring born in their herds. During the interviews held in the evening, mostly husband and wife were present. Due to the harsh winters in the study region, parturitions in small ruminants are restricted to the spring/summer season and mating occurs in autumn. Still, most of the women did not remember the exact month when an animal was born, slaughtered, sold or died. Therefore the answers to these questions were only taken from the male household head. Even when accounting for these difficulties, the reproductive performance of Altay sheep and goats as determined in the present interviews are inferior to data reported from other parts of China. For example, Chen et al. (2015) reported age at first parturition, parturition interval and litter size of 14.2 months, 9.7 months and 1.86 for Hanper sheep and 16 months, 8.9 months and 1.82 for small-tailed Han sheep in Hebei Province, China. Similarly, for Chinese goat breeds, the mean litter size of Fengxian Black (Cheng et al., 1989), Meigu (Ou et al., 1997), Jintang Black (Wang et al., 2002) and Hui (Liu, 1990) was >2 in all cases. However, unlike to other studies carried out in extensive pastoral systems in semi-arid and arid environments, the mortality of young offspring (≤12 months) was only 1% in sheep and 5.4% in goats in our study, and can therefore not be considered a major factor limiting herd productivity as was claimed by Garcia & Gall (1981) and Devendra & Burns (1983). The low productivity of sheep and goat flocks in our study must rather be ascribed to the large proportion of breeding females showing late (>24 months) age at first parturition (75% in sheep and 35% in goats) as well as to the long parturition intervals of 20.9 months in sheep and 18.4 months in goats. Sheep breeds in other parts of China and in neighbouring Bangladesh have shorter parturition intervals compared to the present data. For example, the average parturition interval of Tan and small-tailed Han crossbred ewes from the Chinese region of Gansu was reported to be 6.5 months (Wang et al., 2011); for Hanper and small-tailed Han sheep in Hebei province of China, an average parturition interval of 9.7 and 8.9 months was given (Chen et al., 2015). Average parturition intervals for native sheep breeds in Bangladesh were 6.3 months in Jumuna and Barind, and 6.6 months in the coastal region, respectively (Hassan & Talukder, 2012). For goats, Tan et al. (2008) and Peng et al. (2009) reported parturition intervals of 6.8 months for black goat breeds from Jianchang and Guizhou, China. However, even in other pastoral and agro-pastoral systems in southwestern Nigeria (Bosman et al., 1997) and Kenya (Weiler et al., 2014), low productive breeding females are not necessarily culled as they still provide their owners with social status, a bank substitute and an insurance value for times of need.

4.4.3. Scenario analyses and management implications

Improving the productivity of livestock herds by management optimization has already been explored by various authors using PRY Herd Life model (Dickhoefer et al., 2012; Riedel et al., 2014; Feldt, 2015). The improvement of livestock production through breeding and feeding management can substantially contribute to the livelihood strategies and household income in the study area (Addison & Brown, 2014). Analyzing the current (SQ) reproductive performance and growth of sheep and goats in our study area with PRY predicted an annual monetary output per average herd animal of 50.6 € and 43.7 € for sheep and goats, even though herders in the Altay often keep both species in the same herd and despite their very similar reproductive and growth performance. The most important difference between both species lies in the much higher sales prices for live sheep than for live goats, the former being the preferred meat animals by the regional customers (Gregory & Grandin, 2007). Already Waldron (2007) reported that sheep were more profitable than goats in the study region. By improving growth rates and reproductive performance of sheep and goats through systematic and good quality winter feeding (Addison & Brown, 2014), the annual offtake rates for sheep and goats and hence the monetary output per animal could increase to 53.3 € a^{-1} and 51.4 € a^{-1}, respectively (IF). Despite higher offtakes, also herd expansion would increase, putting in question the sustainability of rangeland management during spring to autumn. On the other hand, improved culling (IC) decreased the annual monetary output per sheep by about 12.8 €, and only slightly improved the revenue in goats. As most of the new born males were culled at 18 months and only few were kept as breeding males (3 - 5 in a herd of 100 head), breeding females constituted more than 80% of total herd. Since there are only few adult males in the herd, the model thus may propose to cull productive females in order to meet the predetermined conditions (see 4.2.5); this leads to a decrease in herd expansion rate as well as in annual monetary output per sheep of about 25%. Even though the IC strategy might have a positive effect on rangeland health and thus animal nutrition through reduced animal numbers, in terms of monetary output it is not attractive for sheep herders as compared to their current management (SQ). Only if on the long run better feeding conditions may also improve age at first parturition, partition interval and litter size, as simulated in scenario IC+IF, such a strategy would pay off.

In terms of monetary output, scenario IF reached highest values for both sheep and goats (53.3 € and 51.4 €). Since IF requires an additional daily input of 0.58 kg and 0.55 kg dry supplement feed (hay and concentrate) to sheep and goats during four months of winter time, feed costs of 10.1 €/sheep and 9.7 €/goat must (Appendix 4.4) be deducted from the sales revenues. These costs completely consume the extra revenue of 7.4 € (sheep) and 2.0 € (goats) gained with IF as compared to SQ. From this perspective, IF is currently not advisable for both species. Compared to the IC and IF, the current management (SQ) has obvious advantage in terms of monetary output per animal in sheep. For goats, strategy IC could be an option since culling more non-productive animals yields 1.4 € per animal unit and year more than SQ. Strategy IC would also slightly reduce the goats' feed requirements and thus improve the nutritional situation of the overall herd, since each herder family grazes a clearly defined pasture area leased from the government (Ning et al., 2012).

4.5. Conclusions

The results of the current study indicate a certain potential to improve the reproductive performance of sheep and goats in the transhumant grazing system of the Chinese Altay Mountains. Despite environmental constrains, particularly forage shortage during the winter season, sheep and goat keeping appears to be profitable and an indispensable part of rural livelihoods in the region. The scenario analysis indicated that the annual output per animal can be increased by better feeding and stringent culling management. Substantial offtake of poorly performing breeding females would enable herders to better exploit the herd’s genetic potential and improve production and productivity. However, since young male and old female sheep are already greatly culled under current management, improved culling is especially needed in goat flocks. On the other hand, improved winter feeding in addition to the current grazing of assigned winter pasture areas may relieve the grazing pressure on these heavily grazed plots, but will enhance feeding costs and therefore not necessarily increase monetary net revenue as compared to current management. Therefore, management recommendations must be species-specific even if sheep and goats are kept as a mixed herd, and must consider the actual performance and monetary profit of each subgroup.

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Appendix

Appendix 4.1 Small ruminant herd size by year (official) and by surveys.

Species	Qinghe county small ruminant number								Baseline data		Progeny history interview	
	2011		2012		2013		2014					
	n	%	n	%	n	%	n	%	n	%	n	%
Sheep	237023	69.8	255042	74.9	287580	77.5	296314	78.2	10659	80.6	1136	89.3
Goats	102363	30.2	85600	25.1	83416	22.5	82697	21.8	2568	19.4	136	10.7
Total	339386	100	340642	100	370996	100	379011	100	13227	100	1272	100

Data source: Official data collected from Qinghe Animal Husbandry Bureau; Baseline data collected during baseline survey (n=258) in 2012; Progeny history data collected in 2014 (n=10).

Appendix 4.2 Initial herd structure as obtained from the baseline survey (Chapter 2).

Age (months)	Sheep (n=61)		Goats (n=15)	
	Male	Female	Male	Female
≤12	14	14	3	2
>12 - 24	-	10	-	2
>24 - 36	1	10	-	2
>36	-	12	2	4

Appendix 4.3 Input parameters for PRY Herd Life Model and their sources.

Parameter	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 per parturition	% of population per parturition	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 offspring per parturition	Survey	1.07	Survey	See results
Feed energy content	MJ ME / kg feed DM	Togtokhbayar (2006)	9	Togtokhbayar (2006)	9
Energy efficiency lactation	Quotient	Drochner (2003)	0.63	Drochner (2003)	0.63
Energy efficiency gestation	Quotient	Drochner (2003)	0.33	Drochner (2003)	0.33
Litter weight gain from milk until weaning	kg for total offspring	Drochner (2003)	3	Torres-Hernandez et al. (2004)	4
Milk energy content	MJ ME / kg milk	Drochner (2003)	3.5	Chadraabal et al. (2011)	4.41
Body weight metabolic exponent	Quotient	Drochner (2003)	0.75	Drochner (2003)	0.75
Price per kg body weight gain	Euro (€/kg)	Survey, model specification	1.92	Survey, model specification	2.81
Metabolizable energy intake per kg body weight gain	MJ ME/kg	Drochner (2003)	6.3-18.4*	Chiba (2009)	7.5-31.0*
Maintenance metabolizable energy requirements	MJ ME / $kg^{0.75}$	Drochner (2003)	0.45	Chiba (2009)	0.43
Energetic efficiency coefficient	quotient	Drochner (2003)	0.43;0.51**	Nie et al. (2015)	0.43;0.50**
Fibre yield	kg/animal*year	Yokohama et al. (2009)	0.017	Chadraabal et al. (2011)	0.12

* The values for goats: lowest 6.3 (LW 2.5 kg), intermediate 12.2 (LW 12-29 kg), highest 18.4 (LW 36 kg); Sheep: lowest 7.5 (LW 5 kg), intermediate 18.9 (LW 20-48 kg), highest 31 (LW 72 kg).

** The values for goats: 0.43 LW range 12-42 kg, 0.51 LW 2.5 kg; Sheep: 0.43 LW range 20-61 kg, 0.50 LW 5 kg.

Appendix 4.4 Feed requirements, winter supplementation (hay and corn) and their cost as well as annual monetary outputs of small ruminants.

Species			Required DM feed (kg/an/year)	Winter feed*			Cost (€)			Annual output (€/an/year)
				Hay	Corn	Total	Hay	Corn	Total	
Sheep	SQ		865	0	0	0	0	0	0	50.6
	IC		865	0	0	0	0	0	0	37.8
	IF	10.5 MJ	663	181.6	20.2	201.8	21.1	5.7	26.8	53.3
	IC + IF	10.5 MJ	663	181.6	20.2	201.8	21.1	5.7	26.8	53.2
Goats	SQ		578	0	0	0	0	0	0	43.7
	IC		578	0	0	0	0	0	0	45.1
	IF	10.5 MJ	452	126.1	113.5	12.6	13.2	3.5	16.7	51.4
	IC + IF	10.5 MJ	452	126.1	113.5	12.6	13.2	3.5	16.7	51

SQ: *Status quo*; IC: Improved culling; IF: Improved feeding;

Improved winter feeding was assumed to increase feed energy content to 10.5 MJ ME/kg DM (Togtokhbayar, 2006).

Cost for hay (0.12 €/kg) and corn (0.28 €/kg) was obtained from survey.

*Units in kg/animal/4 months.

Chapter 5 General discussion and conclusions

5.1. General discussion

Predetermined by the regional ecological and socio-economic conditions, livestock keeping is the preferred livelihood strategy in the pastoral region of Xinjiang (Liao et al., 2015) and the role of livestock goes beyond income generation (Ahuja & Staal, 2012). There are many semi-nomadic people dependent on herding for their living (Squires & Hua, 2010). However, the traditional response of pastoral households to low incomes and absence of alternative income opportunities is to maintain or increase livestock numbers, which perpetuates and intensifies the high degradation-low-incomes cycle (Waldron et al., 2010). Despite the various management policies (Han et al., 2008) and widespread grazing restrictions such as grassland ban, rotational grazing (Dong et al., 2007) and fencing (Zhang & Du, 2006), the grassland degradation has adversely influenced the sustainable development of livestock grazing systems, herders' livelihoods, as well as the ecological environment of Xinjiang (Chai et al., 2010). In the pastoral region of NW China, the main constraints for sustainable development of animal husbandry stems from the over-reliance on extensive livestock herding as the only source of income (Liao et al., 2015) coupled with inadequate and imbalanced feeds and feeding, and poor reproductive management (FAO, 2010).

Livelihood strategies and aspirations of the poor of what an enabling environment would entail were discussed in Chapter 2. The households involved in the present study mostly were pastoralists, drawing their income predominantly from extensive grazing systems; yet, the vast majority (50.2% of 663,410; Xinjiang Statistics Bureau, 2013) tended to operate more intensive livestock production systems along with some cropping, and vegetable gardening. It appeared that the livelihood strategies were strongly associated with the ethnicity/cultural background of a household and its spatial location. Pastoralism has historically been an integral part of the lives of the Kazakhs, whereas crop and vegetable farming is dominated by Han Chinese. However, neither cropping alone (Bhandari & Grant, 2007) nor livestock alone is a viable option to improve the livelihoods if the necessary resource base, motivation and markets are not provided at the same time (IFAD, 2004). Livelihood diversification is an important survival strategy for rural households (Khatun & Roy, 2012). Therefore, the poor households may embrace multiple activities, primarily to ensure survival (Haggblade et al., 2005) and spread the risk (Ellis

& Allison, 2004). However, the importance of each livelihood strategy in the present study context is different. As the water is decisive factor in agriculture, cropping and vegetable gardening can be only practiced in settlements or nearby riversides where the households have access to water for irrigation. Furthermore, low and variable rainfall conditions, steep terrain or extreme temperatures limit the area that has the potential for crop cultivation (Rota & Sperandini, 2009). Most importantly, crop cultivation in the pastoral region of Xinjiang is labor intensive and fixed in space, especially in places suffering from poor infrastructure facilities and unfavorable climate; households need to stay in their settlements to take care of their crops throughout the year, which is less remunerative than herding (Liao et al., 2015). Apart from the lack of labor, Liao et al. (2015) argues that the language skills of ethnic pastoralist is another disadvantage for competing with Han Chinese in cropping (both cash crops and vegetables) or hunting for nonfarm jobs. Therefore, the Kazakhs, majority of interviewed households, who are moving with their livestock seasonally, are not intensively engaged in cropping and vegetable gardening in Qinghe County. Which is similar to the results of another study in the region reporting that crop cultivation does not work well for the mobile pastoral communities (Liao et al., 2015). Livestock as one of the most important and crucial assets was found in all three clusters, which reflects its importance in the study area. Despite environmental constraints, particularly forage shortage during the winter season, sheep and goat keeping appears to be profitable and accounts for 75% of the total livestock in the region (Xinjiang Statistics Bureau, 2013). However, constraints such as over grazing (Brown et al., 2008, Squires et al., 2012), decline in forage yields (Jianwei & Zhiyi, 2016) and lack of winter/early spring feed (Li et al., 1996) in the study region are limiting factors for a sustainable development of animal husbandry. Therefore, it is essential to understand the seasonal and spatial patterns of forage availability and quality for matching animal numbers and needs with forage supply and quality (Chapter 3). The quantity of forage on offer in the present study was significantly different between the years and positively correlated to the precipitation (Fay et al., 2000; Miranda et al., 2009; Kidron, 2014; Xu et al., 2014). Despite the lower rainfall and significant decrease in pasture biomass in 2014, the animal numbers remained constant. No special management practices were used to reduce the pressure on the rangelands or protect the most productive livestock. However, similar stocking rates with low biomass availability in dry seasons/years may result in more rapid pasture degradation. Especially the spring pastures in the Chinese Altay Mountain region are used twice a year for spring and autumn grazing and their carrying capacity is already exceeded by about 138% (Brown et al., 2008). In the worst cases, the seasonal migration of herds and the length of the pasture resting period may not be enough to allow the vegetation to regenerate. Forage quality may also have a direct effect on animal performance, ultimately affecting productivity and health. In spring and summer seasons, the quality of diets in the present study was good or even relatively higher than the requirements (NRC, 2007). However, the animals' nutrient requirements and the demand for feed increase during the winter/early spring due to late gestation, parturitions and start of lactation (Alabama Cooperative Extension System, 2014); this comes at a time when both the availability and the quality of forage is low and even inadequate (Li et al., 1996).

As overgrazing is a major cause of the current state of grasslands, it is a major challenge to reduce animal numbers sufficiently to enable grassland rehabilitation without causing any fall in household incomes. In this regard, analyzing the current reproductive performance of small ruminant herds in the Chinese Altay Mountain region as a basis for devising appropriate livestock management options for local transhumant grazing systems is essential (Chapter 4). According to the progeny history survey and PRY results, we found a certain potential to improve the reproductive performance of small ruminants in the region. Our results corresponds to the insights of other studies conducted in the region (NW China), for which Waldron et al. (2008) stated that there are still too many low productive breeding females in the pastoral system. Keeping 'empty' or barren females for extended periods of time contributes to additional grazing pressure. Improved stock selection, culling and introduction of production regimes (improved feeding, controlled stocking rate) are seen as a best way to manage the livestock and rangelands (Michalk et al., 2011), whereas Wang and Dickerson (1991) emphasized that increasing productivity and reproductive performance of female animals generally improves economic and biological efficiency of livestock keeping. More specific strategies were discussed by Brown et al. (2011), who stated that herd structure, culling strategies and livestock systems have considerable scope for improvement but have often received less attention. From a management perspective, better feeding could improve the weaning rate and change lambing time (Michalk et al., 2011), thus together with stringent culling management will increase the annual output per animal (Fu et al., 2015). The substantial offtake of poorly performing breeding females especially in goat herds could improve herd productivity. On the other hand, improved winter feeding in addition to the current grazing of assigned winter pasture areas may relieve the grazing pressure on these heavily grazed plots, but will increase feeding costs and not necessarily increase monetary net revenue as compared to current management. Therefore, management recommendations must be species-specific even if sheep and goats are kept as a mixed herd, and must consider the actual performance and monetary profit of each subgroup.

5.2. General conclusions and recommendations

The transhumant mode of livestock keeping is the most remunerative livelihood strategy among the various systems encountered in Qinghe County. The seasonal movements with flexible entry and exit dates to specific pastures, seasonality in land use patterns (seasonal pastures) and the governments' livestock inventories and regulative policies enable pastoralists in the region to make good use of the rangeland resources. However, pasture degradation, environmental variability, and unreasonable grazing management still present challenges to the extensive herding system. Therefore, it is necessary to understand the constraints to livestock productivity and devise possible improvement options, thus allowing households to better realize the income generating potential from their livestock resources. Insights into livestock behavior and forage (quantity and quality) selection will allow us to clarify nutritional needs of animals in this specific region, and balance animal numbers accordingly. In the long run, this knowledge will help to prevent the further degradation of rangelands and improve livestock productivity, ensuring pasture re-growth during the grazing season as well as long-term pasture persistence. Culling more males (at early stage) and nonproductive females would cut their extra feeding costs and reduce pressure on rangelands.

Based on the current livelihood challenges of transhumant grazing systems in the Chinese Altay mountain region, the following recommendations can be forwarded to local stakeholders and government institutions:

- An integrated livestock – crop farming can complement one another. Cropping provides fodder and crop residues for livestock and livestock provides manure for crops, thus optimizing the production of the farm as a whole and minimizing risk of over-reliance on only one livelihood strategy in case of extreme climate and unpredicted disasters.

- Winter feed supply is critical for maximizing animal production at a time when the animals graze on poor quality pastures and body weights drop. As the small ruminants in the Chinese Altay mountain region are mainly giving birth between late winter and early spring, winter feeding should meet the nutritional requirements of females during the late gestation period to reduce the incidence of abortions and increase the survival rate of newborns during the harsh winter in the region.

- Constant offtake of males (especially at young ages) and of poorly performing breeding females could substantially improve the performance potential of herds and reduce feeding costs as well as pressure on pastures, thus increasing the annual contribution of small ruminants to the revenue of households.

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