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Modelling spatiotemporal dynamics of nomadic-pastoral land use for environmental impact assessment

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Simplicity is the final achievement

Frédéric Chopin

Summary

Decline in availability and quality of grazing resources caused by natural processes as well as by anthropogenic pressure has become a major challenge faced by the nomadic pastoralists. Often the needs of pastoralists are overlooked in many spatial policies. There is a lack of research on why such challenges associated with nomadic-pastoral land use (dynamic) are not sufficiently addressed by land and environmental management tools in environmental decision contexts. Moreover, a full understanding of the patterns of dynamic land use in nomadic pastoralism is lacking and calculating negative impacts associated with dynamic land use is still an unresolved methodological problem. Environmental impact assessment (EIA) is a key tool for identifying such potential adverse effects of the projects on land use and the environment and defining possible mitigation measures to address these impacts. This dissertation examined the effectiveness of EIA in addressing impacts associated with dynamic land use from the perspective of the pastoralists. It assessed how theories and methods used in EIA incorporate dynamic irrational characteristics and complex unpredictable socio-ecological features of nomadic-pastoral land use. Furthermore, this study investigated the livestock composition, distribution and herding mobility examining environmental and socioeconomic factors influencing the nomadic-pastoral system. It modelled the spatial occupation of grazing land to understand the patterns of land use in nomadic pastoralism to improve impact prediction in EIA.

A mixed method approach was applied in this research. This methodological approach involved content analysis, questionnaire, interviews, statistical modelling, spatial-graphical and spatial data analyses. In addition to journal articles for a literature review, three sets of empirical data were collected from different sources and areas in Mongolia. I conducted a content analysis by reviewing 550 articles using a concept centric approach to examine the needs of nomadic-pastoral land users with respect to EIA theory, its methods and its effectiveness. Furthermore, I evaluated the effectiveness of Mongolia's EIA processes from the perspective of nomadic-pastoral land users based on 50 survey responses from EIA stakeholders in Mongolia. This was intended for identifying specific factors and defects in the EIA processes which contribute to the shortcomings of EIA with regard to addressing impacts on nomadic-pastoral land use. A landscape level time series empirical analysis was conducted for the periods between 1980s and 2010s using environmental, social and land use data from 330 administrative units of Mongolia using a linear mixed model. This research modelled joint distribution and composition of livestock species to understand the patterns of land use in nomadic pastoralism. I then modelled the spatial occupation of grazing areas by applying structural equation modelling using 200 survey responses on livestock, household, and grazing patterns of herders from two ecological zones in Mongolia.

This study concludes that theories and methods used in EIA insufficiently and inappropriately incorporate a conceptual framework which would be able to reflect, qualify or quantify the needs of nomadic-pastoral land users. It is because rationalist and linear cause-effect epistemologies are dominant underlying fundaments of EIA theories and therefore, this gives very little room for the irrational logic of nomadic pastoralism. Moreover, the current EIA methods primarily focus on static land use, and do not incorporate the dynamic nature of land use. Indeed, there is an immense gap between how EIA should be carried out and its implementation processes when EIA deals with impacts associated with nomadic-pastoral land use. One of the significant findings to emerge from

this study is that EIA impact prediction should consider grazing areas as a dynamic space and should examine the relationship between fine-scale and broad-scale herding mobility when calculating pastoral areas affected by the projects as well as it should consider the livestock composition, the number of animals and households at campsites as they all have direct effects on each other. In particular, EIA impact prediction for nomadic-pastoral land use should take into account that the herd size and composition significantly affect the size of grazing areas and the extent of fine-scale herding mobility. Moreover, a landscape level spatial and temporal analyses conducted in this study are consistent with previous findings noting that at the present time, the effects of socioeconomic drivers on the livestock composition and distribution are stronger than those of environmental factors.

The framework designed in this dissertation to examine EIA theory, methods and effectiveness with respect to nomadic pastoralism provides a detailed approach that can be used to systematically examine EIA literature for other disciplines. Moreover, this work contributes to the discussion on EIA theory-building as it investigated for the first time how conceptually EIA addresses impacts associated with nomadic-pastoral land use. Whilst emphasizing the importance of mobility in nomadic pastoralism, this study also quantified for the first time the effects of and relationships between grazing areas, herding mobility, and herd size and composition in the same study. The landscape level analysis conducted in this study also contributes to the current key discussion of the rangeland science on the environmental and socioeconomic factors influencing the spatial and temporal dynamics of pastoral systems. These empirical findings extend EIA's knowledge of impact zones in grazing areas and broadens the perspective of EIA methods with respect to predicting impacts associated with dynamic land use.

Zusammenfassung

Der Rückgang in der Verfügbarkeit und der Qualität von Weideflächen verursacht durch natürliche Vorgänge oder auch anthropogenem Zutun wurde eine große Herausforderung für die nomadischen Hirten. Oft werden die Bedürfnisse der Hirten in vielen Flächennutzungsplänen übersehen. Es mangelt an Forschungsergebnissen darüber, warum die Anforderungen aufgrund der dynamischen Landnutzung durch nomadische Hirten nicht ausreichend durch Flächen- und Landschaftsplanungswerkzeuge im politischen Entscheidungskontext adressiert werden. Darüber hinaus fehlt es an einem vollständigen Verständnis der Merkmale der dynamischen Landnutzung durch die nomadischen Hirten und die Berechnung der negativen Auswirkungen auf sie verbunden mit ihrer dynamischen Landnutzung ist immer noch ein ungelöstes methodisches Problem. Die Umweltverträglichkeitsprüfung (UVP) ist ein Schlüsselwerkzeug bei der Identifizierung von solchen möglichen negativen Auswirkungen von zukünftigen Projekten der Land- und Umweltnutzung. UVP ist auch zentral bei der Definition von möglichen Ausgleichsmaßnahmen, um diese Einflüsse abzufedern. Aus der Sicht der Hirten untersucht diese Doktorarbeit die Wirksamkeit der UVP unter der Berücksichtigung von Auswirkungen, die verbunden sind mit der dynamischen Landnutzung. Die vorliegende Doktorarbeit untersucht, wie in der UVP verwendete Theorien und Methoden die dynamischen und irrationalen Charakteristiken und die komplexen unvorhersehbaren sozio-ökologischen Eigenschaften der Landnutzung durch nomadische Hirten berücksichtigen. Darüber hinaus untersucht diese Studie die Zusammensetzung des Viehbestands, dessen Verteilung und die Herdenbeweglichkeit, wobei besonderes Augenmerk gelegt wurde auf die Umweltfaktoren und die sozio-ökonomischen Faktoren, welche das nomadische Herdenwesen kennzeichnen. Die Studie modellierte die räumliche Nutzung von Weideland, um die Landnutzung in der nomadischen Herdenlebensweise zu verstehen, damit die Auswirkungsbetrachtung im Rahmen der UVP verbessert wird.

Ein Ansatz aus der Verbindung verschiedener Methoden wurde in dieser Arbeit verfolgt. Dieser methodische Ansatz umfasste eine inhaltliche Analyse, einen Fragebogen, Interviews, statistisches Modellieren, räumlich-graphische und räumliche Datenanalyse. Zusätzlich zu Zeitschriftenartikel für einen Literaturüberblick wurden drei Sätze von empirischen Daten gesammelt aus unterschiedlichen Quellen und Gegenden in der Mongolei. Ich unternahm eine inhaltliche Analyse durch das Durchsehen von 550 Artikeln unter Verwendung eines konzeptzentrierten Ansatzes, um die Bedürfnisse der nomadischen Hirten zu bestimmen unter Berücksichtigung der UVP Theorie, ihrer Methoden und ihrer Effizienz. Darüber hinaus untersuchte ich die Effizienz der mongolischen UVP Prozesse aus der Sicht von Weideland nutzenden nomadischen Hirten auf der Basis von 50 ausgefüllten Fragebögen von Beteiligten bei der UVP in der Mongolei. Die Absicht dahinter war es, bestimmte Faktoren und Mängel im Prozess der UVP zu identifizieren, die zum Versagen der UVP beitragen im Hinblick auf die Landnutzung durch nomadischen Hirten. Eine empirische Analyse mit Zeitschnitten auf Landschaftsebene wurde durchgeführt für Zeiträume zwischen den 1980er und 2010er Jahren unter Verwendung von umwelt-, sozial und Landnutzungsdaten von 330 administrativen Einheiten in der Mongolei unter Verwendung von einem linearen, gemischten Modell. Die vorliegende Studie modellierte die Verteilung und Zusammensetzung der Weidetiere, um die Landnutzung der nomadischen Hirten besser zu verstehen. Ich habe sodann die räumliche Verteilung der Weideflächen modelliert durch die Anwendung des Strukturgleichungsmodells unter

Verwendung von 200 ausgefüllten Fragebögen über Weidevieh, Haushaltsdaten und Weideverhalten von Hirten von zwei ökologischen Zonen in der Mongolei.

Diese Studie folgert daraus, dass die in der UVP verwendeten Theorien und Methoden ungenügende und unpassende Elemente enthalten, die nicht in der Lage sind, die Bedürfnisse der nomadischen Hirten zu berücksichtigen und zu quantifizieren. Das liegt daran, dass rationale und lineare Grund-Folge Erkenntnistheorien das hauptsächliche Fundament von UVP Theorien sind. Dies gibt sehr wenig Raum für die irrationale Logik von nomadischem Hirtenwesen. Darüber hinaus konzentrieren sich die bestehenden UVP Methoden hauptsächlich auf statische Landnutzung und enthalten keine Ansätze für die dynamische Landnutzung. Eines der herausragenden Ergebnisse dieser Studie ist, dass die Vorhersage von Auswirkungen auf der Basis einer UVP Weideflächen als dynamischen Raum betrachten sollte und die UVP sollte auch das Verhältnis untersuchen zwischen kleinskaliger und großskaliger Herdenbeweglichkeit, wenn man die Weideflächengröße berechnet, die von einem Projekt betroffen ist. Auch sollte die Zusammensetzung des Weideviehs, die Anzahl der Tiere und Haushalte an einer Siedlungsstelle berücksichtigt werden, da sie alle miteinander wechselwirken. Im Besonderen, sollte eine Auswirkungsanalyse auf die nomadische Landnutzung im Rahmen der UVP berücksichtigen, dass die Herdengröße und Herdenzusammensetzung die Größe der Weidenflächen und die Ausdehnung der kleinskaligen Herdenmobilität signifikant beeinflussen. Darüber hinaus stimmt die in dieser Arbeit durchgeführte zeitliche und räumliche Analyse auf Landschaftsebene überein mit früheren Ergebnissen, die feststellen, dass in der jetzigen Zeit die Auswirkungen der sozio-ökonomischen Faktoren stärker sind als die Umweltfaktoren.

Das Rüstzeug, was im Rahmen dieser Arbeit entwickelt wurde, um die Theorien, Methoden und die Effektivität der UVP im Hinblick auf nomadische Weidewirtschaft zu überprüfen, liefert einen detaillierten Ansatz, der verwendet werden kann, um systematisch die Literatur zur UVP zu untersuchen, um ähnlich gelagerte Fälle und Mängel zu analysieren. Darüber hinaus trägt diese Arbeit zur Diskussion über die Theoriebildung zum Thema UVP bei, da sie zum ersten Mal untersucht hat, wie eine UVP korrekt Auswirkungen auf nomadische Landnutzung berücksichtigen kann. Indem sie die Wichtigkeit der Mobilität in der nomadischen Landnutzung betont, hat diese Studie auch zum ersten Mal die Auswirkungen von und die Verhältnisse zwischen Weideflächen, Herdenmobilität, Herdengröße und Herdenzusammensetzung in einer Studie quantitativ betrachtet. Die Analyse auf Landschaftsniveau, welche in dieser Studie durchgeführt wurde, trug auch zur laufenden Diskussion der Weidelandwissenschaft über die umweltbedingte und sozio-ökonomischen Faktoren bei, die die räumliche und zeitliche Dynamik von Weidelandsystemen beeinflussen. Diese empirischen Ergebnisse vertiefen das Wissen der UVP über Einflusszonen von Weideflächen und weitet die Perspektive der UVP Methoden im Hinblick auf die Vorhersage von Einflüssen verbunden mit der dynamischen Landnutzung auf.

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I dedicate this thesis to the memory of my two grandmothers Orlogor and Urdee. True kindness and integrity are their stories which inspire me in who I want to be in my life.

List of original publications

#	List of original publications	Author contributions	
		Bayarmaa Byambaa	Walter T. de Vries
1	Byambaa B, de Vries WT. The needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness: What are they and does EIA address them? Environmental Impact Assessment Review. 2019;74:54-62.	**80%** Conceptualization Methodology Data curation Formal analysis Investigation Writing - original draft preparation Visualization Funding acquisition	**20%** Supervision Conceptualization Methodology Review and editing
2	Byambaa B, de Vries WT. Evaluating the effectiveness of the environmental impact assessment process in Mongolia for nomadic-pastoral land users. Impact Assessment and Project Appraisal. 2020;38:39-49.	**80%** Conceptualization Methodology Data curation Formal analysis Investigation Writing - original draft preparation Visualization Funding acquisition	**20%** Supervision Conceptualization Methodology Review and editing
3	Byambaa B, de Vries WT. The Production of Pastoral Space: Modeling Spatial Occupation of Grazing Land for Environmental Impact Assessment Using Structural Equation Modeling. Land. 2021;10:211.	**80%** Conceptualization Methodology Data curation Formal analysis Investigation Writing - original draft preparation Visualization Funding acquisition	**20%** Supervision Conceptualization Methodology Review and editing Funding acquisition

Abbreviations

CFI	Comparative Fit Index
EA	Environmental assessment
EFA	Exploratory factor analysis
EIA	Environmental impact assessment
GDP	Gross domestic product
GIS	Geographic information system
HMSC	Hierarchical Modelling of Species of Communities
IA	Impact assessment
LCA	Life-cycle assessment
LUIA	Land use impact assessment
MET	Ministry of Environment and Tourism
ML	Maximum likelihood
NDVI	Normalized difference vegetation index
NGO	Non-governmental organisation
NPLU	Nomadic-pastoral land use
NPLU(rs)	Nomadic-pastoral land users
RMSEA	Root Mean Square Error of Approximation
SD	Standard deviation
SEM	Structural equation modelling
SFU	Sheep Forage Unit
SRMR	Standardised Root Mean Square Residual
TLI	Tucker-Lewis Index

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CHAPTER 1. Introduction

1.1 Background

This work was conceived during my time working with pastoralists and local communities in the Gobi Desert in Mongolia where people still practice nomadic pastoralism which is the prevailing form of land use in Mongolia (Baabar, 1999; Lkhagvadorj, Hauck et al., 2013) and the source for the livestock, tourism and cashmere industries that contribute significantly to Mongolia's national GDP (NSO, 2018). However, degradation and desertification caused by natural processes as well as human activities such as mining and herding have affected the quality of pasturelands drastically over the last years (MET, 2017). Impacts include fragmentation of pasturelands, loss of herders' livelihood (Cane, Schleger et al., 2015) and changes in traditional nomadic lifestyle (CAO, 2013) in mining regions. A recent report notes that 70% of the rangelands in Mongolia which accounts for 1.15 million km^2 land where one million pastoral land users practice herding have been affected negatively by climate change, soil erosion, lack of sound land management control as well as livestock husbandry and activities of the mineral sector (MET, 2017). Thus, personal and professional field experience in Mongolia have brought me to a question whether, and to what extent, environmental impact assessment (EIA) has been effective in eliminating such adverse impacts on nomadic pastoralism and how to improve the performance of EIA with regard to nomadic-pastoral land use.

EIA provides decision makers with an indication of the environmental consequences of the projects and suggests possible mitigation measures to address the adverse impacts associated with such initiatives (Morris and Therivel, 2009; Wathern, 1988). It is important to note that EIA is the most successful policy innovation and is fast becoming a key legally required instrument in environmental and project management since its establishment in 1969 (Morgan, 2012; Pope, Bond et al., 2013; Sadler, 1996). It has been formally introduced in more than 190 countries (Morgan, 2012). Moreover, impact assessment is slowly becoming a professional and academic discipline (Fischer and Noble, 2015). Yet, from my work experience I witnessed a number of cases where communities appeared to be unsatisfied with the documented results of the EIAs conducted for various projects, especially those affecting nomadic-pastoral land use. Thus, my concerns of EIA effectiveness with respect to nomadic pastoralism have led to further questions about EIA, particularly whether theories and methods used in EIA incorporate the needs of nomadic-pastoral land users.

Grazing systems vary depending on the extent of the herding mobility as well as the flexibility of herders' residence. Allen, Batello et al. (2011) defined nomadic, semi-sedentary, transhumance and sedentary grazing systems considering grazing patterns and home base of herders. Among these systems, nomadic pastoralism is the most extensive in terms of herding mobility. In such system, herders often change grazing locations instinctively due to environmental unpredictability including the weather conditions. Thus, land use in nomadic pastoralism is dynamic and differs from static land use. Communal grazing and flexibility are also the norms of land use in nomadic pastoralism (Fernandez-Gimenez, 2000). Moreover, the nomadic pastoral system is not coherent and its elements are rather complicated and interrelated (Dwyer and Istomin, 2008; Sayre, deBuys et al., 2012; Stafford, Morton et al., 2000). There has been little research on how EIA addresses impacts related to land use in such dynamic and incoherent system in comparison to static land use. Moreover, during my time working in the field analysing impacts associated with herding, I witnessed that far little attention has been paid to the interests of nomadic-pastoral land users and often their concerns were overlooked. Hence, particularly the effectiveness of EIA with respect to addressing both environmental and social impacts related to dynamic land use needs to be examined and the specific defects and shortcomings of the EIA processes also need to be investigated.

The term effectiveness refers to whether something meets the purposes for which it is designed and one of the substantive purposes of environmental assessment is to identify and predict the environmental effects, risks, and consequences of the development options and proposals (Sadler, 1996). Thus, impact prediction methods used in EIA are expected to understand spatial patterns of dynamic land use to predict potential impacts associated with nomadic-pastoral land use appropriately and sufficiently. However, the literature on EIA tends to focus on assessment of impacts from static land use only. Koellner and Scholz (2006)'s solution for calculation of the damage from series of land occupation similar to nomadic-pastoral land use is as well suitable for static land use only and does not take account of dynamic characters and mobility of land use in nomadic pastoralism. This indicates that the extent of grazing areas and herding patterns are not understood to a sufficient degree in nomadic pastoralism which in turn affects the precision and quality of impact prediction in EIA dealing with dynamic land use.

Spatiotemporal pattern of grazing movement is not fully understood by science (Zhao and Jurdak, 2016) and significant shortcomings still exist in pastoral mobility quantification (Liao, 2018). In particular, there is a lack of research in how grazing land use occupies the space and what environmental or social factors influence its dimensions. Complexity of pastoral systems is shaped and driven by correlated and interconnected ecological, social and economic variabilities (Zinsstag, Schelling et al., 2016). Such environmental and social factors have profound effects on the distribution of grazing pressure and its impacts at landscape and regional scales (Pringle and Landsberg, 2004). Therefore, to understand mobility and spatial patterns of dynamic land use, first it is important to analyse how environmental and social factors affect land use in pastoralism, especially, the distribution of livestock as it informs about the location and quantity of pastoral land use. In fact, assessment of environmental impacts of pastoral activities require detailed knowledge about livestock distribution (Neumann, Elbersen et al., 2009). In the light of importance of knowledge on livestock composition and distribution to impact prediction of dynamic land use in EIA, more research needs to be undertaken on this topic with relation to grazing locations and factors influencing pastoral land use. A few models tackle land use change such as location and quantity of land use in an integrated way (Veldkamp and Lambin, 2001). Besides, modelling the livestock systems is particularly complex (Jones, Antle et al., 2017). Thus, more studies should attempt to advance knowledge of dynamic land use modelling, in particular, spatial patterns of dynamic land use in connection to impact prediction in EIA.

1.2 Objectives

The overall objective of this study is to investigate the effectiveness of EIA in addressing impacts associated with nomadic-pastoral land use and to gain a clear understanding of spatial occupation of dynamic land use in nomadic pastoralism to predict adverse impacts appropriately in EIA. To achieve this objective, I defined the following specific objectives:

1. to examine the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness based on literature review and to analyse whether EIA addresses them sufficiently and appropriately;

2. to evaluate the effectiveness of the EIA processes from the perspective of nomadic-pastoral land users in a particular case of nomadic pastoralism to identify specific factors and defects in the EIA processes which contribute to the shortcomings of EIA with regard to addressing impacts on nomadic-pastoral land use;

3. to analyse effects of environmental and socioeconomic factors on the livestock composition and distribution in nomadic pastoralism to understand the patterns of dynamic land use for EIA;

4. to model the spatial occupation of grazing land to understand the patterns of dynamic land use in nomadic pastoralism and to explain and predict the patterns of nomadic-pastoral land use appropriately in EIA.

The first two objectives are defined to understand the problems and relationship between EIA and nomadic-pastoral land use. Particularly, they investigate the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness and whether EIA has been effective in addressing those needs. The following two objectives target solutions to the problems and shortcomings of EIA in relation to nomadic-pastoral land use by developing a model on spatial occupation of grazing land which can help EIA in predicting impacts associated with dynamic land use appropriately.

1.3 Outline of the dissertation

This is a publication-based dissertation consisting of four scientific papers. The outline of the dissertation is shown in Figure 1.1. Chapter 1 presents an introductory section which describes the scientific problems, the objectives of this research and methodology applied to collect, examine and analyse data and findings.

Overall, Chapter 2 and Chapter 3 focus on understanding the problems and gaps in EIA theory, concepts and methods regarding their application to nomadic-pastoral land use. Using a concept-centric review and a content analysis covering 550 articles published in EIA, land use and pastoralism related journals, Chapter 2 reviews the literature on EIA and nomadic-pastoral land use which establishes the basis of this research. This chapter has been published as an article in a peer-reviewed journal and examines theory, methods and effectiveness frameworks used in EIA with respect to nomadic-pastoral land use. Chapter 3 tests a case to understand the defects and shortcomings of the EIA processes in addressing impacts associated with nomadic-pastoral land use. This chapter has been published also as an article which evaluated the effectiveness of the EIA process in the case of Mongolian pastoralism from the perspective of nomadic-pastoral land users. In this chapter, the effectiveness of Mongolia's EIA processes has been evaluated using a framework consisting of 81 survey questions and 20 open-ended questions responded by 50 respondents who represented different stakeholder groups.

Moreover, Chapter 4 and Chapter 5 deals with solutions to the problems of EIA with regard to nomadic-pastoral land use. Chapter 4 analyses spatiotemporal dynamics of the livestock composition and distribution at landscape level using statistical and spatial data from 330 administrative units of Mongolia to understand factors influencing the locations of nomadic-pastoral land use as in impact prediction in EIA land use areas are the key parameter which needs to be calculated. This chapter modelled the abundance and joint distribution of all livestock species (sheep, goats, cattle/yaks, horses, camels) in relation to environmental, socioeconomic and land use variables using a hierarchical generalised linear mixed model (Hierarchical Modelling of Species of Communities) and data sets for the periods from 1981-85, 1995-99, and 2010-13.

Chapter 5 expands the knowledge gained in Chapter 4 by modelling spatial dynamics of nomadic-pastoral land use for EIA based on Karplus and Meir (2013)'s concept of pastoral spatiality using structural equation modelling. The model has been developed based on 200 survey responses on animal movement patterns such as fine and broad scale herding mobility, grazing orbit and locations of grazing campsites collected from two different ecological zones in Mongolia. The model explains how the pastoral space is produced and can be used in EIA when predicting impacts associated with dynamic land use.

Chapter 6 and Chapter 7 discuss theoretical and methodological contributions of this study and presents concluding remarks including suggestions for future research.

Chapter 1: Introduction (background, objectives, outline of the dissertation, methods)

Overall objective: To investigate the effectiveness of EIA in addressing impacts associated with nomadic-pastoral land use and to gain a clear understanding of spatial occupation of dynamic land use in nomadic pastoralism to predict adverse impacts appropriately in EIA.

Chapter	Objective	Methods/Data	Outcome (Paper)
Chapter 2: Literature review	**Objective 1** To examine the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness based on literature review and to analyse whether EIA addresses them sufficiently and appropriately;	• Retief (2010)'s framework (defines three key interrelated themes for EIA: theory, methods and effectiveness) • Concept-centric literature review and content analysis • Review of 156 articles and 550 abstracts	**Outcome (Paper) 1** Byambaa B, de Vries WT. The needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness: What are they and does EIA address them? Environmental Impact Assessment Review. 2019;74:54-62.
Chapter 3: Case study	**Objective 2** To identify specific defects in the EIA processes which contribute to the shortcomings of EIA with regard to addressing impacts on nomadic-pastoral land use	• Hanna and Noble (2015)'s framework for evaluation of effectiveness of EIA • Statistical/content analysis • Framework containing 81 survey/20 open-ended questions • 50 survey responses of EIA stakeholders	**Outcome (Paper) 2** Byambaa B, de Vries WT. Evaluating the effectiveness of the environmental impact assessment process in Mongolia for nomadic-pastoral land users. Impact Assessment and Project Appraisal. 2020;38:39-49
Chapter 4: Factor analysis	**Objective 3** To analyse effects of social and environmental factors on the herd composition and spatial distribution of livestock in nomadic pastoralism to understand the patterns of dynamic land use for EIA	• Ovaskainen, Tikhonov et al. (2017)'s Hierarchical Modelling of Species of Communities • Statistical and spatial analysis • R package HMSC, ArcGIS • Environmental, social and land use data from 330 administrative units of Mongolia	**Outcome (Paper) 3** Socio-environmental factors influencing the spatial and temporal dynamics of herd composition and livestock distribution in Mongolia (the manuscript will be submitted to a peer-reviewed journal)
Chapter 5: Model development	**Objective 4** To model spatial occupation of grazing land to predict appropriately impacts associated with nomadic-pastoral land use in EIA	• Karplus and Meir (2013)'s concept of pastoral spatiality • Structural equation modelling (SEM) • R package *lavaan sem* for SEM, ArcGIS • 200 survey responses on grazing patterns of herders from two ecological zones in Mongolia	**Outcome (Paper) 4** Byambaa B, de Vries WT. The Production of Pastoral Space: Modeling Spatial Occupation of Grazing Land for Environmental Impact Assessment Using Structural Equation Modeling. Land. 2021;10:211.

Chapter 6: Discussion and conclusions (theoretical and methodological contributions)

Chapter 7: Opportunities for future research (recommendations for future research)

Figure 1.1. Outline of the dissertation

1.4 Methodology and data collection

Many challenges we are facing today are inherently complex and a comprehensive approach is required to address these problems (Ledford, 2015; Okamura, 2019). This dissertation examined spatial occupation of nomadic-pastoral land use from the perspective of environmental impact assessment and rangeland science. Approaching such interdisciplinary research questions by way of involving more than one discipline simultaneously has gained acceptance long ago by the science communities (Robertson, Martin et al., 2003). Moreover, one way of approaching interdisciplinary research is to think interdisciplinarity, apply multiple perspectives and employ a wide range of methods for understanding and solving complex problems (Lach, 2014).

Various methods are used to collect, assess and analyse data in this study. In total, three sets of empirical data were collected from different sources and ecological regions in Mongolia. Table 1.1 summarises the methods and datasets applied in each chapter of this dissertation.

Table 1.1. Summary of methods and data used in the dissertation.

Chapter	Data collected	Methods used	Reference
Chapter 2: Literature review	• 156 articles and 550 abstracts selected from all journals in the ISI master list	• Concept-centric approach for literature review • Content analysis	Appendix I. Concept matrix and datasets used in Chapter 2
Chapter 3: Case study	• 50 survey responses from EIA stakeholders in Mongolia	• Likert survey questionnaire • Semi-structured interview	Appendix II. Survey questionnaire used in Chapter 3
Chapter 4: Factor analysis	• Environmental, social and land use data from 330 administrative units of Mongolia	• Hierarchical Modelling of Species of Communities • Statistical and spatial	Appendix III. List of data used in Chapter 4: Factor analysis
Chapter 5: Model development	• 200 survey responses on livestock, household, and grazing patterns of herders from two ecological zones in Mongolia	• Questionnaire • Exploratory factor analysis • Structural equation modelling	Appendix IV. Survey questionnaire and results of Chapter 5

The first chapters of the dissertation aimed at understanding the problems and gaps in EIA with respect to addressing impacts associated with nomadic-pastoral land use. Both qualitative and quantitative approaches were employed in these analyses since understanding of complex problems requires different perspectives, and mixing methods offers an effective way of considering various viewpoints (Bryman, 2006). Content analysis, questionnaire and interview approaches were applied in these studies, and they are presented in Chapter 2 and Chapter 3. The results of interviews, observations, and various materials such as journal articles for a literature review were collected as qualitative and quantitative data in these studies.

Furthermore, Chapter 4 and Chapter 5 examined solutions to the problems of EIA with regard to dynamic land use and focused on development of statistical models explaining interrelationships between livestock, grazing areas, herding mobility and how environmental and social factors influence livestock communities in the case of nomadic pastoralism in Mongolia. Since these studies developed statistical models, methods based more on mathematics, mainly statistical and spatial approaches were applied in these analyses. Using geographical information system (GIS), spatial-graphical and spatial data analyses were conducted for data acquisition, visualization, and mapping for Chapter 4 and Chapter 5. Statistical frameworks of structured equation modelling and Hierarchical Modelling of Species of Communities were applied in examining and modelling spatial occupation of grazing areas and distribution and composition of livestock in nomadic pastoralism. The key methods I used in this dissertation are discussed in the following sections and in each articles separately.

1.4.1 Content analysis

Content analysis is widely used in various disciplines. It is a method that provides a systematic means to make theoretically useful generalizations and valid inferences from the original data such as texts to analyse and quantify specific trends and it can be used in conjunction with other methods (Downe-Wamboldt, 1992). The process of content analysis consists of identifying research questions, collecting and coding data such as textual materials according to a classification scheme, defining contexts within which to make sense of the body text, analysing data, validating evidence, and reporting results (Krippendorff, 2004; White and Marsh, 2006).

In this study, I examined whether EIA addresses the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness sufficiently or appropriately using the content analysis tool. Data used for content analysis can be different types of text such as published articles, books or observed notes, and data should provide useful evidence for answering research questions conveying message or meaning to a receiver (White and Marsh, 2006).

I selected 156 articles and 550 abstracts from all journals in the ISI master list as data for this study. Furthermore, I developed a concept matrix organised in an Excel spreadsheet for a content analysis. I classified my research questions into three interrelated EIA themes and categorised the topics I am examining under each theme. I then coded the answers for each category. The coding allows retrieval of content relevant to research questions in a systematic way uncovering patterns of those information (Achterberg and Arendt, 2007; Kondracki, Wellman et al., 2002). Classification or coding schemes vary depending on research objectives. However, coding needs to be consistent and able to count or analyse data adequately. I analysed the full texts in the selected articles manually evaluating yes or no answers to questions such as if the articles discuss about use of particular theories or methods of EIA, or effectiveness dimensions as well as whether the articles discuss the issues of nomadic-pastoral land use with respect to EIA theory, methods and effectiveness.

The validity of a content analysis study is directly linked to the organisation and availability of data (Elo, Kääriäinen et al., 2014). Data collection in this study has been conducted using a two-step approach employed in several peer reviewed content analysis research. Moreover, the results of content analysis should provide sufficient details and the meanings of the categories (Elo and Kyngäs, 2008). I reported findings related to each category I created in this study separately. How these findings contributed to EIA theory-building and future research were also discussed.

1.4.2 Questionnaires and interviews

Questionnaires and interviews are an effective method for evaluating opinions, attitudes and they are used to collect reliable data from a target audience. In particular, the self-administered questionnaire is cost-effective and quick to administer, and there is no possibility of interviewer bias. Combining both quantitative and qualitative approaches enhance research findings (Bryman, 2006). Thus, adding open ended questions to the questionnaire helps in receiving in depth information. Another advantage of questionnaire is that it can be sent out in large quantities at the same time (Bryman, 2016).

I applied a Likert type self-administered questionnaire (a questionnaire with 81 survey questions) which included 20 open-ended questions to understand the problems and to evaluate the effectiveness of Mongolia's EIA processes in addressing impacts related to dynamic land use in Chapter 3. The survey was sent by email to members of two associations of EIA and environmental management professionals, officers of central and local government departments in charge of EIA, members of environmental NGOs, and university lecturers in Mongolia. The survey included questions which might receive critical responses about Mongolia's EIA system. Thus, use of the self-administered questionnaire provided the possibility of receiving honest responses as when there is no interviewer present, interviewer effects are eliminated (Bryman, 2016).

Whilst it was not possible to send the self-administered questionnaire by email to herders who do not have internet access in many cases, the questionnaire was administered through the structured face-to-face structured interviews with senior family members of 200 households in rural areas of Mongolia for the study included in Chapter 5. This survey aimed at finding solutions to the problems of EIA with regard to nomadic-pastoral land use. As the face-to-face interview allows comprehensive understanding on participant actions, this method helped me to investigate the patterns of dynamic land use in depth including grazing strategies of herders. This method also allows use of visual materials during the interviews. Thus, maps were used which included names of local grazing areas to herders to mark grazing distances and locations with the help of respondents.

Since I have collected both qualitative and quantitative data, statistical and thematic analyses were carried out in Chapter 3 and Chapter 5 where questionnaires and interviews were applied. Mixed methods research is a relatively new approach. Therefore, mixed methods research has few writing conventions. It is important that when discussing results, findings from both qualitative and quantitative analyses are integrated to provide a fuller understanding of the phenomenon under study (Bryman, 2016).

1.4.3 Hierarchical Modelling of Species of Communities

Species distribution models quantify the correlation between environmental factors and the distribution of animal species and predicts species occurrence or abundance across landscapes, at times requiring extrapolation in space and time (Elith and Leathwick, 2009; Miller, 2010). In general, species distribution models are applicable for livestock population analysis (Hollings, Robinson et al., 2017). Hierarchical Modelling of Species of Communities (HMSC) is a statistical framework based on a hierarchical joint species distribution approach for analysis of multivariate data developed by Ovaskainen, Tikhonov et al. (2017). It is used to interrelate data on species occurrences, environmental covariates, and species traits, and measures how the occurrences of each species depend on environmental conditions (Tikhonov, Opedal et al., 2020).

Predicting dynamic land use occupations such as space used for grazing of animals in nomadic pastoralism is a methodological problem in land use related impact assessment (Dwyer and Istomin, 2008; Koellner and Scholz, 2006). In Chapter 4 of this thesis, HMSC has been applied to examine spatial and temporal changes of herd composition and livestock distribution at landscape level in the case of Mongolian pastoralism. Due to Mongolia's harsh climate and high-altitude conditions, traditionally for centuries, nomadic pastoralism has been a way of life and the only dominating form of agriculture in this country (Baabar, 1999). Herding is the source of key income for many households in Mongolia. Moreover, the most of meat is supplied from the livestock sector. Thus, the statistical and planning organisations in Mongolia pay special attention to collection of livestock species and production data due to the importance of the animal husbandry sector in Mongolia. Therefore, it was possible to collect from Mongolia comprehensive livestock species data as well as ecological and social datasets which can be applied in HMSC for this study. Livestock species in the pastoral regions of Mongolia include sheep, goat, cattle/yaks, horses and camels. HMSC suited for the purpose of this thesis to analyse abundance and distributions of five livestock species and their relationships with environmental and socioeconomic factors.

HMSC is implemented through the R package HMSC. In HMSC, the first step includes setting model structure and fitting the model where the user loads the data and makes decisions about model structure, including random effects, and environmental covariates (Tikhonov, Opedal et al., 2020). In this study livestock, environmental and social data from 326 administrative units of Mongolia for the periods between 1981-85, 1995-99, and 2010-13 have been analysed. HMSC's functions are used for estimating the model parameters as well as producing plots that illustrate the effects of social and environmental variables on livestock abundance, variances in livestock abundance explained by random spatial, environmental or social factors, and livestock species-to-species associations (Tikhonov, Opedal et al., 2020).

1.4.4 Structural equation modelling

The development of structural equation modelling (SEM) was the consequence of the growing needs of researchers who were looking for effective methods for understanding the interactions of unobserved (latent) variables (Tarka, 2018). The development of many software packages for SEM such as the R package lavaan which was used in this study also influenced wide applications of SEM in the social and behavioural sciences. The analyses conducted in Chapter 5 required examination of many variables including latent variables related to grazing patterns, herding mobility and strategy which I could not directly observe during the fieldwork. SEM is a statistical technique which can be used to reduce the number of observed variables into a smaller number of latent variables by examining the covariation among the variables and estimating the magnitude of effects of one variable on the other (Schreiber, Nora et al., 2006). Thus, SEM also fitted into the purpose of this study to examine both latent and observed variables and to quantify the pastoral areas and mobility.

In most analyses, SEM steps include specifying the model, evaluating model identification, collecting data, estimating the model, and reporting the results. The representation of hypotheses in the form of a structural equation model is specification (Kline, 2011). Relationships between observed and latent variables are hypothesized in the model specification. I specified a model formulating the relations between a set of parameters related to livestock, grazing space and herding mobility based on the Karplus and Meir (2013)'s concept of pastoral spatiality. My model is identified if it is theoretically possible for the software package to derive a unique estimate of every model parameter (Kline, 2011). I evaluated the model by applying exploratory factor analysis using the Zhang, Jiang et al. (2018)'s EFAutilities package in R. Exploratory factor analysis attempts to identify the smallest number of latent variables that can parsimoniously explain the covariation observed among a set of measured variables (Watkins, 2018). It is recommended a minimum sample size of 200 for any SEM (Weston and Gore, 2006). Thus, I collected pastoral data from 200 herder households using questionnaire for this study. Following the model evaluation and data collection, I estimated the model applying the R package lavaan. This step determines how well the model explains the data and if the model fits sufficiently, the parameter estimates are interpreted (Kline, 2011).

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CHAPTER 2. Literature review

The needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness: What are they and does EIA address them? [1]

Abstract

The aim of this article is to examine the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness based on literature review by applying Retief (2010)'s framework. The article intends to identify these needs and analyse whether EIA addresses them sufficiently and appropriately. Retief (2010)'s framework defines theory, methods (quality) and effectiveness as three main interrelated themes of environmental assessment. Our review was guided by these three themes and moreover, using nomadic pastoralism as a test case, we attempted to expand this broad framework into a four-step approach that can be used to systematically examine EIA literature. The approach first adopts the Retief (2010)'s framework and secondly, identifies issues of nomadic-pastoral land use which matter the most with respect to Retief (2010)'s themes. The next step selected 156 articles for literature review considering the issues identified previously and the fourth step examined the selected articles using a concept-centric review and a content analysis. Nomadic-pastoral land users need EIA theory to incorporate irrational logic and complex and unpredictable socio-ecological features of nomadic-pastoral land use. Decisions made based on the rational decision-making model in EIA cannot sufficiently incorporate the needs of nomadic-pastoral land use due to uncertainties associated with rational decision-making and different power, values and interests of stakeholders in pastureland resources. Furthermore, the needs of nomadic-pastoral land users with respect to EIA methods are related to impact pathways and dynamic character of land use. EIA methods systematically address impact pathways. However, the current EIA methods primarily focus on static land use, and do not address sufficiently and appropriately dynamic nature of land use. For nomadic-pastoral land users, maintaining land quality in nomadic pastoralism and participation in EIA are the most important issues with respect to effectiveness of EIA. However, empirical data are needed to examine whether these needs are addressed in EIA. Nevertheless, the current frameworks for evaluation of effectiveness

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of EIA are sufficient for assessment of EIA's capacity for addressing the needs of nomadic-pastoral land users. Further studies should aim at incorporating the nature of socio-ecological interaction and dynamics into EIA theories and developing suitable models on herding mobility and strategy for impact prediction in EIA.

Keywords

Environmental impact assessment; Retief; nomadic-pastoral land use; dynamic land use; land use impact assessment; effectiveness

2.1 Introduction

Pastoralism is one of the key land based production systems in the world which includes activities of extensive grazing in rangelands for livestock production (Blench, 2001). Grazing systems may vary from sedentary to nomadic, depending on grazing mobility and the herders' residence. In contrast to a sedentary system, the nomadic system is based on extensive movement of herds in search of forage, led by herders with no permanent home base (Allen, Batello et al., 2011). This type of nomadic-pastoral land use allows herders to graze dynamically, preserving land quality through seasonal pasture rotation. Therefore, in nomadic pastoralism, the needs of nomadic-pastoral land users are maintaining communal, flexible and dynamic land use in a sustainable manner.

Then, what does this mean for EIA and what issues should EIA consider when dealing with impact prediction or decision-making related to nomadic-pastoral land use? This article aims to examine the needs of nomadic-pastoral land users with respect to EIA by applying Retief (2010)'s framework on three key interrelated themes for environmental assessment (EA): theory, methods and effectiveness. We intend to identify these needs related to EIA theory, methods and effectiveness and analyse whether EIA addresses them sufficiently and appropriately.

Moreover, using nomadic-pastoral land use as a test case, we attempted to expand the broad framework of Retief (2010) into an approach that can be used to systematically examine EIA literature with regard to certain issues of interest. The advantage of applying this approach in this study is that we link the topic of nomadic-pastoral land use with three specific themes instead of investigating numerous EIA related topics. Moreover, the approach helps us to understand what issues to focus on when examining a large EIA literature.

The Retief (2010)'s framework stresses that none of the three key themes can be considered in isolation since they inform each other in an interactive and iterative manner and asks questions, "What is EA?", "How can EA be applied?/How can we do EA?" and "How well is EA being done — and —what is EA achieving?". We examined each of these questions from the perspective of nomadic-pastoral land users separately as follows:

- What are the needs of nomadic-pastoral land users with respect to EIA theory and does EIA address these needs sufficiently or appropriately?
- What are the needs of nomadic-pastoral land users with respect to EIA methods and does EIA address these needs sufficiently or appropriately?
- What are the needs of nomadic-pastoral land users with respect to effectiveness of EIA and does EIA address these needs sufficiently or appropriately?

Section 3–5 examines the questions above. In the concluding section, we synthesise our main findings and propose subsequent further research steps.

2.2 Methodology

The methodology used in this research was based on the broad framework approach of Retief (2010) which defines theory, methods and effectiveness as three main interrelated themes of environmental assessment. We expanded this framework into a four-step approach (Figure 2.1) to examine EIA literature and used nomadic pastoralism as a test case to identify the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness and investigated whether EIA addresses these needs.

The first step of the approach adopts the Retief (2010)'s framework to the issue we examine which is nomadic-pastoral land use. This step defines the themes we need to look at in the EIA literature and guides our review in the direction of three interrelated EIA themes (theory, methods, effectiveness) by Retief (2010) that our analysis should focus on. Comprehensive reviews on theories, practice and effectiveness of EIA (Morgan, 2012) and impact assessment (IA) (Pope, Bond et al., 2013) have been conducted at a high level only. In contrast, this review examines these EIA themes from the perspective of nomadic-pastoral land users. The second step links nomadic-pastoral land use issues with our review themes. We review literature related to nomadic-pastural land use and first identify, the key norms and characteristics of nomadic-pastoral land use. Considering these norms, we identify issues related to the needs of nomadic-pastoral land use with respect to EIA theory, methods and effectiveness. These issues are used in selecting articles we review for this research as well as in analysis of whether EIA addresses the needs of nomadic-pastoral land users in the following steps.

The next step selects articles for our literature review and it follows a two-step approach similar to methods employed by Perminova, Sirina et al. (2016), Pu, Lyu et al. (2016) and Wang, Li et al. (2011) where first journals, then articles are selected. These methods select journals based on subject categories indexed by academic databases or ranking of journals in certain subject categories. The topics we examine are interdisciplinary and the review needs to look at various subject categories. Thus, we used all journals included in the ISI master list as data for our analysis and chose a selection approach which searches by keywords in the titles of journals as a first step to narrow down our search result and yet to focus on all journals. We first select journals which focus on the subjects connected to EIA and pastoral land use searching by combinations of 26 key words (assessment, biodiversity, change, conservation, development, ecology, ecosystems, environment, health, impact, land, life, management, model, pasture, nomad, nomadic, planning, policy, pollution, protection, quality, research, risk, science, sustainability) in the titles of all journals in the ISI master list. The search was carried out in several steps.

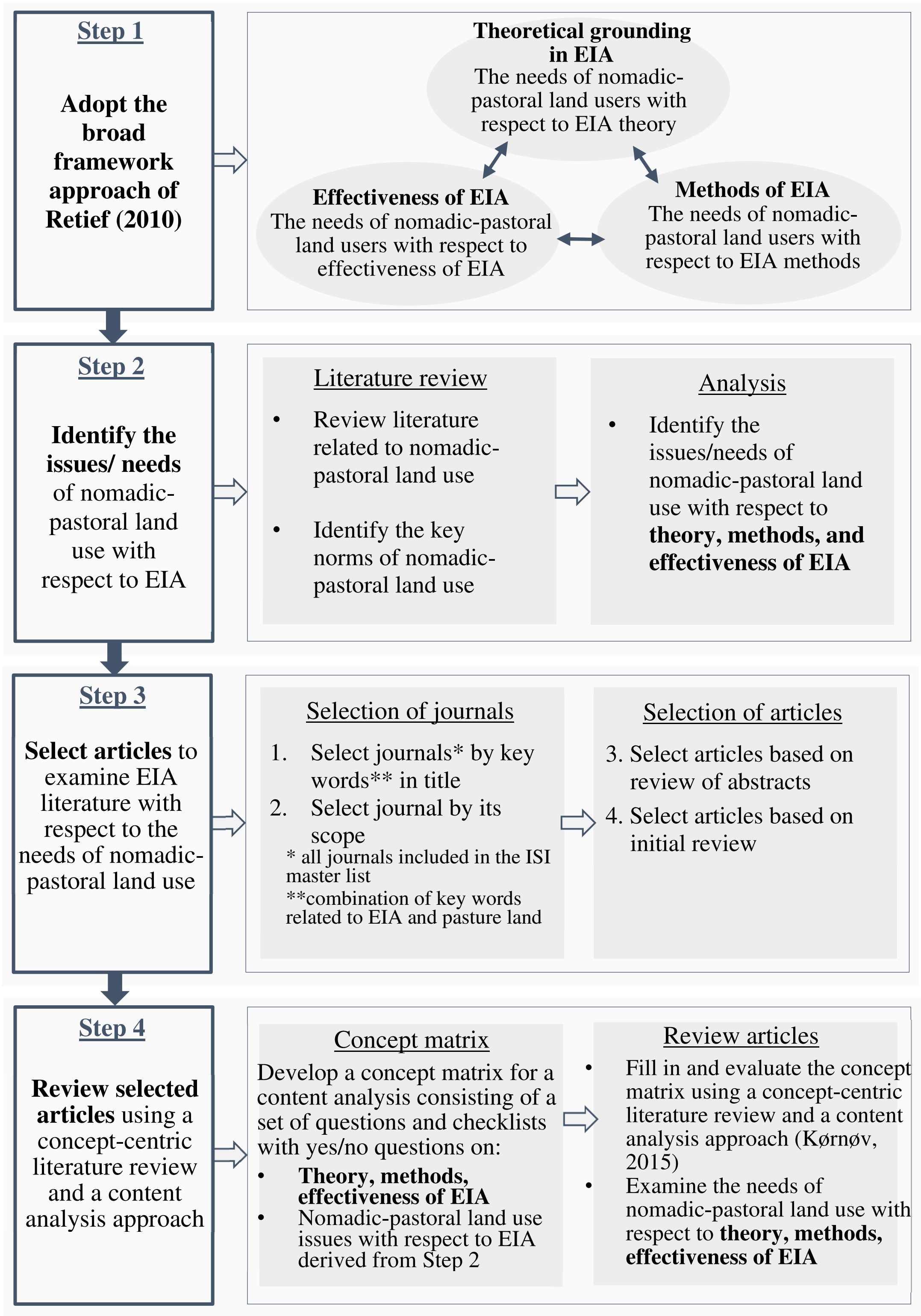

Figure 2.1. Four-step approach to examine EIA literature based on Retief (2010).

We search first with a few key words ("environment, impact, assessment, pasture, land") directly related to our topic, then re-evaluate our selection and re-search adding more key words until we get a sufficient number of journals. As result 83 journals were selected. Furthermore, we selected 40 journals which specifically focus on the themes of our literature review by examining the scope of the previously selected 83 journals.

Following that, we reviewed the abstracts of these 40 journals published over the last 10 years starting from June 2008 (20 years for Environmental Impact Assessment Review journal). We selected 550 articles from 25 journals which primarily focus on EIA and IA theory, methods (focusing on land use impact prediction methods) and effectiveness. From our review, we subsequently excluded articles on environmental management, evaluation of national EIA systems, IA methods and types of IA other than EIA or land use. This step resulted in a selection of 156 articles.

The fourth step focuses on a concept-centric review of selected articles. First we developed a concept matrix organised in an Excel spreadsheet for a content analysis (Kørnøv, 2015) which evaluates yes or no answers to questions such as if the articles discuss about use of particular theories or methods of EIA, or effectiveness dimensions as well as whether the articles discusses the issues of nomadic-pastoral land use with respect to EIA theory, methods and effectiveness which we identified in the Step 2. The results of the literature review are included in the following discussions.

2.3 Nomadic-pastoral land use and EIA theory

2.3.1 The needs of nomadic-pastoral land use with respect to EIA theory

Communal grazing, mobility, flexibility and reciprocity are the norms of land use in nomadic pastoralism (Fernandez-Gimenez, 2000). A nomadic pastoralist system is not a coherent unit and interrelations between its elements are rather complicated (Dwyer and Istomin, 2008). In nomadic pastoralism, grazing locations and length of the time herders occupy certain grazing locations are often spontaneously changed due to unpredictability of the environment such as the biogeographical and weather conditions as well as other external interventions. Moreover, nomadic pastoralism is based on a wide variety of features of the natural as well as social environment (Dyson-Hudson and Dyson-Hudson, 1980).

Whether EIA addresses the needs of nomadic-pastoral land users would depend on how theories, methods and practice of EIA further evolve. It is because "theories provide a framework for analysis, and efficient method for field development and clear explanations for the pragmatic world" (Wacker, 1998, p. 362). EIA theory should "further understanding of human activity, the environment, and critical interactions between the two" (Lawrence, 1997, p. 81). Moreover, Cashmore (2004) noted that EIA theory should be based on a good understanding of causal processes to achieve the substantive purposes of EIA. Therefore, from the perspective of nomadic-pastoral land users, EIA theory should provide a framework for analysis and explanations for interactions between project interventions, nomadic-pastoral land use and decision-making. In particular, EIA theory should incorporate incoherent, ad hoc and irrational characteristics of nomadic-pastoral land use and consider complex and unpredictable socio-ecological features which influence nomadic pastoralism.

2.3.2 Addressing the needs of nomadic-pastoral land use with respect to EIA theory

This section examines whether theories used in EIA incorporate irrational logic and unpredictable socio-ecological features of nomadic pastoralism. For this analysis, we search for information about various theories in the articles we review and examine if these articles discuss about irrational logic and socio-ecological system.

Our data show that 33 out of 156 articles we reviewed discuss theories in relation to the EIA process (Table 2.1). Moreover, 10 different theories were applied in 36 cases for various purposes such as to conceptualise certain EIA related ideas, processes and methods or to contribute to EIA theory-building. The most frequently used theories were the rationalist theory and decision-making theory which were used 14 and nine times respectively.

Table 2.1. Theories discussed in the articles (by frequency).

Theories discussed	Discusses theories applied in EIA	Discusses the challenges of addressing irrational logic	Discusses the challenges of addressing complex and unpredictable socio-ecological system
Rationalist theory	14	4	0
Decision-making theory	9	3	0
Planning and power theory	4	4	1
Political theory	2	0	0
Communication theory	2	1	1
Actor–network theory	1	1	1
Complexity theory	1	1	1
Traditional scientific theory	1	1	1
Democratic theory	1	0	0
Deliberative planning theory	1	0	0
	36	**15**	**5**

The rational decision-making chooses the best solution for a defined need from a range of alternatives based on the analysis of all relevant information (Morgan, 2012). Initially, the rational process view originated from the theory on rational decision-making which has its roots in the sociological traditions of Weber, Henderson et al. (1947) and was applied to town planning in 1960s before it was adopted to EIA (Taylor, 1998; Weston, 2010). However, the rational decision-making model applied to EIA has been criticised by scholars for failing to accommodate the values of those potentially affected by the project activities and despite these critical views an abundance of literature and practice suggest that the root of EIA is still firmly based on a rationalist model of planning and decision-making (Morgan, 2012).

The current legal frameworks for EIA emphasise simplistic understandings of cause–effect and liability, although it is generally understood there is no single cause for a particular response and at some tipping point, ecosystem response becomes nonlinear (Wenning, Apitz Sabine et al., 2017). In 15 cases, articles we reviewed discuss about the challenges of using such simplistic linear logic in EIA as well as share a critical view of using the rationalist decision-making model in EIA.

Rationality in decision making is defined by reasoning in a way which helps one to achieve one's goals and reasoning by a process of logic (Evans, Over et al., 1993). By contrast, irrationality is defined by a notion of being poorly adapted to goals (Simon, 1993). However, it does not suppose that it is less intelligent (Howard, Bennett et al., 1993). In fact, with bounded capacities sometimes goals are achieved without close examination of the logic (Evans, Over et al., 1993). Five articles discuss about the challenges of addressing complexity of socio-ecological systems in EIA and we note that the EIA literature pays attention to issues related to irrational logic and unpredictable socio-ecological features of nomadic pastoralism. However, the discussions are more focused on the challenges and needs rather than addressing nonlinear effects and complexity, and unpredictability of social and environmental systems. Two discussion points arise in connection with application of the rational decision-making model in EIA and how it affects the interests of nomadic-pastoral land users.

The first point concerns the uncertainty in EIA, linked to the rationalist theory. Uncertainty is present and almost unavoidable in EIA predictions at varying levels at different stages of the EIA processes for a number of complex reasons (Leung, Noble et al., 2016; Tenney, Kværner et al., 2006). In addition to uncertainty being an inherent feature of EIA predictions, uncertainty is also a direct result of discretionary features of EIA steps. First of all, priorities and multi-criteria selections inherently relate subjective values applied for defining impact significance. Secondly, discretionary decision-making occurs in multiple steps of implementing the recommendations of EIA. Ultimately, where decision makers have the task of weighing different interests according to their subjective preferences and derive a decision (de Jongh, 1988). Hence, it is not a given that decisions are made on the basis of a weighing process which considers all possible alternatives on an equal basis.

Thus, uncertainty in EIA is not only related to the unknowns within the impact prediction methods, but also caused by a rational decision-making model. Weighing and making decisions in a rational way leaves more room for various alternatives to take advantage of such uncertainties. It makes decision-making not clear and transparent for nomadic-pastoral land users. Moreover, opinions and concerns expressed by nomadic-pastoral land users can be not considered in decision-making due to weighing of different kinds of interests than those of nomadic-pastoral land users.

The second point to make note of is that power, values and interests of non-nomadic-pastoral stakeholders influence the rational decision-making related to nomadic-pastoral land use. As the treadmill of production theory suggests, the strong relationship between environmental harms and economic development will remain constant or possibly increase through time (Gould, Pellow et al., 2008). Therefore, a typical scenario decision makers often face is that choices have to be made between alternatives whereby the first option brings significant economic benefits and meanwhile causing more negative environmental impacts and an alternative option whereby the project profits less financially, however harms the environment to a smaller extent. The latter option is usually more favourable for nomadic-pastoral land users, as their needs are simply long-term sustainable land use. However, firms aiming to be good at improving environmental performance face a trade-off which in consequence leads to self-limiting with regard to continuously moving towards greater corporate sustainability by simultaneously improving environmental and economic performance (Wagner, 2015). Thus, non-nomadic-pastoral stakeholders often opt for the first option as this serves their power, value and interest in the project. Moreover, according to Lukes (1974), power allows one to make decision, set the agenda and even manipulate the view of others. Therefore, those stakeholders who have more power than nomadic-pastoral land users are in the position to influence the decision-making more.

2.4 Nomadic-pastoral land use and EIA methods

2.4.1 The needs of nomadic-pastoral land use with respect to EIA methods

In nomadic pastoralism, the needs are that herding activities be not affected negatively by the projects and therefore, requires EIA methods to predict potential impacts appropriately. Hardin (1968)'s model suggests that as a rational being each herder tends to maximise his or her herds' size in a communal grazing system. In this case, herders increase their gain; however, the decision results in the "tragedy of the commons" causing overgrazing which is shared by all herders. Hence, in a limited communal grazing space, any new land use including project intervention causes negative effects on each land use.

Depending on the project complexity, EIA often analyses a large number of environmental and social impacts of land use. The biophysical environment itself is an incredibly complex system and when it is interacted with human intervention, impact pathways which link cause with effects become more complicated to examine. Slootweg, Vanclay et al. (2001)'s framework (conceptualised based on analysis of the environmental functions by de Groot (1992a) and de Groot (1992b)) provides a clear logic of how environmental and social impacts are derived from project interventions and their links to human society and the biophysical environment (Figure 2.2).

Moreover, Slootweg, Vanclay et al. (2001)'s framework suggests two interrelated impact pathways for nomadic-pastoral land use. These are impacts of projects on nomadic-pastoral land use and impacts of nomadic-pastoral land use such as overgrazing on the environment.

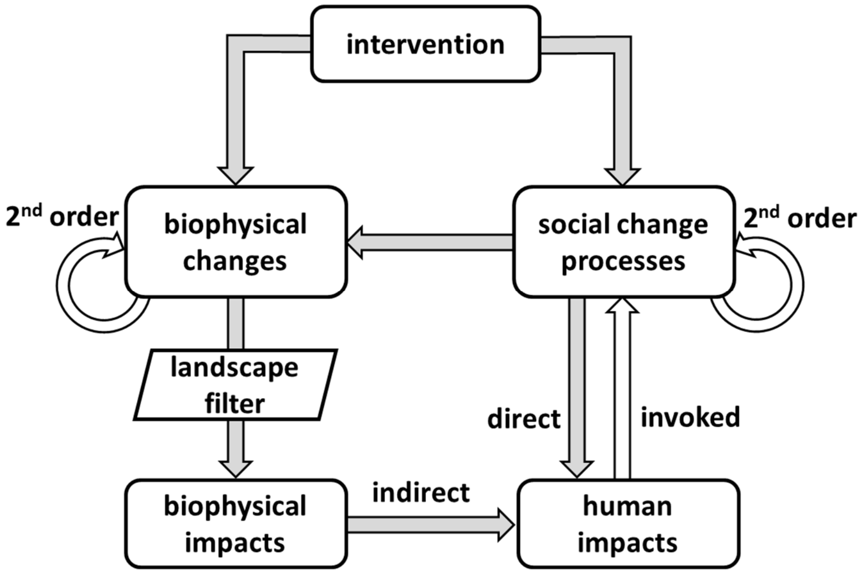

Figure 2.2. Pathways deriving biophysical and human impacts (Source: Slootweg, Vanclay et al. (2001)).

Particularly, in nomadic pastoralism, mobility allows herders to move freely through large areas and to constantly change their grazing locations. Such dynamic character of land use complicates impact pathways between projects and nomadic-pastoral land users. Thus, nomadic-pastoral land users need EIA methods to predict and address impact pathways and dynamic character of land use sufficiently and appropriately.

2.4.2 Addressing the needs of nomadic-pastoral land use with respect to EIA methods

The next step examines whether the EIA methods incorporate the needs of nomadic-pastoral land users. For this, we look at questions: if the articles we review discuss EIA methods and if yes, what kind of methods are discussed; and if these methods consider impact pathways and dynamic character of land use. A total of 131 out of 156 articles we reviewed discuss a variety of 19 different EIA methods (Table 2.2) and most articles discuss methods related to EIA pre-decision analysis (114 out of 131), particularly impact prediction, whilst the rest of the methods refers to EIA follow-up issues. The methods described in these 131 articles can be categorised into three types. The first type focuses on traditional methods for EIA including approaches of matrices, weights, check lists, networks, impact pathways, and stakeholder engagement. The second type discusses EIA follow-up methods. Third group discusses EIA impact prediction methods such as GIS, remote sensing, multi-criteria analysis, physical, mathematical and simulation models, scenario and Delphi analyses, and land use impact assessment (LUIA) approaches such as predictive land change models and LUIA within life-cycle assessment (LCA). No article specifically focuses on impact prediction methods for nomadic-pastoral land use.

Table 2.2. Methods discussed in the articles (by frequency).

Methods		Number of articles discussed		
		Methods used in EIA	Impact pathways	Dynamic land use
EIA pre-decision analysis	LCA/LUIA within LCA	31	11	0
	GIS/Remote sensing	19	2	0
	Mathematical models	12	2	0
	Simulation models	7	1	0
	Predictive land-change models	8	1	0
	Multicriteria analysis	3	0	0
	Scenario analysis	3	0	0
	Others	9	0	0
Traditional methods	Matrices, weights, check lists	7	0	0
	Networks, impact pathways	11	6	0
	Stakeholder engagement	4	0	0
EIA follow-up	EIA follow-up	17	0	0
		131	**23**	**0**

Likewise, we reviewed if these methods used in EIA consider impact pathways and dynamic land use. A good number of articles (31 out of 131) we reviewed are related to LUIA within LCA and 11 out of these articles discuss impact pathways extensively. It indicates that LUIA within LCA addresses issues of impact pathways which need to be analysed to predict impacts about nomadic-pastoral land use. Moreover, from our selected repository 23 articles discuss methods used in EIA, such as causal networks, impact pathways and system diagrams which deal with cause-effect chains in a detailed or broader context. In particular, causal networks suit well to explore cause-effect relationships when they regard indirect and cumulative impacts, and impact interactions (Perdicoúlis and Glasson, 2006). Thus, there are specific approaches in EIA which address impact pathways, and the needs of nomadic-pastoral land users with respect to impact pathways can be met. In contrast, no article focuses on predicting impacts related to dynamic land use and it appears that issues related to mobile and flexible type of land use are left out of the methods used in EIA.

The review shows that LUIA within LCA is the most repeated method among articles we reviewed and based on a review of 187 articles, Perminova, Sirina et al. (2016) also concluded LCA as the most frequently used method for LUIA. If it is the case, we follow up to understand why this key method for LUIA is not addressing dynamic character of land use. Milà i Canals, Bauer et al. (2007) posits that there is no widely accepted standard method for assessing environmental impacts related to land use. LCA assesses environmental impacts associated with product's life cycle. When LCA moves into land use related issues the clear borders between LCA and EIA become somewhat less distinct (Milà i Canals, Bauer et al., 2007, p. 6). The key distinction is the aspects covered by these tools. LCA focuses purely on physical aspects of land, in contrast EIA addresses both physical and social impacts of land use. Moreover, it can be determined that the key similarity is that the both assessments look at changes in land quality and identify potential damages to biodiversity and ecosystem services caused by human activities.

LUIA within LCA considers two processes of physical land use. Land transformation process where the type/quality of land use is changed to make it suitable for a new use (e.g. the topsoil is removed to start mining) and land occupation process when land is used for the intended new land use (e.g. the mining itself) (Lindeijer, 2000; Milà i Canals, Bauer et al., 2007). In EIA, these processes are usually referred as construction and operation phases. Land use impacts are calculated for each of these processes and three aspects influence the land use impact significance. These are i) A - area used, ii) t – time required for transformation process including time for full regeneration of land quality; T - time required for the occupation process, and iii) ΔQ - difference in land quality between the current (after intervention - Qfin) and initial (reference/baseline situation - Qini) land use (Figure 2.3). Land use impacts are calculated as follows using suitable indicators for the different affected impact pathways (biodiversity, ecosystem services, etc.) (Koellner, de Baan et al., 2013; Lindeijer, 2000; Milà i Canals, Bauer et al., 2007):

land transformation impacts = area $A \times$ time $t \times$ land quality ΔQ;
land occupation impacts = area $A \times$ time $T \times$ land quality ΔQ.

This calculation is for a single land use, however, Koellner and Scholz (2006) proposed a solution for calculation of the total damage from a series of land use activities, including a complex series of transformation and occupation. This has been a methodological problem for LUIA and the proposed method assesses impacts of complex sequences of land use such as rotation systems in agriculture. It is possible to use this method for calculation of impacts from a series of nomadic-pastoral land use where rotation systems are used as described in Koellner and Scholz (2006)'s example. Still, this method is applied to a static land use where locations of activities and transformation and occupation time are known and therefore, the method is not addressing the needs of dynamic land use. As mentioned, in dynamic land use, grazing locations and occupation time are often spontaneously changed due to unpredictability of the environment. Therefore, to apply this method, models which predicts herding mobility such as grazing locations and time of occupation should be used in EIA.

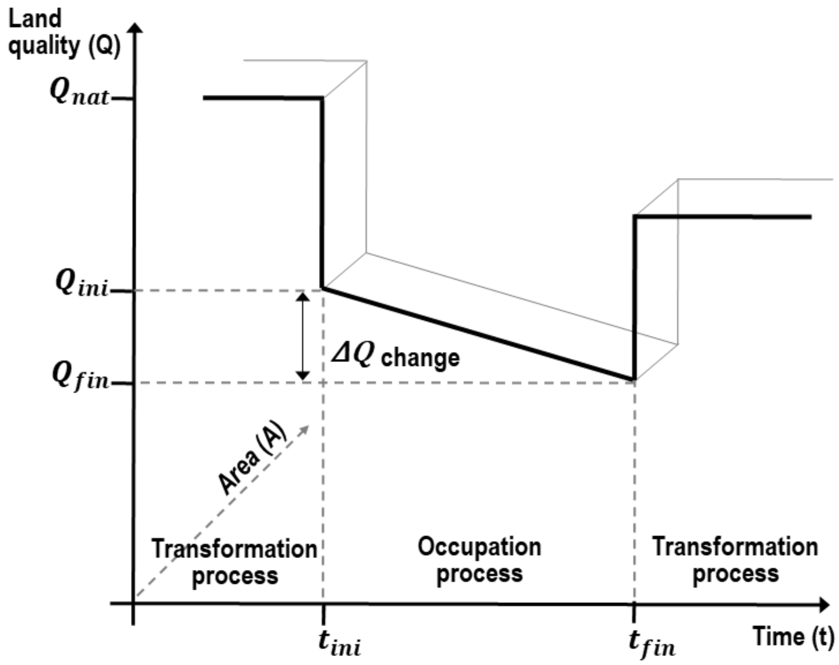

Figure 2.3. Evolution of land quality with land use interventions
(adapted from Lindeijer (2000); Milà i Canals, Bauer et al. (2007)).

Fully unravelling spatiotemporal pattern of grazing movement remains a difficult scientific challenge (Zhao and Jurdak, 2016). However, promising new results (modelling cattle movement (Zhao and Jurdak, 2016), grazing resource management and mobility strategies (Wario, 2015), pastoral mobility for transhumance system (Xiao, Cai et al., 2015), etc.) are contributing to development of herding mobility models. EIA would meet the needs of nomadic-pastoral land users if such herding mobility models suitable for each project area conditions are incorporated into EIA prediction methodologies to reduce uncertainty of nomadic-pastoral land use.

2.5 Nomadic-pastoral land use and effectiveness of EIA

2.5.1 The needs of nomadic-pastoral land use with respect to effectiveness of EIA

Cashmore, Gwilliam et al. (2004) and Rozema and Bond (2015) note that EIA has a limited role in consent and design decisions, and such concern about EIA practices has resulted in ongoing debate and the progressive development of a substantial body of research on the issue of effectiveness. Sadler (1996) suggested that the term effectiveness refers to whether something works as intended and meets the purposes for which it is designed, and first defined procedural (whether EIA conforms to established provisions), substantive (whether EIA achieves its purposes, e.g., environmental protection), and transactive (whether EIA is cost efficient) effectiveness to measure whether EA is effective or not. Normative (how individual and social norms are achieved in IA) effectiveness (Baker and McLelland, 2003; Bond, Morrison-Saunders et al., 2013) and aspects of pluralism (whether assessment takes different views) and knowledge and learning (whether the assessment process facilitates knowledge sharing) (Bond, Morrison-Saunders et al., 2013) were added later. Pope, Bond et al. (2018)'s recent work proposed to replace the final three dimensions with legitimacy which measures whether the assessment process perceived to be legitimate by a wide range of stakeholders.

As pastoralism is a land based production system, in the case of nomadic-pastoralism the substantive effectiveness can refer to whether EIA works to the extent that land quality level is maintained when projects intervene in land use systems. Moreover, herders' participation in EIA such as considering opinion and concerns of nomadic-pastoral land users in the decision-making relates to procedural effectiveness and legitimacy dimension of EIA. Land use impacts depend on difference in land quality (ΔQ) between the current (after intervention - Qfin) and initial (reference/baseline situation - Qini) land use (Koellner, de Baan et al., 2013; Lindeijer, 2000; Milà i Canals, Bauer et al., 2007) (Figure 2.4).

The needs of nomadic-pastoral land use are met if EIA ensures that the difference in land quality is reduced to zero when projects may affect the land use system. EIA can set a more ambitious goal of reaching the natural quality of pasture land which represents the natural mix of grassland. At least a safe minimum standard or sustainability limit of acceptable change the land use system can benefit or risk should be maintained (Potschin and Haines-Young, 2008). Moreover, depending on the land quality which EIA is aiming to reach, a suitable reference situation can be chosen from Cao, Margni et al. (2017)'s model on different land reference situation.

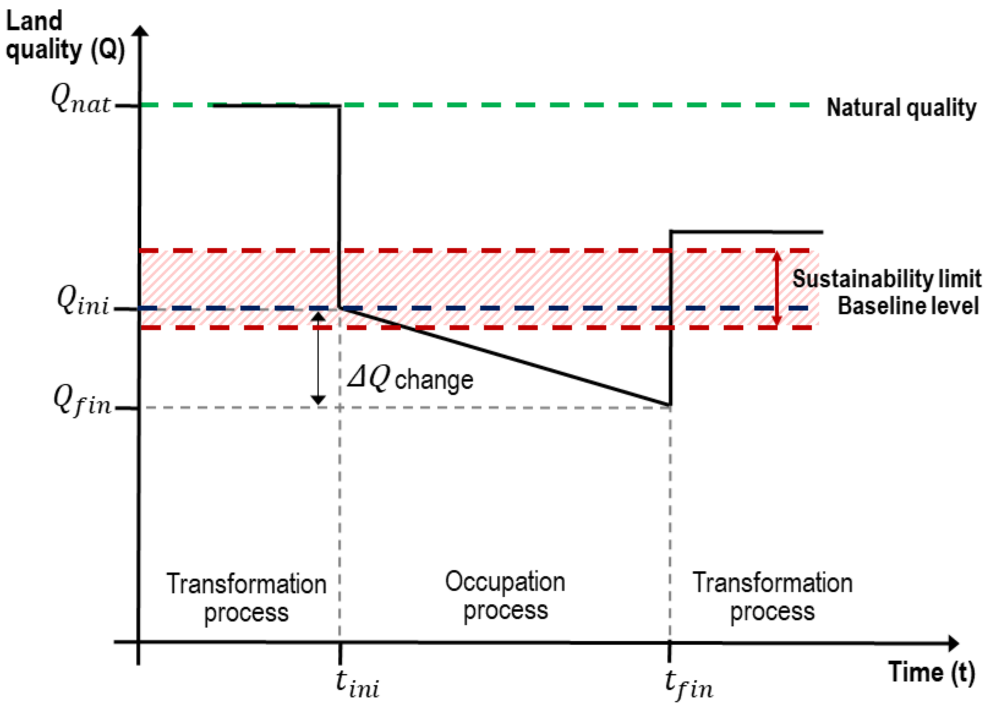

Figure 2.4. Reference levels for evaluation of EIA's substantive effectiveness for land use (adapted from Lindeijer (2000); Milà i Canals, Bauer et al. (2007); Potschin and Haines-Young (2008)).

As a process EIA includes a baseline monitoring component which may be carried out over seasons or years to quantify ranges of natural variation that are relevant to impact prediction and mitigation (Morris and Therivel, 2009). Nomadic-pastoral land users can monitor the level of land quality comparing such monitoring results with different reference levels. However, nomadic-pastoral land users need to participate in the EIA process in order to be informed about monitoring activities and raise concerns if their needs regarding land quality are not met. Therefore, land quality and participation in EIA are the most important issues for nomadic-pastoral land use with respect to effectiveness of EIA.

2.5.2 Addressing the needs of nomadic-pastoral land use with respect to effectiveness of EIA

The question of effectiveness has been a topic of research from the earliest days of IA (Pope, Bond et al., 2018) and indeed, a good number of articles (32 out of 156) we reviewed discuss about topics related to effectiveness of EIA.

Land quality which is the most important issue for nomadic-pastoral land users as mentioned relates to substantive effectiveness of EIA. It is possible to know whether EIA protects the quality of pasture land if there are sufficient project monitoring data as well as methodology available for such evaluation. Loomis and Dziedzic (2018) notes that there are still no studies that empirically measure the direct influence of EIA on decision-making. Moreover, none of 156 articles we reviewed discusses nomadic pastoralism and its link to the substantive outcome of EIA. Our initially selected 550 abstracts also do not discuss the needs of nomadic-pastoral land use regarding EIA, even in general. It shows that not much studies focus on this topic, hence as there are no sufficient research, one can neither draw any conclusions on whether EIA is effective in addressing the needs of nomadic-pastoral land users regarding their needs for land quality nor their participation in EIA. However, data we collected was useful for discussion about whether EIA literature pays attention to addressing the needs of nomadic-pastoral land users with respect to effectiveness of EIA. One way to analyse this question is to look at the existing evaluation frameworks for effectiveness of EIA and examine whether these frameworks include criteria to evaluate EIA effectiveness related to land quality or herders' participation in EIA (Table 2.3). Inclusion of such criteria is important as evaluation systems are in place to improve effectiveness and it would show that EIA recognises the importance of the needs of nomadic-pastoral land users.

We examined frameworks listed in Table 2.3 which were developed for evaluation of effectiveness of IA. All frameworks consider dimensions of effectiveness discussed above and include general criteria or questions for evaluation covering a wide aspects of EIA processes.

Table 2.3. Criteria for evaluation of the needs of nomadic-pastoral land users.

Framework for evaluation of effectiveness of EIA	Whether the framework includes criteria related to	
	land quality	participation
Bond, Morrison-Saunders et al. (2013)	Yes	Yes
Chanchitpricha and Bond (2013)	No	Yes
Hanna and Noble (2015)	Yes	Yes
Bond, Pope et al. (2015)	Yes	Yes
Pope, Bond et al. (2018)	Yes	Yes

Except one case, all frameworks include general criteria related to the needs of nomadic-pastoral users. Thus, the needs of nomadic pastoral land users with respect to effectiveness of EIA are considered in these frameworks.

2.6 Conclusions

Reflecting on the original research questions, first of all nomadic-pastoral land users need EIA theory to incorporate irrational characteristics of nomadic-pastoral land use and to consider complex and unpredictable socio-ecological features which influence nomadic pastoralism. We note that the theory on which EIA has been grounded insufficiently and inappropriately incorporates a conceptual framework which would be able to reflect, qualify or quantify the needs of nomadic-pastoral land users. This conclusion is substantiated in the first place by the fact that our literature review could not find any studies which specifically explain how conceptually EIA could address or incorporate impacts on nomadic-pastoral land use. This missing link can only be explained by a number of fundamental assumptions which are generally adopted by EIA theorists.

First of all, among the articles we reviewed, rationalist and linear cause-effect epistemologies are dominant underlying paradigms or fundaments of EIA discourses. Given this, there is very little room for the 'irrational' (read: heuristic, ad hoc, pragmatic) logic of nomadic-pastoral land users. Accordingly, if decisions are made in a rational way in EIA, the needs of nomadic-pastoral land users cannot be sufficiently incorporated in EIA due to uncertainties associated with rational decision-making as well as different power, values and interests of stakeholders in pasture land resources. However, further empirical studies are needed to examine to what extent the theory on which EIA has been grounded incorporates the needs of nomadic-pastoral land users and issues which should be considered in the EIA theory-building.

A second problem with this linear thinking whereby a socially constructed decision has a direct impact on a physical characteristic is that the dynamics of land use and of land users, which are complex and unpredictable socio-ecological systems, are not conceptually anchored in EIA fundaments or theories. It is therefore recommended that EIA theories are constructed reflecting the nature of socio-ecological interaction and dynamics. Simply put, the nature of how people and the environment interact can be altered ad hoc and for pragmatic reasons. This calls for theories of a more adaptive, and what we refer as more 'nomadic', EIA.

Secondly, we identified that the needs of nomadic-pastoral land users with respect to EIA methods are related to impact pathways and dynamic character of land use. Our review notes that there are specific approaches used in EIA which address impact pathways systematically and therefore, impact pathways associated with nomadic-pastoral land use can be addressed in EIA. However, our review found that the methods of EIA address issues related to dynamic character of land use insufficiently and inappropriately. Regardless of whether EIA refers to static or dynamic land use, EIA first predicts potential land use impacts using models and tools founded on various scientific disciplines. Information from this prediction process is used for decision-making to ensure that environmental issues are able to be considered in the decision-making.

However, in EIA impact prediction of nomadic-pastoral land use, uncertainty arises due to dynamic character of land use and it creates risks of predicting impacts insufficiently. The review notes that the current EIA methods primarily consider static land use, whilst at the same time there is a lack of studies on methods for dynamic land use. Hence, EIA practice should be improved and particularly, further research is needed on models for land use impact assessment capturing dynamic nature of land use to reduce uncertainty in EIA and to appropriately incorporate the needs of nomadic-pastoral land users.

Thirdly, for nomadic-pastoral land users, maintaining land quality in nomadic pastoralism and participation in EIA are the most important issues with respect to effectiveness of EIA. Land quality relates to substantive effectiveness and procedural effectiveness and legitimacy dimension of EIA should be measured to evaluate whether EIA ensures participation of herders in the decision-making processes. Our literature review did not provide any empirical data on nomadic pastoralism which could be used to analyse effectiveness of EIA with respect to nomadic-pastoral land use. However, we found that the current frameworks for evaluating effectiveness of EIA include criteria which cover a wide range of aspects of EIA, and therefore, are able to assess EIA's capacity for addressing the needs of nomadic-pastoral land users.

Use of Retief (2010)'s expanded four-step approach allowed us to systematically examine EIA literature and find answers to our research questions. This approach narrowed down topics we needed to consider in our review guiding it to three key EIA themes. Moreover, the approach provided clear links between the questions we examined in this article, data we used and our conclusions.

The questions examined in this article have never been studied previously and we note that future research could explore these questions further by investigating possibilities of improving EIA theory and practice to incorporate the needs of nomadic-pastoral land users. As mentioned previously, interesting topics for future work can be issues of addressing complexity of socio-ecological systems in EIA theories and development of suitable models which explain grazing patterns in nomadic pastoralism for impact prediction in EIA.

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CHAPTER 3. Case study

Evaluating the effectiveness of the environmental impact assessment process in Mongolia for nomadic-pastoral land users [2]

Abstract

The aim of this article is to evaluate and improve the effectiveness of Mongolia's EIA processes for nomadic-pastoral land use(rs) (NPLU(rs)). NPLU(rs) are often overlooked in many spatial policies, so the justification for this study is to improve the EIA processes regarding impacts on NPLU. This is the first study to examine EIA effectiveness for NPLA(s) specifically. It employs a Likert survey of 50 respondents based on the framework of Hanna and Noble (2015). The results of this study indicate that there is indeed an immense gap between how EIA should be carried out and its implementation processes in practice. We find that although the EIA framework has good ambitions and is relying on a sound legislative and institutional set-up in Mongolia, it lacks stakeholder confidence, participation and the effectiveness in mitigating both social and environmental impacts associated with NPLU failing to ensure substantive gains to pastureland resources. Improvements are especially required in EIA practice, impact prediction methods suitable for dynamic land use, capacity building, transparency, EIA integration into spatial planning, and stakeholder engagement.

Keywords

Effectiveness; Environmental impact assessment; Mongolia; Nomadic-pastoral land use; Hanna and Noble's framework

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3.1 Introduction

Since its introduction in a legislative form in 1969, the use and relevance of environmental assessment has significantly increased (Morgan, 2012; Pope, Bond et al., 2013) as a component of land and environmental interventions. Over time, the environmental impact assessment (EIA) processes have become more elaborate and comprehensive, and have thus become more supportive for policy innovations. As a result, in more than 190 countries EIA has become a legally required instrument for any environmental intervention (Morgan, 2012; Sadler, 1996). At the same time, however, there has always been a debate about the effectiveness of EIA, and about its (sometimes partisan) role in decision-making (Banhalmi-Zakar, Gronow et al., 2018; Cashmore, Gwilliam et al., 2004; Pope, Bond et al., 2018; Rozema and Bond, 2015). This includes the question whether EIA is effective in addressing impacts on all types of land use and land users, such as nomadic-pastoral land use (NPLU) (Byambaa and de Vries, 2019).

Nomadic pastoralism is a land-based production system where herds move extensively in rangelands (Allen, Batello et al., 2011; Blench, 2001). Moreover, pastoralism is the most sustainable food system on the planet practiced on more than a quarter of the world's land surface by almost 500 million people and it plays a major role in safeguarding natural capital (McGahey, Davies et al., 2014). However, drivers such as growth of populations and consumption, the commodification of nature, and climate changes are transforming land use and land tenure around the world, causing loss and fragmentation of rangelands (Reid, Fernández-Giménez et al., 2014). Examples include pastoralism in Mongolia where it is the prevailing form of land use (Lkhagvadorj, Hauck et al., 2013) and a significant contributor to its national GDP (NSO, 2018). Rangelands have been significantly affected by degradation, caused by both natural processes as well as human activities such as mining and herding in Mongolia (MET, 2017). Since the mining industry's boom, available pasture have increasingly become fragmented and herders in mining regions have lost a sizable amount of their pasture and livelihood due to competing land uses such as the expansion of the mining industry (Cane, Schleger et al., 2015). Moreover, there were cases where complaints were filed by herders to international organisations like Office of the Compliance Advisor Ombudsman regarding negative impacts of mining projects on their traditional nomadic lifestyle and rangeland yields (CAO, 2013).

EIA is the key process which identifies potential impacts of such activities at an early stage. Besides this, it suggests possible mitigation measures to address associated adverse or unwanted impacts (Morris and Therivel, 2009). However, Byambaa and de Vries (2019), who conducted a literature study on EIA and pastoralist land use, argue that the rationalist and decision-making theories as well as static land use-oriented methods underlying the current EIAs restrict them to sufficiently mitigate impacts on dynamic land use in nomadic-pastoralism. To understand this misfit in depth, we advance these earlier findings by looking at the actual practice. This article zooms in to evaluating the effectiveness of the EIA processes from the perspective of nomadic-pastoral land users (NPLU(rs)) in a particular case of nomadic-pastoralism in Mongolia to identify specific factors and defects in the EIA processes which contribute to the shortcomings of EIA with regard to addressing impacts on NPLU. In recent years, there has been a growing interest in increasing the livestock productivity and pastoralists' income through secure and equal access to land, and the newly-adopted United Nations Sustainable Development Goals (UN, 2015) recognised this issue as one of the goals of sustainable development. Thus, there is a need to advance EIA such that it can better connect to the needs and specificities of pastoralism. In view of this need, the objective of this paper is to evaluate and improve the effectiveness of Mongolia's EIA processes for NPLU(rs). This is the first case study which investigates the effectiveness of EIA with respect to pastoralism. Based on this evaluation, the study suggests possible solutions to make Mongolia's EIA more effective and inclusive for NPLU(rs).

3.2 Key features of Mongolia's EIA processes

The Ministry of Environment and Tourism (MET) of Mongolia began to conduct screening in 1994 and introduced EIA officially in 1998 by adopting the Law on EIA. Two major revisions have been made in 2001 and 2012 to this law since its introduction. The key revisions include introduction of the deposit of environmental restoration "bonds", cumulative impact assessment, strategic environmental assessment, biodiversity offsetting, and public participation in impact assessment (IA). The purpose of this law is to ensure the citizens' rights to a healthy and safe environment guaranteed by the Constitution of Mongolia, to protect the environment, and to regulate relations concerning the environmental assessment processes and decision-making related to policies, programmes, plans, and projects implemented at local and regional levels (SGH, 2012a). EIA is applied to new projects as well as to restoration and expansion of existing projects prior to their implementation.

Key stages in the EIA process in Mongolia include screening (general EIA), detailed EIA, review, and follow-up stages, and the process is administered by the MET and its local offices. The screening conducted by the MET at the commencement of the EIA process makes four types of decisions: the initiative is rejected on the grounds that it does not meet conditions related to legal, planning, policy and technology issues; the initiative can be implemented without a detailed EIA; the initiative receives approval for implementation subject to specific conditions without further assessment; or a detailed EIA is required. Scoping is merged with screening and it requires EIAs to address impacts that have a significant effect on the environment and human health as well as to consider possible alternatives. However, scoping does not involve any interested stakeholders. According to the EIA law and regulations, the public is engaged in the EIA process during the detailed EIA and follow-up stages. Detailed EIAs are conducted by licenced legal entities, and reviewed and approved by a Technical Board under the MET (SGH, 2012a). Environmental monitoring and auditing are the main EIA follow-up activities (SGH, 2012b). In Mongolia 5,376 EIAs have been approved between 1995-2019 and 20.6% of them are EIAs conducted in the mining sector (MET, 2019).

3.3 Methods

3.3.1 Effectiveness of EIA

The concerns about EIA practices have resulted in the development of a substantial body of research debating the issue of EIA effectiveness (Cashmore, Gwilliam et al., 2004; Loomis and Dziedzic, 2018). Though this article does not claim to synthesise all literature on this debate, we highlight a number of seminal articles. The development of the EIA effectiveness discourse began (Pope, Bond et al., 2018) with the release of Sadler (1996)'s "International Study of the Effectiveness of Environmental Assessment" in 1996 in which procedural, substantive and transactive dimensions of effectiveness were distinguished.

The procedural dimension measures whether EIA conforms to established provisions and principles. Substantive dimension examines whether EIA achieves its purpose of supporting decision-making and protecting the environment. Transactive effectiveness looks at whether EIA delivers its outcomes at least cost in the minimum time possible. Subsequent studies suggested other dimensions as evaluation criteria for IA, such as normative (how individual and social norms are achieved in IA) effectiveness (Baker and McLelland, 2003), pluralism (whether assessment takes different views), and knowledge and learning (whether the assessment process facilitates knowledge sharing) (Bond, Morrison-Saunders et al., 2013).

Loomis and Dziedzic (2018) notes that the first four dimensions can refer to a wider EIA system. Pluralism and knowledge and learning were included in a framework developed by Bond, Morrison-Saunders et al. (2013) for evaluation of sustainability assessment practice in different jurisdictions. Thus, these two dimensions can be applied to a macro level evaluation as well (Pope, Bond et al., 2018). These subsequent contributions suggest that there is no uniform or standard framework in use, but that effectiveness is an extendable and scalable concept.

A pragmatic way to look at effectiveness is about how well EIA works in relation to macro or micro-systems, whereby macro-systems review EIA experience, activities or outcomes and micro systems address specific elements such as decision audits, component-specific evaluations (Doyle and Sadler, 1996; Sadler, 1996). In their recent study, Pope, Bond et al. (2018) refined Bond, Pope et al. (2015)'s framework (a modified framework of

Bond, Morrison-Saunders et al. (2013)) to make it more applicable to IA in general and proposed to replace the normative effectiveness, pluralism, knowledge and learning with legitimacy which measures whether the EIA processes are perceived to be legitimate by various stakeholders.

3.3.2 Measuring effectiveness of EIA for nomadic-pastoral land users

Byambaa and de Vries (2019) derive that aspects of land quality and herders' participation in EIA are the most important issues for NPLU with respect to effectiveness of EIA. Land quality relates to results in environmental protection, thus can be measured by substantive criteria. Whereas participation in EIA relates to stakeholder confidence as well as to established processes. Hence, it is measured by procedural and legitimacy dimensions. Transactive effectiveness criteria are less frequently used (Bond, Pope et al., 2015) and not directly affect interest of NPLU(rs), therefore, this study did not consider the transactive dimension of EIA.

Existing frameworks applicable to evaluation of EIA effectiveness include those discussed and presented by Arts, Runhaar et al. (2012); Bond, Morrison-Saunders et al. (2013); Bond, Pope et al. (2015); Chanchitpricha and Bond (2013); Hanna and Noble (2015); Pope, Bond et al. (2018); Wood (2003). The frameworks developed by Chanchitpricha and Bond (2013) and Wood (2003) do not include criteria on substantive effectiveness. Criteria defined in the frameworks of Bond, Morrison-Saunders et al. (2013), Bond, Pope et al. (2015), Arts, Runhaar et al. (2012) and Pope, Bond et al. (2018) are not detailed and few in number. Therefore, for this evaluation we choose to employ Hanna and Noble (2015)'s framework as it includes the most comprehensive detailed criteria on substantive, procedural and legitimacy dimensions that are necessary for this evaluation. This framework consists of 49 criteria related to nine IA themes: stakeholder confidence, decision-making, gains to environmental management and protection, comprehensiveness, evidence-based decisions, accountability, participation, legal foundation for IA, and capacity and innovation. For the purpose of our evaluation, we applied Likert survey (Likert, 1932) and derived 81 survey questions (Likert statements) from these 49 criteria following steps shown in Table 3.1.

Table 3.1. Approach applied to formulate survey questions.

Steps	Hanna and Noble (2015) 's criteria (examples)	Likert statements derived from Hanna and Noble (2015) 's criteria
Convert criteria into Likert statements in the context of NPLU/NPLU(rs)	The process assesses *cumulative effects*.	The EIA process assesses *cumulative effects on NPLU*.
Add questions to examine whether the EIA process addresses the issues of NPLU differently than environmental issues	The EIA process seeks betterment of the environment, when possible, by ensuring *net benefits to the environment*.	The EIA process seeks betterment of pastureland, when possible, by ensuring net benefits to *pastureland resources*.
Formulate multiple questions from one criterion to avoid ambiguous questions	There is open and easy access to timely, accurate and full and complete information early and throughout the assessment process through formats that provide extensive access and acknowledge different forms of access need (multiple formats are used: electronic, print, languages, verbal and other).	• There is *open* access to information for NPLU(rs) early and throughout the EIA process. • There is *easy* access to information for NPLU(rs) early and throughout the EIA process. • There is access to *accurate* information for NPLU(rs) early and throughout the EIA process. • There is access to *complete* information for NPLU(rs) early and throughout the EIA process. • The EIA process provides information for NPLU(rs) through formats that provide extensive access using different forms such as electronic, print, languages, verbal and other.

For the Likert statements, we choose scales ranging from 1 (strongly disagree) to 7 (strongly agree) to evaluate respondents' attitude and opinion (Jamieson, 2004) on the effectiveness of Mongolia's EIA processes in addressing impacts related to NPLU. The questionnaire also included 20 open-ended questions to obtain respondents' insights on solutions to the Mongolia's EIA processes. Thus, the evaluation employs multi-strategy combining both quantitative and qualitative approaches to enhance or build upon our research findings (Bryman, 2006).

In the following step, a survey questionnaire containing questions and statements mentioned above are completed by 50 respondents who represented various stakeholder groups with broad experience in rangeland management and EIA. The survey was sent by email to members of two associations of EIA and environmental management professionals, officers of central and local government departments in charge of EIA, members of environmental NGOs, and university lecturers. The survey included questions which might receive critical responses. Thus, we assured respondents that the information provided by them will be kept confidential. The idea of executing such a long survey – which at times took almost 4 hours to complete – is indeed a risky and ambitious data collection strategy. However, the respondent rate and respondent type also indicate how serious and committed they were despite the prior warning of the length of the survey. EIA consultants from private sector accounted for 38% which were the majority of survey respondents and 18% of the total respondents were from research organisations. Participants from non-government organisations and community groups accounted for 24% and government organisations accounted for 20% of the total respondents respectively.

Respondents answered to each statement in two ways. Firstly, they had to rate how certain issues are addressed in the existing EIA laws and regulations and secondly, they were required to evaluate how in their opinion each statement sufficiently emerged during the execution of EIAs. After obtaining the responses, we analysed answers to the Likert statements using statistical methods. Likert surveys are used widely and yet there seems to be a lack of statistical tools for analysis of Likert data (Gosavi, 2015). However, when using Likert survey, it is recommended that authors determine how they will describe and analyse their data in their methodology (Sullivan and Artino, 2013). All the frameworks for evaluation of EIA effectiveness discussed above do not measure outcomes systematically in a qualitative or quantitative way. However, we attempted to conclude quantitatively whether Mongolia's EIA processes are effective for NPLU(rs) in terms of procedural, substantive or legitimacy dimensions.

To quantify effectiveness, firstly, we grouped survey statements into three dimensions of effectiveness. The statements were also classified whether they are directly related to the issues of NPLU, or generally related to the EIA process, or the statements were added for additional comparison analyses. We calculated then how many percentages of all respondents agreed or disagreed (calculated separately for each of seven Likert scale points) with each of the statements. We aggregated then positive (somewhat disagree, disagree, strongly disagree) and negative responses (somewhat agree, agree, strongly agree) for each statement. If the positive values exceed the negative values, we considered it that respondents perceive the EIA process in Mongolia more effective for NPLU(rs). To the contrary, in cases if the negative values exceed the positive values, it is interpreted that respondents perceive the process rather ineffective. For the responses to the open-ended questions we relied on content analysis in order to infer the meaning of their answers to evaluation questions and in order to triangulate with other comments made by each of the survey respondents. This method follows a same procedure as described by Fink (2017).

3.4 Results and discussion

Survey results were aggregated and analysed in four parts. The first part evaluates the procedural effectiveness of the EIA process in Mongolia with regard to addressing impacts on NPLU. It will then evaluate the substantive effectiveness looking at whether EIA fulfils its purpose of protecting the environment. The third part examines legitimacy of the EIA process from the perspective of NPLU(rs). In the final part, a summary of results of open-ended questions is presented and solutions to improvement of the EIA processes for NPLU(rs) are suggested.

3.4.1 Procedural effectiveness of the EIA process in addressing impacts on NPLU

This sub-section sets out how the assessment of the procedural effectiveness of the EIA process in Mongolia for NPLU(rs) took place. For our evaluation, we applied 38 criteria. The results are presented and discussed below.

The first question in this study sought to determine whether the EIA process in Mongolia is integrative and linked to approval decision-making when addressing the issues related to nomadic-pastoralism. More than 70% of respondents somewhat to strongly disagree that the results of the EIA process are clearly accounted for in the ultimate decision to go ahead with the initiative (median = 3, SD = 1.3) which may have an adverse effect on NPLU. This indicates that the EIA decision-making does not consider information about adverse impacts on NPLU although 88% and 78% of respondents agreed that according to the EIA legislation, the intent of the EIA process is to advise decision-making which may affect NPLU(rs) (median = 6, SD=1.3). Particularly, compared to respondents originating from the government sector (30%), only 8% of community group respondents somewhat to strongly agreed that the results of the EIA process are clearly accounted for in the decision which was the lowest percentage among respondents' groups. There are several possible explanations for this result. It may be related to poor uncertainty disclosure in EIA and different perceptions about uncertainty by stakeholders (Leung, Noble et al., 2016), or lack of trust in EIA as for example, several respondents commented in their answers to the open-ended questions that NPLU(rs) view EIA as a flawed process designed to ensure project approval. The next statements (Figure 3.1) were about capacity of the EIA process to inform and be integrated into other subsequent or coincident environmental approval and review processes when dealing with initiatives which may affect NPLU.

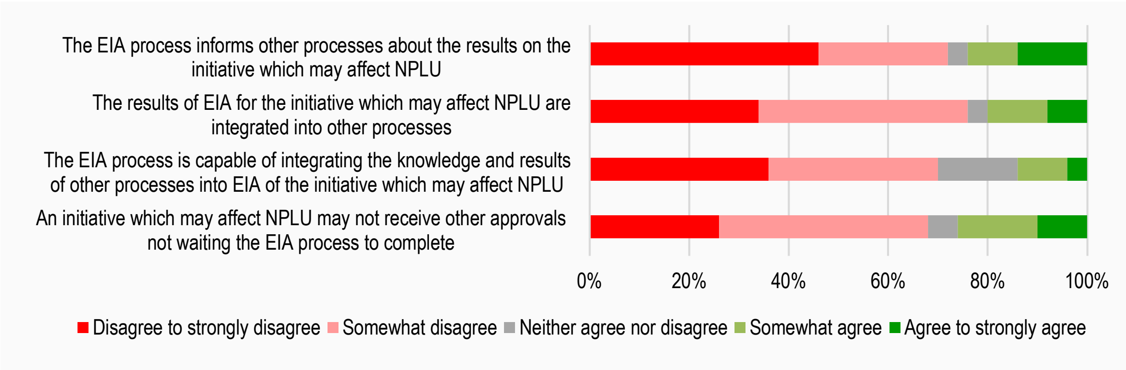

Figure 3.1. Responses on integrative and linked to approval decision-making.

Results show that nearly 70% of all respondents somewhat to strongly disagree with these four statements shown in Figure 3.1. Although 58% (median = 5, SD = 1.7) of all respondents somewhat to strongly agree that in legal documents, the EIA process is designed to demonstrably inform other environmental approval and review processes about the results on the initiative which may affect NPLU(rs), 72% (median = 3, SD = 1.7) of respondents perceive that in practice this approach is not implemented. Moreover, even less respondents agreed that the results of EIA are integrated into other approval and review processes and the EIA process is capable of integrating the knowledge and results of other processes into EIA of the initiative which may affect NPLU without unduly influencing its outcomes. These findings indicate a clear perceived gap between formal procedures and actual practice. This gap is in particular felt for NPLU(rs). If their existence is already hardly acknowledged in the formal process the actual process is likely to neglect their interests all together.

Finally, 68% (median = 3, SD = 1.5) of respondents indicate that an initiative which may affect NPLU can proceed through other approval processes or receive other approvals not waiting the EIA process to complete and the initiative to get approved although 66% of respondents suggest that according to EIA related laws, this action is not possible (median = 5, SD = 1.5).

The next question of the survey was concerned with evidence-based decision-making in EIA. The most challenging problem in EIA concerns its ability to predict impacts and to address issues of uncertainty in complex and dynamic environmental systems (Noble, 2000). Results show that only 14% of participants somewhat to strongly agree with EIA's ability to disclose and acknowledge uncertainties and assumptions about data, system behaviours and future conditions related to NPLU (Table 3.2). This result suggests that in most cases, uncertainties about adverse impacts on NPLU are not disclosed and acknowledged and therefore, in EIA, impacts on NPLU are not predicted appropriately and sufficiently if there are uncertainties with regard to project impacts.

Table 3.2. Evaluation of evidence-based decision-making in EIA for NPLU(rs).

Evaluation statements	Median 95% CI, p=0.05	Standard deviation	1-2	3	4	5	6-7
Uncertainties and assumptions about data, system behaviours and future conditions about NPLU are disclosed in the decision.	3.0	1.1	38%	44%	4%	12%	2%
Uncertainties and assumptions about data, system behaviours and future conditions about NPLU are acknowledged in the decision.	3.0	1.1	38%	36%	12%	14%	0%
Impact predictions about NPLU are formulated in such a way that they can be tested or used for follow-up.	3.0	1.3	34%	34%	12%	14%	6%

1-Strongly disagree; 2-Disagree; 3-Somewhat disagree; 4-Neither agree nor disagree; 5-Somewhat agree; 6-Agree; 7-Strongly agree;

Uncertainties in EIA are related not only to the rationalist model of planning and decision-making in which EIA is firmly based (Morgan, 2012) but also to the unknowns within the impact prediction methods (Tenney, Kværner et al., 2006). Review conducted by (Leung, Noble et al., 2015) on uncertainty research in IA notes that notwithstanding early guidance on uncertainty treatment in IA from the 1980s, there is no common, underlying conceptual framework used in identifying and addressing uncertainty in IA practice. The majority of respondents also somewhat to strongly disagree that EIA discloses (82%, median = 3, SD = 1.1) and acknowledges (74%, median = 3, SD = 1.0) uncertainties and assumptions about data, system behaviours and future conditions of NPLU sufficiently. Moreover, respondents perceive that EIA is weak in predicting impacts associated with NPLU as nearly 70% somewhat to strongly disagree that impact predictions about NPLU are formulated in such a way that they can be tested or used for follow-up (median = 3, SD = 1.3).

In the following part of the survey, respondents were asked about accountability, legal framework for EIA, and capacity and innovation. Results related to questions on comprehensiveness show that the majority of respondents (66%) view EIA as a mandatory process which cannot be avoided. They somewhat to strongly agree that roles and responsibilities in the assessment, review and decision-making processes (80%, median = 5, SD = 1.5) and for post-EIA (82%, median = 5.5, SD = 1.4) are clearly identified in the Mongolian EIA laws and regulations. However, far fewer respondents agree that requirements such as consideration of alternatives (38%, median = 3, SD = 1.6) and assessment of cumulative effects (20%, median = 3, SD = 1.5) on NPLU are implemented in practice effectively although these issues are required by EIA legislation. However, 74% (median = 5, SD = 1.3) somewhat to strongly agree that the EIA process has an effective monitoring system which follows up on implementation of measures for mitigation of adverse impacts on NPLU including audit system (54%, median = 5, SD = 1.2).

It can be noted that the legal framework for EIA is well established in Mongolia as 98% of respondents somewhat to strongly agree that EIA is appropriately codified in law (median = 6.5, SD = 0.8) and 86% of respondents perceive that the framework provides clarity for stakeholders with respect to applicability, assessment requirements, disclosure requirements, and process components, reporting and decision-making (median = 6, SD = 1.1). Moreover, nearly 80% of respondents somewhat to strongly agree that the EIA process outlines provisions for enforcement (median = 6, SD = 1.3). However, results suggest that nearly 60% of respondents somewhat to strongly disagree that the EIA system provides decisions (for approvals, conditions, rejections, exemptions and inclusions) that may be appealed by NPLU(rs) based on questions of process veracity or interpretation of law.

Although most respondents agree that the EIA process contains a legal base for participation and accountability requirements (68%, median = 5, SD = 1.4), only 38% of respondents indicate that various communication formats are used in EIA to enhance participation of NPLU(rs) (median = 3, SD = 1.6). Results suggest that respondents are not confident with financial and human resource capacity of EIA agencies as only 10% of respondents somewhat to strongly agreed that the EIA process provides sufficient financial resources to review agencies to ensure the integrity, effectiveness of, and confidence in the process (median = 3, SD = 1.2) and 28% of respondents somewhat to strongly agree that the EIA process is administered by competent authorities (median = 3, SD = 1.5).

Furthermore, more than half of government respondents (60%, median = 5, SD = 1.3) as well as private (53%, median = 5, SD = 1.9) organisation respondents somewhat to strongly agreed that the EIA process and its supporting institutional framework are flexible, adaptive and open to new and innovative tools and approaches to assessment and evaluation. In contrast, 67% of respondents from community and non-governmental organisations (median = 3, SD = 1.3) and 78% of academic respondents (median = 3, SD = 1.2) somewhat to strongly disagreed with this statement.

We analysed 38 questions to evaluate the procedural effectiveness. There were 27 negative responses which disagreed with the statements when respondents were asked to evaluate EIA practice. This result suggests that the EIA process in Mongolia has not been following established provisions and principles when addressing the issues related to NPLU and has not been effective in practice in the past for NPLU(rs).

3.4.2 Substantive effectiveness of the EIA process in addressing impacts on NPLU

In this sub-section we evaluate the substantive effectiveness of the EIA process in Mongolia from the perspective of NPLU(rs). We applied five criteria to evaluate the substantive effectiveness and five additional criteria were used to compare respondents' perceptions of EIA's roles in addressing impacts on the environment and NPLU.

Results show that with regard to EIA's role in environmental protection, 32% of respondents somewhat to strongly agree that the EIA process minimises adverse impacts on NPLU (median = 3, SD = 1.4) whereas nearly 90% of respondents somewhat to strongly disagree that EIA eliminates adverse impacts (median = 3, SD = 1.2) (Figure 3.2). Moreover, nearly 70% of respondents somewhat to strongly disagree that in practice, the EIA process seeks betterment of pastureland resources (median = 3, SD = 1.3) and prevents imposition of significant adverse effects onto future generations of NPLU(rs) (median = 3, SD = 1.2).

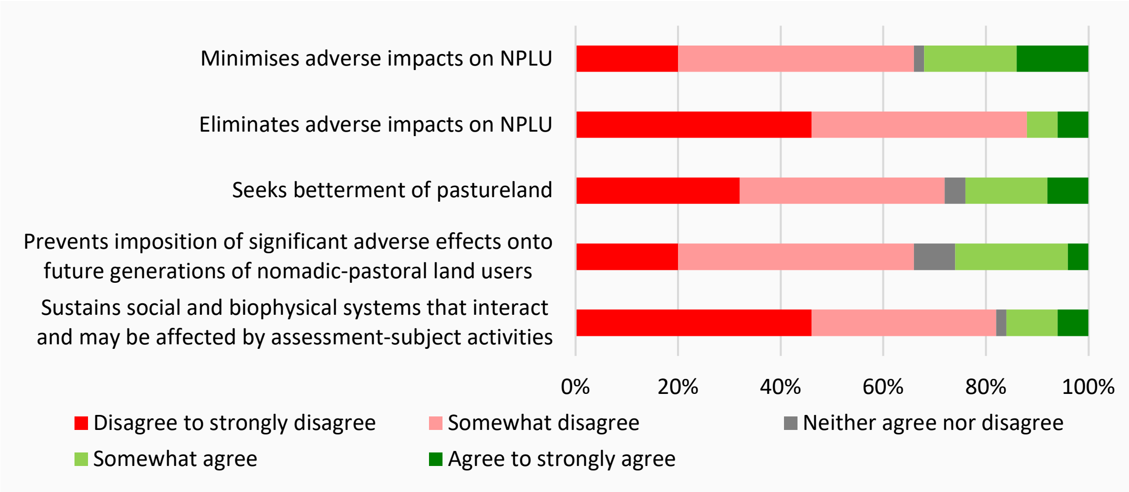

Figure 3.2. Responses on substantive effectiveness of EIA.

Furthermore, a comparison of results show that respondents have significantly different views about how EIA fulfils its substantive purpose (Table 3.3). The majority of respondents agree that environmental legislation includes provisions which require the EIA processes to minimise and eliminate adverse impacts on the environment and NPLU as well as seek betterment of the environment including pastureland. However, most respondents perceive that these provisions are not implemented in practice. In particular, respondents' perception differed on effectiveness of EIA in addressing negative impacts on the environment and NPLU.

The majority of respondents perceive that the existing legal EIA framework pays less attention to the issues related to NPLU than to general environmental issues. Similarly, in practice, impacts associated with NPLU are addressed also in a less effective way than impacts on the environment in general. Firstly, it may be related to lack of appropriate impact prediction methods for NPLU which incorporate dynamic character of nomadic-pastoralism (Byambaa and de Vries, 2019). Moreover, it may also be related to lack of comprehensive consideration of both environmental and social impacts into the EIA process in Mongolia.

Table 3.3. Comparison of results on the substantive purpose of EIA

Survey statements	The environment	NPLU	The environment	NPLU
	By laws		In practice	
The EIA process:	Agree to strongly agree		Disagree to strongly disagree	
minimises adverse effects on	96%	76%	56%	66%
eliminates adverse effects on	62%	58%	86%	88%
seeks betterment of	88%	60%	52%	72%

Although the legislative context has historically favoured biophysical impacts in most jurisdictions, social impacts are assessed usually within EIA (Esteves, Franks et al., 2012). However, neither the legal framework for EIA nor EIA practice in Mongolia integrates and addresses the social impacts for NPLU. More than 80% of respondents somewhat to strongly disagreed that EIA sustains social and biophysical systems that interact and may be affected by assessment-subject activities (median = 3, SD = 1.3). A number of responses to our open-ended questions also noted that the existing EIA process focus mainly on environmental issues.

This indicates that the majority of participants perceive EIA as a process which does not consider social and biophysical system as a complex system that interacts with each other. As rangelands are linked social-ecological systems (Reid, Fernández-Giménez et al., 2014), it is particularly crucial to assess social effects in connection with environmental impacts in the case of pastoralism.

Nevertheless, quantitative results of responses to all five criteria used in evaluation of substantive effectiveness showed that the EIA process in Mongolia has not been effective and successful in eliminating negative impacts on NPLU and promoting longer-term and substantive gains to pastureland resources.

3.4.3 Legitimacy of the EIA process from the perspective of NPLU(rs)

We applied 27 criteria to evaluate whether the EIA process is perceived legitimate in Mongolia in addressing impacts on NPLU. Firstly, we examined stakeholder confidence and decision-making in the EIA processes. Results show that only 10% of respondents somewhat to strongly agreed that the EIA process is objective in practice. However, 40% of respondents somewhat to strongly agreed that the EIA process is intended to be objective as how it is designed in the Mongolian legal and institutional system. All academic and community group respondents perceive that the EIA process is not objective. By contrast, 10% and 30% of respondents representing the government and private organisations view the EIA processes as objective respectively. Similar responses were given by the stakeholder groups to our next question on stakeholder confidence in EIA. Respondents representing the government (40%) and private organisations (27%) have more confidence that other processes do not predetermine the EIA decision and major projects cannot circumvent the EIA process whilst only 8% of participants from communities indicate that this is the case and none of academic organisation respondents agreed with this statement. Such doubt and distrust may be occurred due to the current sociopolitical situation in Mongolia as answers to our open-ended questions note that there are concerns over political and corruption issues likely to influence the EIA decisions.

On the other hand EIA is often perceived ineffective or flawed due to its limited roles in consent and design decisions, and the gap between high expectations of EIA and poor practical performance remains significant (Banhalmi-Zakar, Gronow et al., 2018; Cashmore, Gwilliam et al., 2004; Nykvist and Nilsson, 2009; Rozema and Bond, 2015; Zhang, Kørnøv et al., 2013). Thus, it is possible that such perception affects stakeholder confidence in EIA. Moreover, EIA encompasses the diversity of scientific disciplines and models (Cashmore, Gwilliam et al., 2004; Wallington, Bina et al., 2007). Hence, lack of confidence in the EIA system may be also related to its complexity as only 22% of all respondents think that the EIA process is understood by stakeholders. Particularly, all NGO and community group respondents perceive that the EIA process is not understood by stakeholders whilst half of government respondents indicate that stakeholders understand the EIA process.

The next section of the survey was concerned with participation of NPLU(rs) in the EIA process. The dominant view of scholars and practitioners is that public participation in EIA is highly desirable yet that the key practical challenge is to make participants more effective (O'Faircheallaigh, 2010). Pohjola and Tuomisto (2011) argues furthermore that the discourse on participation in environmental assessment focuses too much on processes and procedures, and too little on the purpose, outcome and effectiveness in policy making. Respondents mostly disagreed with the statements regarding effective participation of herders in EIA. Mongolia's legal EIA framework prescribes public participation (46%, median = 3, SD = 1.5). However, the majority of respondents somewhat to strongly disagreed that there is open (74%, median = 3, SD = 1.3), easy (92%, median = 3, SD = 0.9), accurate (86%, median = 3, SD = 0.9) and complete (86%, median = 3, SD = 0.9) information for NPLU(rs) early and throughout the EIA processes. NPLU(rs) are simply not informed about how they are engaged in the EIA process (56%, median = 3, SD = 1.6) and how their participation is accounted for in the decision-making processes (66%, median = 3, SD = 1.5).

Over 50% of respondents indicate that hearings and other similar deliberations are open to NPLU(rs) (median = 5, SD = 1.6). Compared to other three groups, only 11% of research organisation respondents indicated that such EIA meetings or consultations are open to herders (median = 3, SD = 0.9). By contrast, the majority of EIA consultants (74%, median = 6, SD = 1.5) and government respondents (60%, median = 5, SD = 1.5) who are often involved in engaging the public in the EIA processes somewhat to strongly agree that EIA hearings are open to the public. Such difference clearly reflect how openness is viewed from an academic's perspective compared to practitioners working in the field. Nonetheless, 42% of non-governmental organisation respondents and community groups who are representing the NPLU(rs) in our study somewhat to strongly agreed that EIA hearings are open for them (median = 3, SD = 1.7). Most respondents perceive that participation opportunities are not known to herders (88%, median = 3, SD = 1.0). Moreover, the majority of respondents somewhat to strongly disagree that the EIA process provides information for NPLU(rs) through various formats (78%, median = 3, SD = 1.3) and allocates sufficient resources and time to support participation process (88%, median = 2, SD = 1.0). More than half of the respondents also disagree that the EIA process prevents unjustified limitations to open deliberation and presentation of evidence for NPLU(rs) (56%, median = 3, SD = 1.6).

The third set of criteria in this section examined how participation of NPLU(rs) influence the decision-making in EIA. Responses of all survey respondents (72%, median = 5, SD = 1.3) including government group respondents (80%, median = 5, SD = 0.9) show that Mongolian laws and regulations on EIA ensure herders' participation in the decision-making in EIA. However, responses significantly differed when respondents answered to this same question considering how this issue is dealt in practice. More than half of respondents (62%, median = 3, SD = 1.6) somewhat to strongly disagree that in practice

NPLU(rs) influence decisions during the EIA processes. Moreover, as Figure 3.3 reveals, compared to government and research organisations (20%, median = 3, SD = 1.1; 22%, median = 2, SD = 1.7), more respondents representing the private organisations and community groups (53%, median = 5, SD = 1.1; 42%, median = 3, SD = 1.6) perceive that the participation of NPLU(rs) influences the decision-making in EIA.

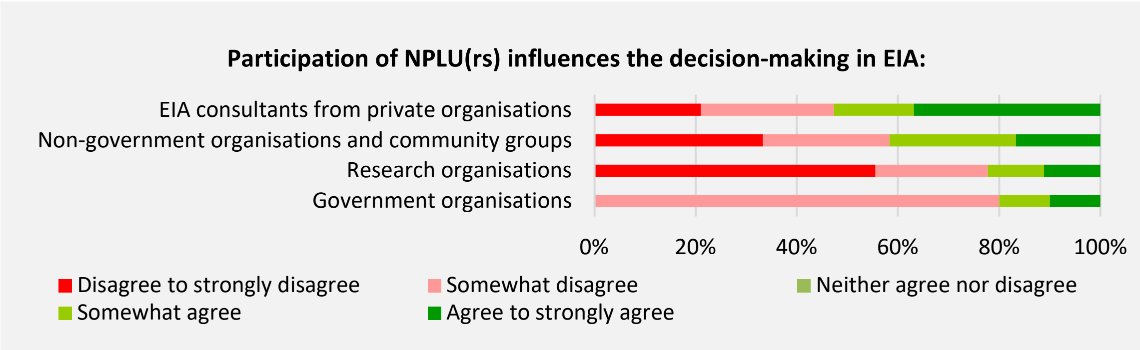

Figure 3.3. Responses on participation of NPLU(rs) in the decision-making in EIA.

Furthermore, 50% of respondents indicate that the participation of NPLU(rs) in the EIA processes improves the quality of the proposa..l and affect the assessment of the initiatives (median = 4.5, SD = 1.6). In particular, 77% of research organisation respondents (median = 5, SD = 1.2), 58% of EIA consultants (median = 5, SD = 1.5) and 40% of government respondents (median = 3, SD = 1.3) somewhat to strongly agreed that EIA benefits from the participation of NPLU(rs) indicating that they acknowledge use of herders' knowledge in EIA. However, only 25% of community groups (median = 3, SD = 1.5) perceive that their participation improves the quality of the proposal and affects the EIA processes.

The most obvious finding to emerge from this study is a contrast between the existing EIA framework and its implementation in practice. As explained in the Methods section, respondents were asked to evaluate the survey statements in two ways. Results of 16 criteria out of 27 were positive when respondents evaluated how the issues related to legitimacy of EIA are addressed in the existing legal EIA system. It can therefore be assumed that the EIA process is perceived legitimate by the respondents. However, responses to 23 criteria out of the same 27 criteria were negative when respondents evaluated EIA practice. This also accords with results of the open-ended questions where respondents raised a number of issues related to weak EIA practice. By contrast to the previous finding, this result suggests that the EIA process is not seen legitimate by the stakeholders. Taken together, although there is some strength in the legal framework for EIA in Mongolia, poor quality of EIA practice causes lack of stakeholder confidence in EIA and create perception that the EIA process is dysfunctional.

3.4.4 Effectiveness of the EIA process from the perspective of NPLU(rs)

Respondents identified a many number of problems which the EIA process is facing in Mongolia. Many issues were related to poor quality of EIA practice (insufficient public participation, poor consideration of cumulative impacts and alternatives, follow-up system is not effectively linked to the subsequent decision-making processes, etc.), ineffective law enforcement, capacity of EIA agencies and practitioners. These problems in general affect the effectiveness of the EIA process, thus, influence the issues of NPLU as well. Moreover, the survey found the following problems specifically related to NPLU:

- Lack of NPLU(rs) confidence in EIA
- Lack of suitable impact prediction methods for dynamic land use
- NPLU issues are not clearly accounted for in the decision-making in the EIA process
- Social aspects of NPLU are not sufficiently addressed in EIA

Respondents suggested a number of solutions to these problems (Table 3.4). Many responses were about ensuring meaningful engagement with NPLU(rs) throughout the EIA processes and using knowledge of NPLU(rs) in impact prediction. Respondents also suggested that there is a need to improve impact prediction methods for NPLU and guidelines and regulations on stakeholder engagement in EIA for NPLU.

Integrating environmental and social concerns into the spatial planning process as well as all levels of decision making will contribute to sustainable development, however, it is difficult to achieve (Eggenberger and Partidário, 2000). Respondents pointed out the importance of EIA integration and noted that in practice EIA is not fully integrated within decision making and not sufficiently coordinated with multidisciplinary organisations as well as spatial planning process in Mongolia. Thus, EIA needs to be integrated into all levels of decision making and territorial planning system. Moreover, respondents believe that new provisions and guidelines on addressing social impacts associated with NPLU are also required.

Table 3.4. Suggestions by respondents to improve the EIA process in Mongolia.

Number of times mentioned by respondents	Suggestions to improve the EIA process in Mongolia
35	Ensure meaningful engagement with NPLU(rs) throughout the EIA processes
28	Improve impact prediction methods for NPLU
24	Fully integrate EIA within decision making as well as territorial planning system
18	Improve enforcement of EIA laws and regulations
17	Improve guidelines and regulations on prediction of impacts related to NPLU and stakeholder engagement in EIA
16	Improve capacity of EIA organisations and practitioners
15	Increase and enforce accountability in practice
12	Develop guidelines on identification of social impacts associated with NPLU
11	Improve quality of EIA
10	Use NPLU(rs)' knowledge in impact prediction
3	Ensure monitoring is linked to subsequent decision-making and applies adaptive management

In developing countries, capacity building can offer an overall comprehensive solution to shortcomings of EIA and moreover, a precondition for an effective capacity building is improvement of institutional capacity (Khosravi, Jha-Thakur et al., 2019). In fact, many respondents indicated that there is a need to enhance capacity building, increase accountability in practice improving enforcement of EIA laws and regulations as well as quality of EIA practice as it is perceived that stakeholders are not confident with the EIA process and capacity of EIA agencies and practitioners.

In summary, the overall responses to the Likert statements were poor when respondents were asked to evaluate EIA practice with respect to NPLU. Out of 70 statements, only 15 responses were positive and agreed that the EIA process has been effective in addressing impacts on NPLU. However, 55 statements were positive when respondents evaluated the legal framework for EIA with respect to NPLU. This indicate that EIA legislation includes necessary provisions for the issues of NPLU. Therefore, the implementation process of EIA in Mongolia should be improved.

3.5 Conclusions

We note that within 20 years since the 1998 introduction of the regulatory framework for EIA in Mongolia, it has succeeded in gaining acceptance and recognition. The EIA framework in Mongolia defines responsibilities and its scope of application to a sufficient extent and relies on a sound legislative and institutional set-up. To a certain extent, it considers alternatives, cumulative impacts, public participation and applies follow-up. However, in practice the situation appears different. Mongolia's EIA processes have not been appropriately conforming to its established provisions and procedures described in the regulations, nor have they sufficiently adopted the objective to protect pasturelands or to engage NPLU(rs) in the decision-making. In other words, the EIA process in Mongolia have not been effective for NPLU(rs) with regard to procedural and substantive dimensions of EIA. Moreover, it lacks stakeholder confidence and do not meet the expectations of stakeholders. Respondents were vastly critical of the EIA processes. In particular, those who are not directly involved in EIA such as academic and community respondents were more disapproving than government organisations and EIA consultants. Important improvements are needed in many areas of EIA to address the issues of NPLU better in future. The first priority should be improvement of impact prediction methods for dynamic land use and consideration of social and cultural impacts associated with NPLU in EIA.

Overall, our findings concur with those of Banhalmi-Zakar, Gronow et al. (2018) and Pope, Bond et al. (2013) on the shortcomings of IA. We go however one step further by stating that in particular the needs and participatory opportunities for NPLU(rs) are far too limited, and perhaps even deliberately denied. We believe this constitutes an unwanted situation which needs to be redressed. We strongly believe that this situation also occurs in countries with similar characteristics and a similar significance of nomadic-pastoralists traditions. Hence, by highlighting the flaws of the current EIA system in Mongolia, it should not only provide an opportunity to improve the EIA process in Mongolia only, but also stimulate other countries to follow this example and lead to EIAs which better address impacts on NPLU. Further research is therefore needed to address the EIA issues specific to dynamic land use in nomadic-pastoralism in multiple countries. These studies should investigate impact prediction methods suitable for NPLU and effects of EIA integration into spatial planning system on NPLU, and evaluate to which extent these problems and solutions are idiosyncratic and context-dependent or more structurally ingrained in EIA professional practices globally.

Disclosure statement

No potential conflict of interest was reported by the authors.

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CHAPTER 4. Factor analysis

Socio-environmental factors influencing the spatial and temporal dynamics of herd composition and livestock distribution in Mongolia[3]

Abstract

Understanding interconnection between socio-environmental factors and livestock communities is crucial to research on pastoral systems dynamics. This article aims at examining landscape level spatial and temporal effects of socio-environmental drivers on the herd composition and livestock distribution in Mongolia. We use a R based statistical framework Hierarchical Modelling of Species of Communities (HMSC) for analysis of multivariate data. This study models the joint distribution and composition of five livestock species (horses, camels, cattle, sheep and goats) in relation to vegetation, topography, population, household, land use and poverty variables from 326 soums (the second-level administrative subdivision) of Mongolia for the periods between 1981-85, 1995-99, and 2010-13. The effects of socioeconomic factors versus environmental forces on the herd composition and distribution considerably differ in these three periods. The results indicate that the influence of socioeconomic factors increased with time in contrast to environmental drivers. Particularly, effects of socioeconomic drivers on the number and distribution of goats significantly altered the patterns of livestock communities. The landscape level time series empirical analyses in this study contribute to the current key discussions of the rangeland science and enhanced our understanding of livestock patterns and socio-environmental drivers of the pastoral systems.

Keywords

environmental and socioeconomic factors; herd composition; Hierarchical Modelling of Species of Communities; joint species distribution modelling; livestock distribution; Mongolia; pastoral system; R

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[3] This manuscript will be submitted to a peer-reviewed journal as Byambaa B, Burgas D, Ovaskainen O, de Vries WT, Manzano P, Cabeza M. Socio-environmental factors influencing the spatial and temporal dynamics of herd composition and livestock distribution in Mongolia.
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4.1 Introduction

Pastoralism is a complex socio-ecological system (Dwyer and Istomin, 2008; Sayre, deBuys et al., 2012; Stafford, Morton et al., 2000) for which a holistic understanding is still very limited (Manzano, Burgas et al., 2021; Sayre, deBuys et al., 2012). Despite acknowledging that ecological, social and economic components shape and drive pastoral system dynamics (Zinsstag, Schelling et al., 2016) and their sustainability, studies along extensive periods of time are often reduced to environmental perspectives. Examples include most studies of large-scale livestock distribution patterns (see e.g. for global studies: FAO (2007); Robinson, Wint et al. (2014), regional studies: Cecchi, Wint et al. (2010); Neumann, Elbersen et al. (2009), and national studies: Fu, Zhu et al. (2012); Orhan, Ozturk et al. (2009); Proffitt, Gude et al. (2011); Nandintsetseg, Shinoda et al. (2018a); Saizen, Maekawa et al. (2010); Tsutsumida, Harris et al. (2017); Verburg and Keulen (1999)). However, rapid changes in climate, land-use, accessibility to markets, culture and other globalization aspects demand more integrative research with attention to the interactions between biophysical and socioeconomic drivers (Manzano and Casas, 2010; Sayre, deBuys et al., 2012).

In spite of a few integrative research examples (Chen, John et al., 2015a; Chen, John et al., 2015b; Fernández-Giménez, Venable et al., 2017; Linstädter, Kuhn et al., 2016; Manzano and Casas, 2010) mostly represented by qualitative system descriptions, advances at this front have largely been lacking due to shortage of good, long term comprehensive data (Johnson, Sheehy et al., 2006; Ulambayar and Fernández-Giménez, 2019). Mongolia offers a great opportunity to start closing this research gap, given the high quality data available at multiple administrative levels, some of which has been standardly collected since the 1970s and have seen large increases and decreases in livestock linked to a change of political-economic system (Bold, 2009; Mearns, 2004) and *dzud* (severe winter disasters), resulting in spatial re-distribution of livestock types (NSO, 2019) (Figure 4.1).

Livestock is the essence of nomads' livelihoods in Mongolia, thus in general sense, knowing number of herders' animals may have always been of interest to any authorities in Mongolia. Besides, the livestock count attached a great importance to taxation and military planning during the period of the rise of Mongols. Hence, historical evidences about livestock counts date back to Xiangnu period in the 3rd century BC (NSO, 2014). Detailed information about how taxes were levied based on the number and type of animals of pastoral nomads is known (Smith, 1970) starting from 13th century in Mongolia. Thus, such long tradition may have built practices among herders to keep detailed records of their animals at household level and report such information to their authorities.

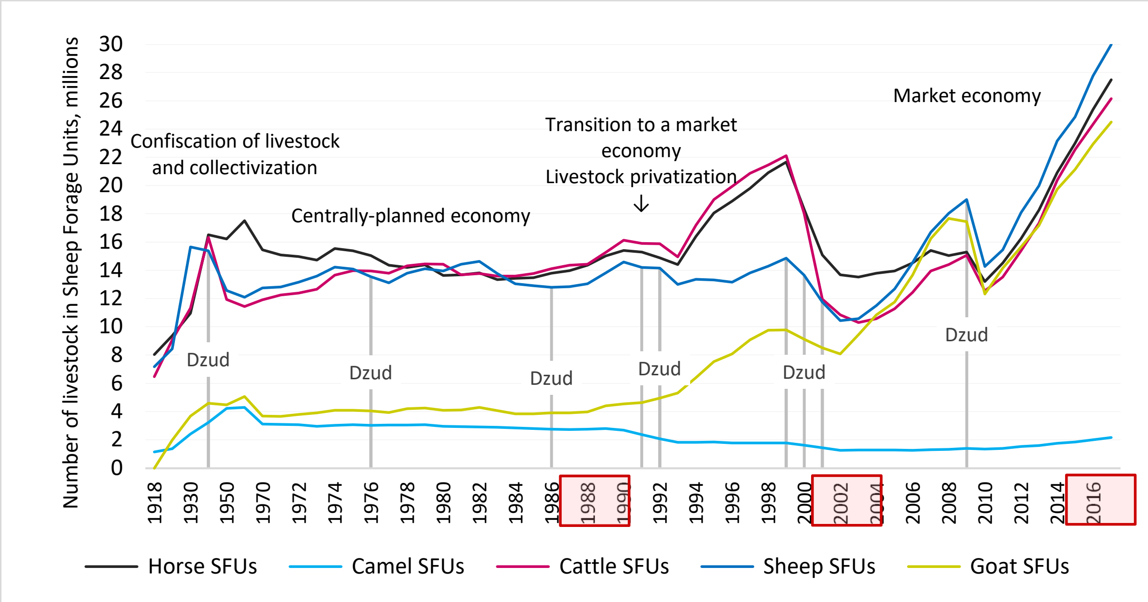

Figure 4.1. Historical trends of livestock in Sheep Forage Units (SFU) between 1918-2017
(In Mongolia, the number of livestock species are converted into the number equivalent to sheep (SFUs) for the purpose of calculating grazing capacity and forage intake. 1 horse = 7 SFUs; 1 cattle = SFUs; 1 camel = 5 SFUs, 1 sheep = 1 SFUs; 1 goat = 0.9 SFUs (NSO, 2012a)). Red boxes indicate the periods for which the models used in this study are run.

The modern history of statistics began in Mongolia with the first official population and livestock census conducted in 1918 and with the establishment of the Statistics Office in 1924 (NSO, 2014). In contrast to the needs to count the livestock number centuries ego in connection with supporting the military and collecting taxes, recording high quality data during the socialist system can be explained with the demand of a centrally planned economy. During socialist time, Mongolia had implemented nine Five Year Plans starting from 1948 in which the activities of the different sectors were programmed. For instance, Mongolia planned to increase its animals up to 31 million in the First Five Year Plan (1948-1952). There were government regulations and entities which monitored and registered the implementation of the Five Year Plans (Batsaikhan, 2016) including the number of animals. On the other hand, the development of statistics in Mongolia was certainly the key contributing factor in the availability of such good quality livestock data.

Mongolia's pastoralism has witnessed a number of important transitions (Fernández-Giménez, 1999; Undargaa and McCarthy, 2016) and remains the basis for the livestock, tourism and cashmere industries in the country and contributes significantly to its national GDP (NSO, 2018). Several key milestones which influenced the pastoral system and livestock population in Mongolia in the last 100 years can be noted. The first transition is associated with the early phase of collectivization of the pastoral production from the 1920s through 1959 during which a large number of state collectives were organised under a socialist development concept of the pastoral economy when the country entered into a socialist system from a feudal society (Rosenberg, 1981) and to avoid giving up their animals to the collectives, they slaughtered and sold animals on a massive scale reducing the number of animals within a few years in the 1930s (Bold, 2009) (Figure 4.1). Far fewer animals were counted in the beginning of 1920s. It is likely that during this period, households were deliberately underreporting the actual numbers of their animals to avoid the confiscation.

In the following years between late 1950s to early 1990s, the state intensified the livestock production under a centralised control providing infrastructure and social services to herders through collectives (Fernández-Giménez, 1999; Undargaa and McCarthy, 2016; Upton, 2009). Johnson, Sheehy et al. (2006) defined the pastoral system existed in this period as semi-extensive pastoralism dependent on energy inputs from the state. Moreover, during the socialist period, all pasture lands belonged to the state and despite new statutory laws which regulated land tenure in that time, herders continued practicing customary rights which allowed them to maintain rotational seasonal movements. When the socialist system collapsed in 1990, Mongolia began transformation to a market economy in which the state supported collectives were dissolved and livestock were privatized (Nixson and Walters, 2006). During this transition, the livestock production system became extensive as the physical and socioeconomic support infrastructure collapsed (Neupert, 1999; WB, 2010). The extensive Mongolian traditional nomadic pastoral systems were used in the pre-collectivization time and they operated as a natural economy in a natural system (Johnson, Sheehy et al., 2006). In such extensive systems, environmental drivers are thought to more shape the livestock production and distribution. However, studies (Chen, John et al., 2015a; Chen, John et al., 2015b; Fernandez-Gimenez and Allen-Diaz, 1999; Saizen, Maekawa et al., 2010) carried out to date indicate that social, institutional, and economic factors have been playing significant roles in Mongolian pastoral systems since the collapse of the socialist system.

Much of pastoralism related studies conducted at national level in Mongolia focus on causes and impacts of *dzud*, pasture production and degradation and land tenure. With respect to how socioeconomic and environmental factors have been influencing the pastoral systems, we know that both climatic and man-made factors such as increase in nonprofessional herders and the livestock population contributed to livestock mortality risk as well as pasture degradation in Mongolia (Du, Shinoda et al., 2018; Hilker, Natsagdorj et al., 2014; Nandintsetseg, Shinoda et al., 2018a; Nandintsetseg, Shinoda et al., 2018b; Tsutsumida, Harris et al., 2017). Moreover, several studies confirmed that the formal and customary land tenure systems in Mongolia are one of the contributing factors limiting herding movements in pastoralism (Fernández-Giménez, 2001; Undargaa and McCarthy, 2016; Upton, 2009). Socioeconomic and environmental drivers reduced seasonal migrations in the regions, for instance the Mongolian Altai (Lkhagvadorj, Hauck et al., 2013). A socioeconomic policy such as privatization made the livestock sector highly vulnerable to harsh winter and summer droughts (Nixson and Walters, 2006). Moreover, Joly, Sabatier et al. (2018) suggested that density dependent factors such as competition between herders over forage is an important driver which affects livestock productivity and vulnerability to climate shocks in the Mongolian Gobi. In fact, when grazing pressure is very strong, grass biomass in the focal rangeland becomes depleted, and some herders choose to use an alternative rangeland (Lee, Kakinuma et al., 2015).

Few other studies at national scale investigated coupled ecological and social systems in Mongolia. These studies reported that since 1991, livestock densities and forage use increased in most regions (Fernández-Giménez, Venable et al., 2017) and the correlation between livestock densities and land cover change has been increased as well (Chen, John et al., 2015a). In all or most regions, the spatial distribution of grazing pressure is more heterogeneous, and variability increased in stocking densities, forage use and forage production (Fernández-Giménez, Venable et al., 2017). Analyses at *aimag*[4] level concluded that human influences on the Mongolian coupled natural and human system exceeded the biophysical changes dissimilarly in different time and regions (Chen, John et al., 2015a) and in the future, socioeconomic forces will increase in Mongolia and the same time the climate

[4] The first-level administrative subdivision of Mongolia

change will become an increasingly important driver for grazing and livestock when Mongolia is in the market economy (Chen, John et al., 2015b).

Understanding how socioeconomic and environmental factors influence the spatial and temporal patterns of livestock composition and distribution is essential for effective rangeland management (Liao, 2018; Nandintsetseg, Shinoda et al., 2018b; Tsutsumida, Harris et al., 2017), environmental impact assessment, mitigation and disaster responses (Byambaa and de Vries, 2019; 2021; Gilbert, Nicolas et al., 2018; Nandintsetseg and Shinoda, 2013; Nandintsetseg, Shinoda et al., 2018a; Saizen, Maekawa et al., 2010; Tsutsumida, Harris et al., 2017). Moreover, the spatiotemporal characteristics of the population change of all livestock species across Mongolia should be conducted exploring the full data set of goats, sheep, cattle, camels, and horses to understand the patterns of livestock composition and distribution (Tsutsumida, Harris et al., 2017). Thus, this article seeks to contribute to research on interconnection between socioeconomic and environmental factors influencing the pastoral systems at national scale by investigating high quality data at a district level administrative unit.

Spatial data at the resolution of *soum*[5] which cover distinct rangeland ecosystems in Mongolia such as mountain-steppe, forest-steppe, steppe and desert-steppe regions are used to analyse the herd composition and livestock distribution throughout Mongolia. We model the joint distribution of all livestock species: horses, camels, cattle/yaks, sheep and goats in relation to a) environmental b) socioeconomic and c) land use variables, using data sets for the periods from 1981-85, 1995-99, and 2010-13. We hypothesize that the herd composition and livestock distribution is today more aligned with socioeconomic drivers than to environmental conditions, and that association to environmental drivers was stronger in the past, until the end of the soviet period. The objectives of this study are 1) to examine spatial and temporal changes of herd composition and livestock distribution at landscape level, and 2) to analyse effects of socioeconomic and environmental factors on the spatial patterns of herd composition and livestock distribution. We present and discuss the results of our model which focused on spatial changes occurred in the herd composition and livestock distribution in the three periods between 1981-85, 1995-99, and 2010-13. We also discuss how socioeconomic and environmental drivers influence such patterns in pastoralism at national scale.

[5] The second-level administrative subdivision of Mongolia

4.2 Data and methods

4.2.1 Study area

Mongolia has a land area of 1.56 million sq. km. Of the total area 0.5% is urban areas, 0.3% forest, 0.4% water bodies and 73.5% grasslands (MET, 2017). The topography of Mongolia includes mainly a vast plateau with an average elevation of 1,580 m. The northwest and central parts of the country consist of high mountainous, mountain forest and steppe regions (Figure 4.2). Much of Mongolia's southern part is covered with desert and desert-steppe. Mongolia has a harsh continental climate with high annual and diurnal temperature fluctuations. Average annual temperatures are around 8.5 C° in the southern desert-steppe areas and -7.8 C° in the high mountainous areas. Precipitation is scarce and the annual amount is in average 200-220 mm (MET, 2014).

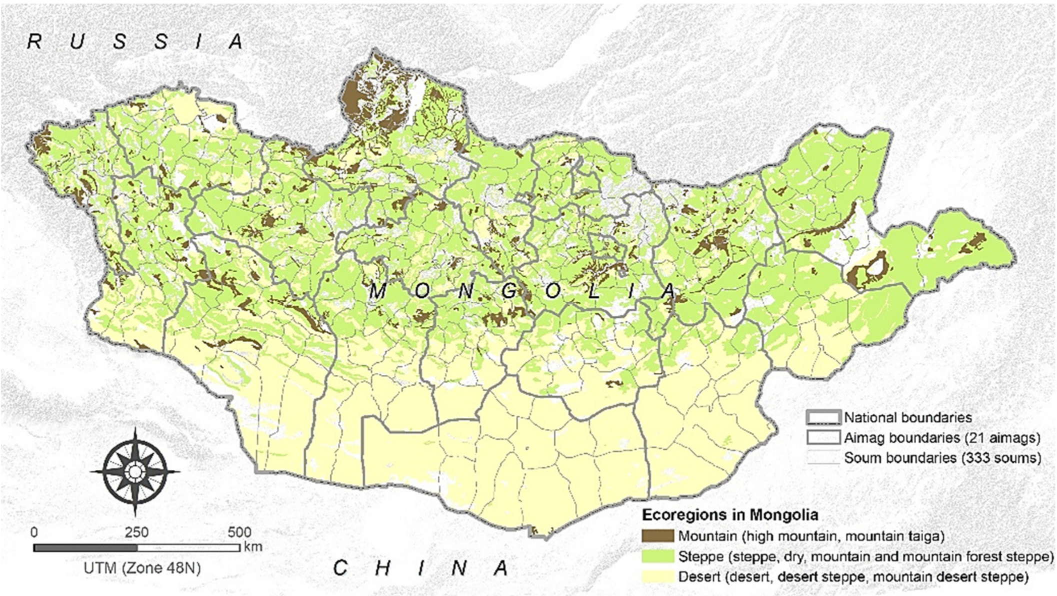

Figure 4.2. Map of the study area. Boundaries of administrative units and key ecoregions of Mongolia.

Excluding the capital city, the territory of Mongolia is divided into 21 *aimags,* then the *aimags* are divided into 330 *soums*, and the *soums* are further divided into 1615 *baghs*. Mongolia's population is 3.2 million and a quarter of all households are herder households which practice herding activities in rural areas. The share of the agricultural sector in Mongolia's GDP in 2020 was 11.9% whilst the dominant mining industry contributed 22.5%. Since liberalization of the herding activities in 1991, livestock numbers have been increasing and doubled over the last 20 years reaching 67 million animals. However, in 2018, 30.8% of the rural population were living below the national poverty line. In 2017, 42.6% of Mongolia's total herder households had up to 200, 34% of households had between 201-500, and 23.3% of households had more than 500 animals respectively (NSO, 2017).

4.2.2 Data collection

This study models livestock abundances in the period between 1981-85, 1995-99, and 2010-13, as a function of social-demographic and environmental variables. We also include a third group of variables that indicate spatial limitations to the practice of herding due to land use regulations and restrictions. The three groups of variables are described below and listed in Table 4.1. The datasets are available for each 326 soums collected mainly from various government agencies of Mongolia. A livestock and demographic (average herder households of 2012-17) census as well as some social related datasets such as poverty and household data were downloaded from the website (www.nso.mn) of National Statistical Office of Mongolia. The average number of sheep, goats, cattle, horses and camels of the periods between 1981-85, 1995-99, and 2010-13 were chosen as livestock community data. Poverty data includes poverty headcount ratio calculated at soum level in 2011. It measures the proportion of the population that is poor.

Table 4.1. Variables used in the modelling of livestock abundances.

Livestock	Social and demographic variables	Topographic, climatic and environmental variables	Land use
Sheep	Herder household index	Area	Urban areas
Goats	Herder population density	Elevation	Forest areas
Cattle	Poverty ratio	Precipitation	Water bodies
Horses			Agriculture land
Camels		NDVI	Strictly protected areas
			Mining areas

We prepared topographic, climatic, normalized difference vegetation index (NDVI) and land use datasets for each *soum* using spatial data collected from The Shuttle Radar Topography Mission; WorldClim; Mongolian Plateau Data Portal; Agency for Land Administration and Management, Geodesy and Cartography; Mineral Resources and Petroleum Authority; and Ministry of Environment and Tourism of Mongolia. We defined six GIS layers as areas where pastoralists are not allowed to graze their animals. These are urban areas (2018), forest areas (1981), water bodies (1983), agriculture land (2018), strictly protected areas (2008), and areas under mining licences (2014). These layers were overlaid to identify restricted land use areas for herders. GIS layers of NDVI for each *soums* were also prepared.

4.2.3 Hierarchical modelling of species of communities

We applied Hierarchical Modelling of Species of Communities (HMSC) (Ovaskainen, Tikhonov et al., 2017), a framework based on a hierarchical joint species distribution approach. HMSC is a hierarchical generalised linear mixed model and a statistical framework for analysis of multivariate data, and it is often used in analysis of data on species communities (Tikhonov, Opedal et al., 2019). As a hierarchical generalised linear mixed model, it allows to analyse dynamic phenomena and to model nonlinear and individual characteristics (Krueger and Tian, 2004). It offers correlative analysis and therefore, allows us to examine relationships between ecological and social factors affecting livestock distribution and herd composition. HMSC approach estimates species association networks at different spatial or temporal scales (Ovaskainen, Tikhonov et al., 2017), thus, we modelled variances in livestock abundance, herd composition and livestock distribution for three periods of time as well as examined covariances between socioeconomic and environmental variables at two spatial (administrative) levels.

We analysed our data using the R package HMSC following the HMSC steps for a linear model for a community with five species (Tikhonov, Opedal et al., 2020; Tikhonov, Opedal et al., 2019). First, we use HMSC to set our model structure and fit our multivariate linear model which we specified as a joint distribution and composition of five livestock species (horses, camels, cattle, sheep and goats) in relation to environmental (NDVI, topography) and social (population density, household index, land use and poverty) variables. We evaluate the model fit through the HMSC functions which examine different aspects of model fit. HMSC also include functions which we used for estimating the model parameters as well as functions for producing plots that illustrate the effects of social and environmental variables on livestock abundance, variances in livestock abundance explained by random spatial, environmental or social factors, and livestock species-to-species associations (Tikhonov, Opedal et al., 2020).

4.3 Results and discussion

4.3.1 Spatial and temporal changes in herd composition and livestock distribution

Changes in herd composition

The statistical data of last one hundred years show that the livestock population has been constantly changing in Mongolia (NSO, 2012b). Changes in livestock number and herd composition may adversely affect the wildlife populations associated with high altitude pastures (Singh, Sharma et al., 2015). It is also argued that increase in animal population leads to a decline in vegetation density and overgrazing which consequently contribute to degradation and desertification (Batunacun, Wieland et al., 2019; Hilker, Natsagdorj et al., 2014). Maasri and Gelhaus (2011) noted that the increase of livestock numbers in Mongolia is reaching beyond the grassland capacity and affecting the stream ecosystem. Although, the increase in livestock population creates damages, we lack sufficient evidences and understanding about the causes of such degradation (Harris, 2010). Thus, quantitative analyses are crucial in understanding factors influencing the livestock systems.

Figure 4.3 illustrates how the patterns of herd composition in Mongolia have changed over the last three decades. The results show that except camels there were strong correlations between all the livestock species in the 1980s. Herders did not prioritise one type of species over the other species. The changes in the numbers of sheep, goats, cattle, and horses and the herd composition patterns were similar each year in all administrative regions of Mongolia between 1981-1985. It indicates that there was a need to increase or decrease the number of animals keeping the herd composition homogenous across different regions. During the socialist period, one of the main consumers of livestock commodities was the Soviet Union (officially the Union of Soviet Socialist Republics (USSR)) countries (Altantugs, 2019). It is likely that the supply of livestock commodities to the USSR influenced the herd composition during this period. Altantugs (2019) reports that in 1960, Mongolia introduced a government enforced purchase of livestock commodities. This system implemented Five Year Plans of the government by ordering the state agricultural cooperatives to supply specific numbers of animals and livestock commodities regularly each year. Therefore, the herd composition and the number of animals were strictly controlled by the government in relation to the goals of centrally planned economy in

Mongolia. According to Altantugs (2019), camels were not listed as one of the main livestock commodities which were supplied to the state and USSR. This can explain the weak correlations between camels and other livestock species during this period.

It is apparent from the Figure 4.3 that in the 1990s, the patterns of herd composition kept through the socialist period had been lost as the correlations between species have become weaker. After the collapse of the Soviet Union, the state owned agricultural cooperatives were dissolved in 1991 privatizing animals to herders and the government enforced purchase was withdrawn (Potkanski, 1993). In addition to the loss of primary market for livestock commodities, *dzud* occurred in 1992 might have affected the herd composition in Mongolia. After losing many of their animals in *dzuds,* for herders financially it is difficult to afford buying expensive animals such as cattle, camels and horses than sheep and goats which are small and cheaper. Thus, it is possible that herders opted for more sheep and goats.

In 2010-13, there was a positive, but weak a correlation between sheep and cattle. Sheep and goats correlate positively more than with other livestock species confirming the general tendency for herd composition in many *soums* (NSO, 2012b) (Figure 4.3). The graph shows that sheep is also positively correlated with cattle, camels and horses. When herders increase the number of other species, the number of sheep has also been increasing. This trend can be explained by herders' traditional approach of handling sheep. Sheep has been considered by Mongolian herders to be the most useful of the five livestock species due to multiple benefits which sheep bring to herders including production of wool, leather, milk, meat, fat and dung (Minzhigdorj and Erdenebaatar, 1993). Therefore, herder households tend to favour sheep over other livestock species.

Moreover, the graph indicates that between 2010-13, there were no correlations between cattle, goats, and cattle, camels. Commodity markets influence livestock distribution and herd composition (Nakamura, Dorjjadamba et al., 2017; Saizen, Maekawa et al., 2010). Thus, it is possible that herders increased the population of some livestock species which bring more economical benefits as explained in the case of sheep. In fact, since the livestock privatization in Mongolia, the authorities no longer influence the herder's decision on herd composition (Fernández-Giménez, 2001). As private owners, herders themselves choose which type of livestock species to herd. The environmental constraints such as climate or the suitability of topography and vegetation type for a particular livestock species naturally play an important role in the herd composition and structure.

Herders prioritising sheep and goats over cattle can be also related to foraging and feeding of these species. Sheep and goats utilise a wide range of food sources and they have the ability to cope with harsh climatic conditions (Dwyer, 2009). It is a major advantage in a country like Mongolia which has an extreme continental climate.

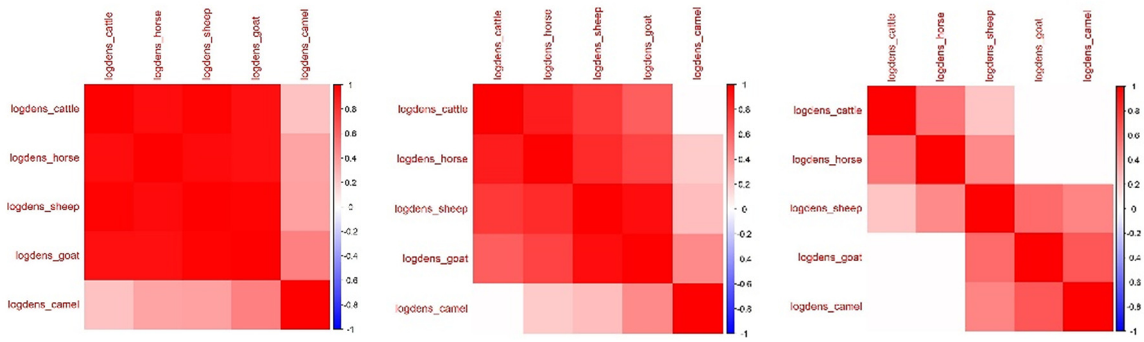

Figure 4.3. Cross-correlation comparisons between livestock species for periods 1981-85 (left), 1995-99 (center), and 2010-13 (right).

In addition to modelling the livestock distribution and abundance, we investigated temporal changes in herd composition using multidimensional scaling (MDS) and visualised livestock dissimilarities between the *soums* and *aimags* in Figure 4.4. We compared the *soum* and *aimag* livestock numbers in sheep foraging unit (SFU) per square kilometre. The points where the arrows start in the Figure 4.4 show the livestock dissimilarity between the regions in the period from 1981-1985. The middle points are the changes occurred in the herd structure of the *soums* and *aimags* between 1995-1999. The arrow tips show the patterns between 2010-13.

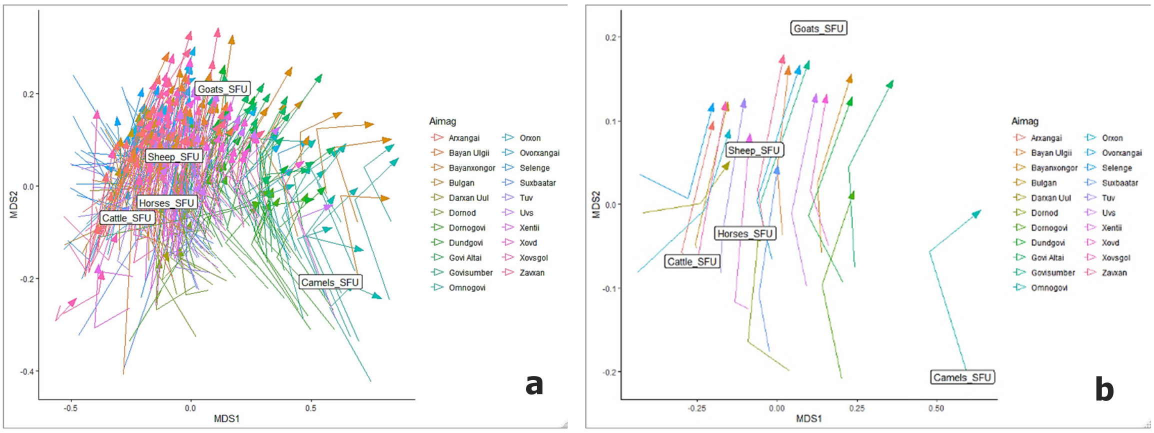

Figure 4.4. Community dissimilarity based on livestock abundances in SFU (sheep foraging unit)/km², (a) at *soum* level (each arrow represents a *soum*) and (b) at *aimag* level (each arrow represents an *aimag*).

The graph shows that the most administrative units had decreased the share of cattle in the 1990s and 2010s. However, during this period the number of goats had significantly increased in many regions. Bolortsetseg and Tuvaansuren (1996) assessed impacts of climate change on pasture and cattle production during the period of 1961-90. This study concluded that cattle intake and weight were not adversely affected by climate change in the 1980s. Indeed, during this period, the number of big livestock had been quite stable. In fact, there are not many studies which analysed environmental and social factors affecting specifically the number of cattle or other big livestock species such as horses or camels. Nevertheless, a number of studies concluded that social implications (poverty, rural-urban migration, etc.) of a series of climatic hazards such as *dzuds* in the 2000s significantly changed the herd composition and livestock distribution in Mongolia (Fernández-Giménez, Batkhishig et al., 2012; Nandintsetseg, Shinoda et al., 2018b; Sternberg, 2018; Tsutsumida, Harris et al., 2017). The statistical data show that herd composition changed more into smaller animals of goats and sheep in the 2000s (NSO, 2012b).

Using livestock and household data collected between 2004-14, Nakamura, Dorjjadamba et al. (2017) investigated why herders in Mongolia increased goats and decreased big livestock. They note that the high price for cashmere and the food culture that requires goat milk products were the main contributing reasons for herders to prioritise goats. In one of their study areas, raw cashmere from goats generated half of herder households' income. Moreover, cashmere goats in Mongolia have gained worldwide recognition for their finer fiber and Mongolia now has become the second largest producer of cashmere in the world (Tseveenjav, Garrick et al., 2020). Thus, such high global demand of cashmere is certainly linked to increase in goats in Mongolia.

On the question of decrease in big livestock, Nakamura, Dorjjadamba et al. (2017) suggested that a short period of herding experience is one of the reasons why herders were unable to keep big livestock in their study areas. Similarly, Nandintsetseg, Shinoda et al. (2018a) noted that over the past two decades, traditional herding strategies were affected by more and more inexperienced herder-households which increased herders' vulnerability to natural hazards. They posit that such vulnerability contributes to livestock mortality changing the herd composition and livestock distribution.

Moreover, traditional roles of some livestock species in nomadic pastoralism are changing due to the changing lifestyles of nomads in Mongolia (Yembuu, 2016). Camels are almost not used these days for transportation when herders move between their grazing campsites. Traditionally, mostly horses were used for herding animals. However nowadays, often motorcycles are used for herding replacing horses. Such changes may have influenced herd composition and the herder's decision about increasing the number of certain type of livestock species as well.

Changes in livestock distribution

Areas depicted with the same colours in Figure 4.6 characterise regions with similar combination of livestock composition and proportions. The results show that the compositions of livestock proportions in several major regions in Mongolia remained nearly constant from 1980s through 1990s and 2010s. These regions include areas in the Gobi Desert, desert steppe, and mountain desert steppe, as well as in western Mongolia (Figure 4.5).

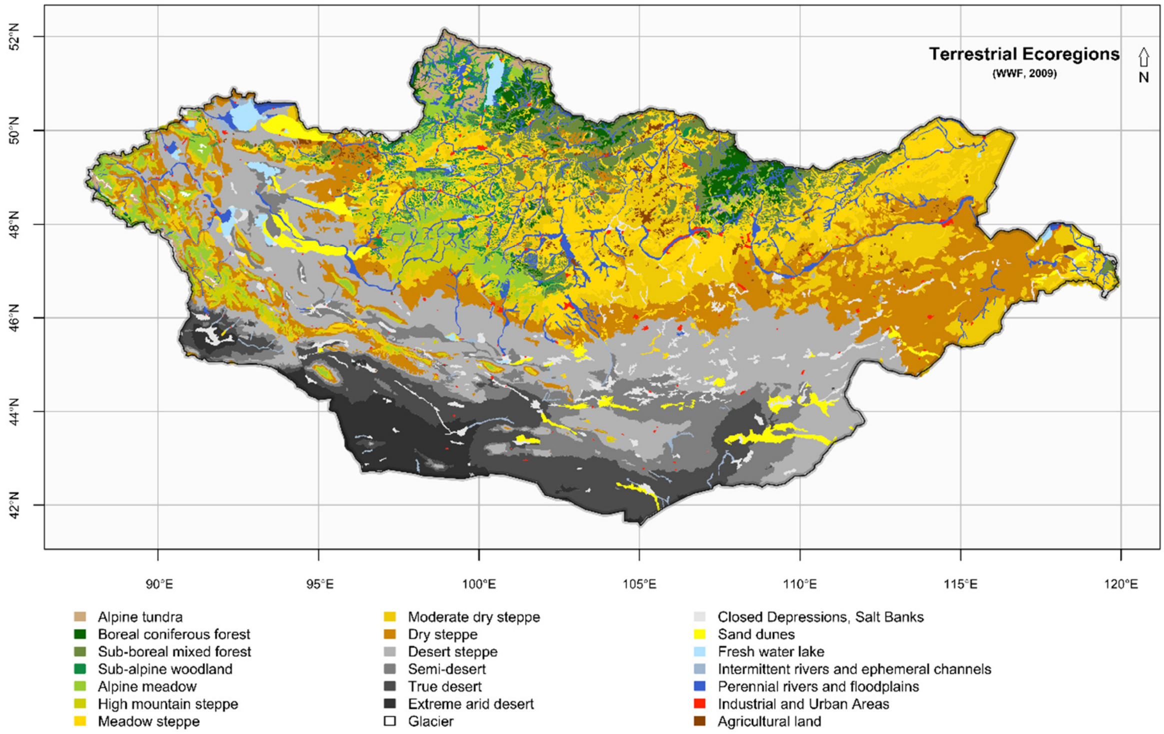

Figure 4.5. Map of key ecoregions and land use of Mongolia.

The biggest region which maintained its similar characteristics of livestock composition and proportions is the desert areas in southern Mongolia. However, a spatiotemporal analysis of vegetation growth found that the desert steppe and Gobi desert showed a degradation tendency during 1982-2015 (Meng, Gao et al., 2020). These findings suggest that despite degradation, herder households have been keeping livestock proportions similar and the influences of environmental factors on spatial distribution of livestock were insignificant in the Gobi Desert and desert steppe regions. It is possible that migration of herders to these regions as well as increase in the livestock number by local herders were discouraged by degradation tendency occurred between 1980s and 2010s. Such factors might have influenced the causes why the spatial patterns of livestock proportions were maintained in the desert regions.

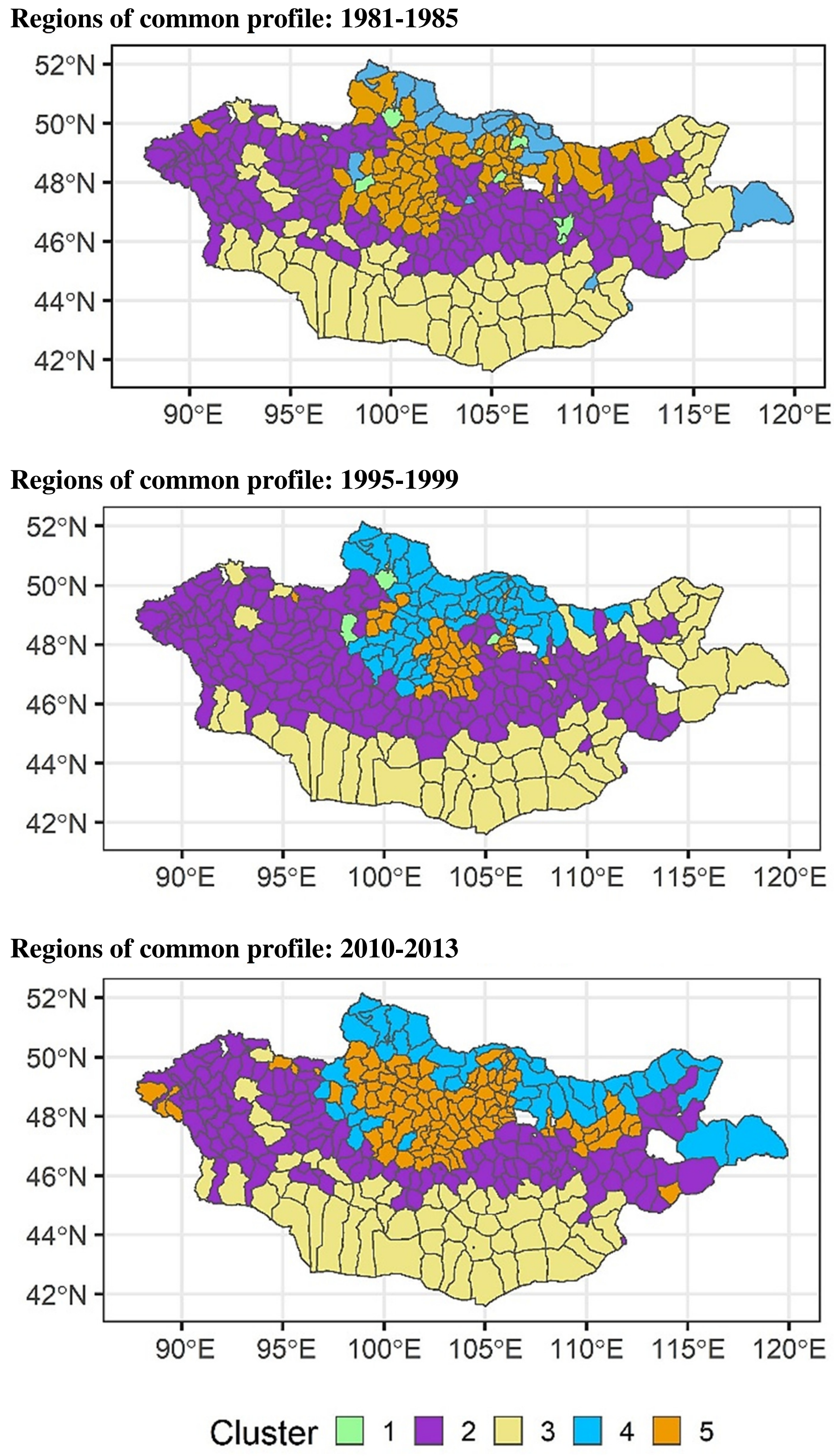

Figure 4.6. Areas with similar combination of livestock proportions for periods 1981-85 (upper), 1995-99 (center), and 2010-13 (lower). The same colours characterise regions with similar combination of livestock composition and proportions.

In western Mongolia, administrative units also maintained almost similar livestock compositions and proportions from 1980s to 2010s. Most of the western Mongolian ecological regions consists of steppe, mountain and mountain forest steppe (Figure 4.5). Such ecosystems in Mongolia possess some important features of equilibrium rangelands (Fernandez-Gimenez and Allen-Diaz, 1999) which are characterised by plant-herbivore interactions and in such systems when herbivore density increases, plant density decreases (Caughley, 1979). During 1982-2014, forage demand and grazing pressure were relatively stable and lower in western Mongolia compared with the Central regions of Mongolia (Fernández-Giménez, Venable et al., 2017). One of the likely causes for this difference could be attributed to decrease in the number of herders in the Western regions. Migration from western Mongolia to the capital city of Mongolia increased sharply after a deadly *dzud* occurred in 1992 in western Mongolia (NSO, 2021). Many herders lost large numbers of their animals and faced livelihood loss which resulted in large-scale migration to urban areas of central Mongolia. Difficulties such as poverty caused by loss of animals and state support in the transition from a centrally planned to a market economy also contributed to this mass rural-urban migration. In contrast to the Eastern regions of Mongolia, out-migration from western Mongolia was four times higher between 1992-93 (NSO, 2021). Thus, in the Western regions it seems possible that relatively low grazing pressure and forage demand influenced the region to sustain and control its livestock proportions and similar patterns between 1980s and 2010s.

Most of the spatial changes occurred in the Central and Eastern regions of Mongolia. In the Figure 4.6, it can be seen that in these regions, livestock composition and proportion patterns significantly changed in 1990s and 2010s by contrast to the patterns in 1980s. The changes in the patterns are a result of social, environmental, and economic influences which led many herders to migrate to areas near cities altering the characteristics of land tenure, land use and livestock proportions in pastoralism especially in the Central regions of Mongolia. Livestock privatization is one of the important factors which influenced herders' livelihood and pastoral land use (Fernández-Giménez, 2001; Nixson and Walters, 2006). Availability of water resources also affects locations of pastoral land use and herders' strategies for herding (Ono and Ishikawa, 2020). In the period between 1995-2006, due to the expansion of agricultural water use, water resources were overexploited in Mongolia (Priess, Schweitzer et al., 2011). Thus, water use in the different sectors might have contributed to the changes in patterns of livestock proportions. Moreover, for instance, the herder population increased in the North Central region due to migration of herders from the regions in the West and Gobi as they preferred to access more reliable forage production and markets (Fernández-Giménez, Venable et al., 2017). Herders migrated to the Central region also to access better health and social services such as education for their children or search for better job opportunities. When herders moved to new areas, they accessed pasture land through non-traditional strategies such as buying winter campsites or sharing pasture with relatives or friends. Such alternative strategies are qualitatively different from customary pasture land use and create undesirable patterns of pasture land resource use (Fernández-Giménez, 2001). These factors may explain the changes in the spatial patterns of livestock distribution in Mongolia.

4.3.2 Influences of socioeconomic and environmental factors on herd composition and livestock distribution

The correlations between livestock abundance and environmental and social variables were tested for the periods 1981-85, 1995-99, and 2010-13. Different livestock species responded to our environmental and social variables in a similar manner across three periods, with only goats changing their densities differently in relation to variables such as NDVI and elevation (Figure 4.7). Most studies (Chen, John et al., 2015a; Chen, John et al., 2015b; Fernández-Giménez, Venable et al., 2017) conducted in Mongolia which explained the relationship between livestock abundance and vegetation biomass over different periods of time focused only on total livestock population. However, a few studies (Saizen, Maekawa et al., 2010; Tsutsumida, Harris et al., 2017) emphasised changes in the goat population and their spatial association. The results of this study are consistent with those observed in earlier studies. In the 1980s and 1990s, when vegetation biomass increased, there was no change in the goat population. Apparently, in these years, elevation played a role in goat abundance. Goats were grazed in particular areas at specific altitudes. However, in the 2010s, this link has been lost and there was no association between the goat population and the elevation. By contrast, in this period, with an increase in vegetation biomass, the number of goats increased. It is particularly the number and distribution of goats has altered the patterns of all livestock communities in Mongolia. This finding confirms the association between cashmere production and market incentives observed in Saizen, Maekawa et al. (2010); Tsutsumida, Harris et al. (2017)'s studies.

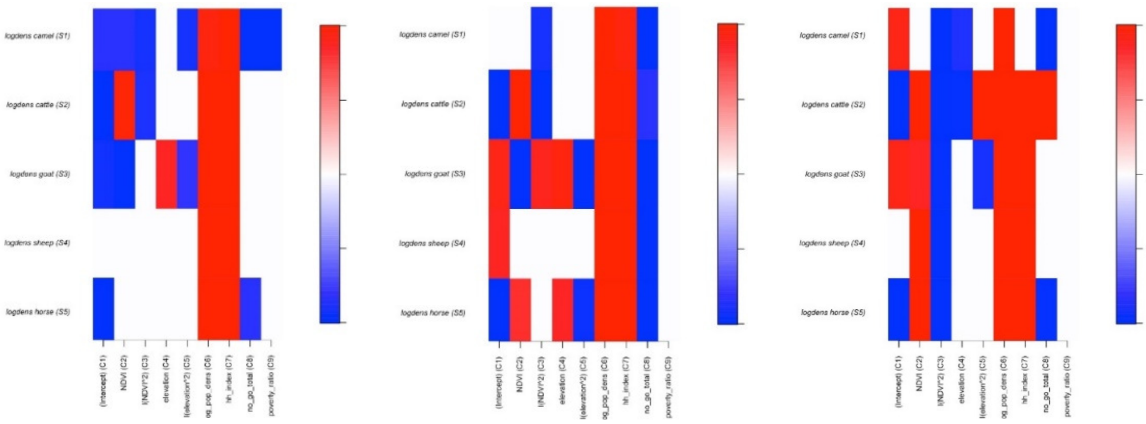

Figure 4.7. Effects of social and environmental variables on livestock abundance.
for the periods 1981-85 (left), 1995-99 (center), and 2010-13 (right). Red, significant ($p<0.05$) positive correlation; blue, negative significant correlation; white, non-significant correlation. Explanatory variables from left to right: NDVI, NDVI2, elevation, elevation2, population density, household index, land use/no-go areas (water bodies, croplands, forest, urban settlements, protected and mining areas), poverty ratio.

Moreover, our results show that small animals have no association with restricted land use, i.e., the size of areas where herders cannot graze their animals in the 1980s and 2010s. These restricted areas for grazing include urban settlements, water bodies, croplands, forest, protected and mining areas. Such association indicates that herders maintain sheep and goats regardless of pressure on or availability of pasture land. Whereas big animals have negative correlations with these restricted areas. It seems that when the size of areas restricted for grazing increases, the number of big animals decreases. Thus, it is likely that herders prioritise small livestock when they make choices about which livestock species to keep depending on the availability of their grazing areas.

There are positive correlations between all livestock species and both population density and household index in the three periods we analysed. Only camels lost their association with the household index between 2010-13 and also only camels have a link with the poverty ratio. Moreover, compared to other species, it is only the number of camels which had decreased between 1980s and 2010s (Figure 4.1). There have been little studies conducted specifically on the camel population and distribution in Mongolia. Further studies need to be undertaken to investigate the connections between social issues and the camel population and distribution. On the other hand, within the frame of this study, most of the socioeconomic variables were available only for the period between 2010-13. Thus, all the models were fit with the most recent socioeconomic data. Therefore, future research would benefit from these set of variables as their explanatory power will only increase with time.

In summary, modelling livestock communities at soum level for each of the chosen periods highlights some differences in the influence of environmental as opposed to socioeconomic drivers. The graphs in Figure 4.8 show that the effects of random factors decrease with time, while the explanatory value of socioeconomic factors increases in general. Moreover, for some of the livestock species such as camel and goat, the variance explained by environmental variables seemed to decrease with time. Taken together, our results suggest that the livestock communities were more influenced by environmental factors in the 1980s when Mongolia was in a centrally planned system and the pastoral systems were semi-extensive (Figure 4.9).

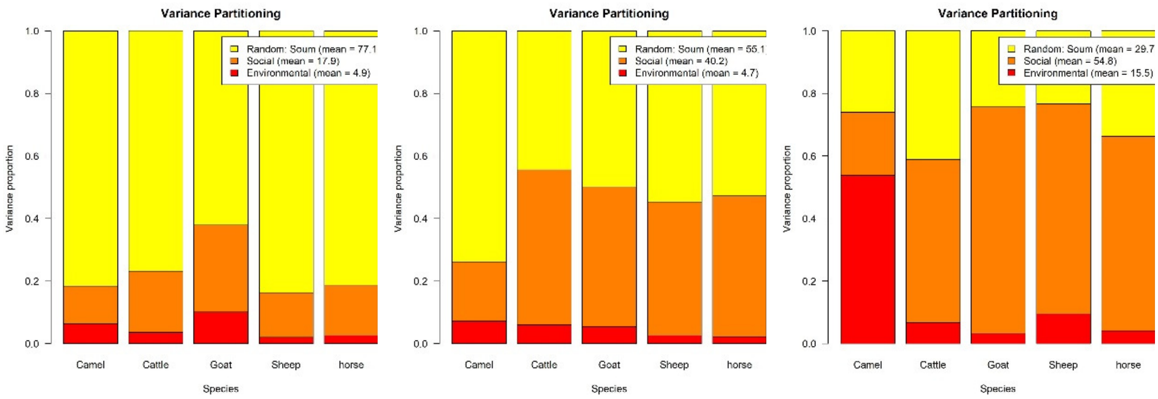

Figure 4.8. Variance in livestock abundance explained by random factors. (spatial correlation, yellow), social variables (orange), and environmental variables (red) for the periods 1981-85 (left), 1995-99 (center), and 2010-13 (right). Species from left to right: camel, cattle, goat, sheep, horse.

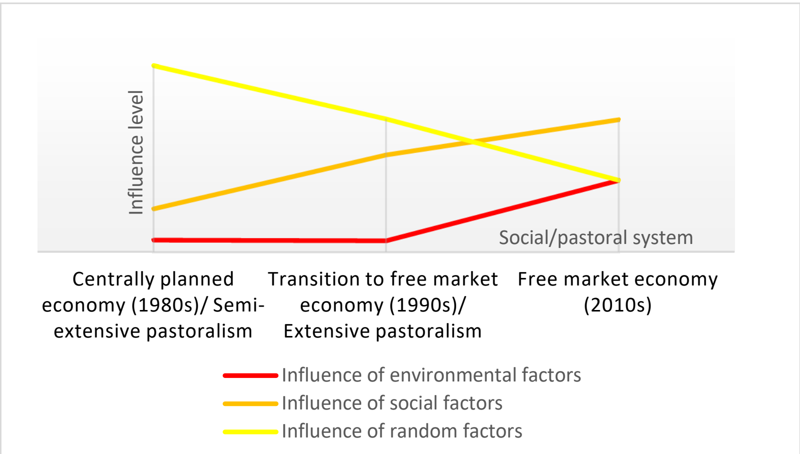

Figure 4.9. The influence of socioeconomic and environmental variables on livestock communities in Mongolia during different social systems.

However, the effects of environmental drivers seemed to have decreased during the transition period to a free market economy and this result is consistent with Chen, John et al. (2015a)'s finding which used socioeconomic and physical data at *aimag* level. By contrast, since the transition time when herders began to practice an extensive pastoralism again, socioeconomic factors have gained more influences on livestock communities in Mongolia compared to the period when the country had a centrally planned economy. This change is interesting because in an extensive livestock production system, environmental factors are expected to influence livestock communities more than socioeconomic drivers. The results, as shown in Figure 4.8, indicate that the effects of environmental factors on the pastoral systems remained low in the 2010s when Mongolia was fully shifted economically towards a free market system.

4.4 Conclusions

In this study, aim was to examine effects of socioeconomic and environmental factors on the spatial and temporal dynamics of herd composition and livestock distribution in Mongolia. The results of this study have shown that in the periods between 1981-85, 1995-99, and 2010-13, in all regions of Mongolia, when herders increased one livestock species, the number of other species also increased except camels. The compositions of livestock proportions nearly remained constant in the desert, desert steppe, and mountain desert steppe, as well as in the Western regions of Mongolia over the last forty years. By contrast, considerable spatial changes in the livestock communities occurred in the Central and Eastern regions of Mongolia. This study suggests that the number and distribution of goats played a significant role in these changes. Only goats responded to our environmental and socioeconomic variables differently. Effects of environmental and socioeconomic factors on the other livestock species were similar.

We hypothesized that until Mongolia's transition to a free market economy, the effects of environmental factors were stronger on the livestock communities than of socioeconomic factors and today the livestock composition and distribution are more aligned with socioeconomic drivers. Our analyses conducted using spatial data at the resolution of soum provide sufficient evidence to support this assumption and are consistent with previous findings (Chen, John et al., 2015a) concluded using datasets at *aimag* level.

The empirical findings in this study which used more detailed landscape level data enhance our understanding of the environmental and socioeconomic factors influencing the spatial and temporal dynamics of livestock composition and distribution in Mongolia. Particularly, this research extends our knowledge of the effects of environmental and socioeconomic factors on each individual livestock species. However, this study examined socioeconomic data of only 2010s. Thus, future studies using the same methods and updated time series datasets are needed to better understand the pastoral systems in Mongolia and contribute more to the current key discussion of the rangeland science.

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CHAPTER 5. Model development

The production of pastoral space: Modeling spatial occupation of grazing land for environmental impact assessment using structural equation modeling [6]

Abstract

Environmental impact assessment (EIA) is a key tool for both environmental and land management. It identifies potential adverse and unintended consequences of the projects on land use and the environment and derives possible mitigation measures to address these impacts. Calculating the volume and severity of impacts is complex and often relies on selections and simplifications. Moreover, calculating impacts associated with nomadic-pastoral (dynamic) land use is still an unresolved methodological problem. A full understanding of the patterns of dynamic land use in nomadic pastoralism is still lacking. Consequently, EIAs are currently able to predict the negative impacts associated with dynamic land use insufficiently. This article addresses this lacuna by modeling the spatial occupation of grazing land using a statistical modeling technique of structural equation modeling (SEM) and the R package lavaan for SEM, in order to explain the behavior of dynamic land use for EIA. Based on the concepts of the production of space and pastoral spatiality, we specified and tested a model of spatial occupation of grazing areas hypothesizing interrelationships between factors influencing the pastoral space using empirical data from two different ecological zones in Mongolia. The findings suggest that grazing areas, herd mobility, and herd size and composition have direct positive effects on each other. Compared to broad-scale pastoral movements, the herd size and composition significantly affect the size of grazing areas and the extent of fine-scale herding mobility. Herders occupy more pastoral space and increase their daily herding movements at their campsites when the population of livestock increases. By contrast, the herd size and composition do not considerably affect the herders' decision to migrate for extensive grazing between their seasonal campsites. Likewise, the scale of grazing areas and fine-scale pastoral mobility do not affect significantly the broad-scale herding mobility between campsites. The broad-scale herding mobility is relatively independent of the fine-scale mobility; however, they covary. This is the first study to analyze and quantify the effects of grazing areas, herding mobility, and herd size and composition in the same study. EIA impact prediction should consider grazing areas as a dynamic space that is influenced by grazing orbits, fine and broad-scale herding movements including *otor*, livestock species, the number of animals as well as households at campsites.

Keywords

environmental impact assessment; grazing land; herd size strategy; lavaan; Mongolia; pastoral mobility; pastoral space; R; spatial occupation; structural equation modeling

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5.1 Introduction

Land use is a complex process and operates at the interface of multiple socio-economic and environmental systems (Letourneau, Verburg et al., 2012; Verburg, Soepboer et al., 2002). Land use in the context of nomadic pastoralism makes this interface more complex and non-linear due to the inherent dynamic equilibrium of pastoral systems (Zinsstag, Schelling et al., 2016). Byambaa and de Vries (2019); 2020) argue that current environmental impact assessments (EIAs) do not address this dynamic character in nomadic pastoralism and therefore, impacts associated with nomadic-pastoral (dynamic) land use are not sufficiently and appropriately predicted in EIA. EIA is a legally required tool for environmental management applied in more than 190 countries (Morgan, 2012; Sadler, 1996) and it is the key process that identifies potential adverse impacts of projects and initiatives at an early stage (Morris and Therivel, 2009). Moreover, EIA suggests possible mitigation measures to address negative impacts on the environment and people's health and livelihood and informs decision-makers about those impacts. Thus, impact prediction about nomadic-pastoral land use in EIA needs to be improved in order to inform the decision-making properly.

In 2012, a complaint was filed to the Compliance Advisor Ombudsman (CAO) by the representatives of 89 herder households affected by the Oyu Tolgoi project in Mongolia, which is one of the largest known copper and gold deposits in the world. Herder households were concerned that the negative impacts of the project on their grazing areas were not appropriately quantified and the methodology used to identify impacts was not clear to the herders (CAO, 2013). Indeed, impacts associated with grazing areas of each individual herder household were not identified sufficiently by the project (OyuTolgoi, 2012). Moreover, the impact prediction (OyuTolgoi, 2012) failed to look at the interrelationship between grazing areas and pastoral mobility such as *otor*[7] movements and did not consider the number of livestock and herd composition when conducting EIA. Environmental and social impact assessment of a new wind park project in Mongolia also failed to consider the characteristics of dynamic land use when identifying impacts on grazing areas (Tecol and SharedResources, 2017). These EIAs identified project impact areas as radial or linear zones around the project facilities and only impacts associated with grazing campsites located

[7] Migration of herders to fatten their animals or to escape drought or harsh winter to distant pastures other than their winter, summer, spring, and autumn campsites where grasses are available for grazing.

within these impact areas were addressed. Connections of the affected herders' campsites with other seasonal grazing areas, which are used by the same herder, for instance, were not assessed sufficiently. Such links between seasonal grazing areas are dynamic as pastoral mobility is influenced by various climate, environmental and social factors. EIA's objective is to identify these dynamic grazing areas affected by the project regardless of how they were generated. A framework by Slootweg, Vanclay et al. (2001) suggests that interrelated impact pathways in nomadic pastoralism include impacts of projects such as mining on pasture land and impacts of pasture land use, such as overgrazing, on the environment (Byambaa and de Vries, 2019) as well as on land use itself. Thus, impacts, as well as impact areas, of both project and pastoral land use need to be identified in EIA. Hence, so far there is a deficiency in addressing impacts associated with dynamic land use, as the current EIA methods primarily focus only on static land use such as mining interventions (Byambaa and de Vries, 2019; 2020).

In recent years, the most commonly used method of land-use impact prediction has been the land-use impact assessment within life-cycle assessments. This method investigates the quantities of land-use changes (Byambaa and de Vries, 2019). It calculates land-use impacts as a function of i) the area used for the land use process, ii) the time required for the transformation and occupation process of land use, and iii) the difference in land quality between the current and initial land use (Koellner, de Baan et al., 2013; Lindeijer, 2000; Milà i Canals, Bauer et al., 2007). Thus, one of the key parameters of land-use impact is the area for a specific land-use type. This implies that in order to quantify nomadic-pastoral land use, an EIA needs to properly account for the dynamic aspects of this land-use type; there is a spatial variation in land use through the pastoral movements.

In the context of pastoralism, the complexities of spatiotemporal use of pasture land tend to be oversimplified in existing conceptual models (Frank, Dickman et al., 2012) and have not been analyzed in a way that has led to an explanatory model of nomadic movement (Dwyer and Istomin, 2008). Explaining why, where, and how pastoral land use and movement occur requires considerable effort in terms of mobility modeling and evaluation (Liao, 2018a). The scientific understanding of land-use changes, which are both spatial and categorical, is still insufficient due to gaps in knowledge about the pattern and dynamics of land-use intensity (Erb, Haberl et al., 2013). Land-use intensity is a multidimensional process and can refer to different aspects including the land area used and the time required for land-use occupation processes (Kuemmerle, Erb et al., 2013). To date, adequate approaches, conceptualizations, and datasets are often missing for measuring land-use intensity qualitatively and quantitatively to a sufficient extent (Erb, Haberl et al., 2013; Kuemmerle, Erb et al., 2013; Veldkamp and Lambin, 2001).

A few land-use change models deal with both the location and the quantity of its change in an integrated way offering only case-specific solutions (Veldkamp and Lambin, 2001). Jones, Antle et al. (2017) note that the modeling of livestock systems is particularly complex as it requires a good understanding of the use of land by herds at various levels and the existing models of livestock systems mainly focus on predicting animal productivity, animal numbers, herd dynamics, and herd structure. From case studies, in various pastoral contexts, we know that it is possible to predict the probability of a livestock movement link between two locations (Nicolas, Apolloni et al., 2018; Xiao, Cai et al., 2015). There are also models that examine the dynamics of livestock in terms of sales, self-consumption, and stocking (Xu, Zhang et al., 2019), and pasture land use with respect to the demands of domestic consumption and international trade (Guo, Jiang et al., 2019). Associations between herding practice and water availability as well as cattle productivity (intake rates, foraging behavior, milk yields, and body conditions) were also examined (Coppolillo, 2000). Moreover, it is possible to predict the resource selection patterns for cattle (Liao, Clark et al., 2018), and factors that can play a role in the generation of mobility patterns of grazing cattle are known (Zhao and Jurdak, 2016).

Although extensive research exists on defining, categorizing, and explaining the variations in pastoral space and its mobility patterns, there is still a need for better insights, which would explain why, and how herders spatially occupy and alter their dynamic land use. Only with more detailed information on the significance of factors such as livestock species and size, location and size of grazing areas, and mobility patterns, is it possible to conduct an EIA in a more comprehensive way. Access to pastoral data is one of the challenges of rangeland science for better understanding the grazing interactions and processes comprehensively (Liao, 2018a; Sayre, deBuys et al., 2012). Liao (2018b), for instance, notes that significant shortcomings still exist in pastoral mobility quantification and only little empirical work has been conducted to quantify pastoral mobility extensively. Moreover, calculating the total impacts associated with a complex series of land occupations still remains unresolved and this is a methodological problem for impact assessment

(Koellner and Scholz, 2006) as the current EIA methods are designed for static land use (Byambaa and de Vries, 2019). This study examined the following twofold questions to contribute to explanations and quantifications of the dynamic land use: *How does dynamic land use produce pastoral space? How do factors influencing dynamic land use interrelate with each other?* The article intends to address these questions by modeling and explaining the spatial occupation of grazing areas, using a structural equation modeling (SEM) technique based on empirical data collected from two different ecological zones in Mongolia. This is the first study, to our knowledge, to quantify the effects of grazing areas, herd mobility, and herd size on each other all together. Moreover, the empirical study presented in this study extends the previous works (Chen, John et al., 2015; Fernandez-Gimenez, Allington et al., 2018), which applied latent variable modeling in the evaluation and quantification of complex and dynamic interactions in nomadic pastoralism.

5.2 Model specification

5.2.1 Measuring the pastoral space and mobility

The methodological problem in impact assessment related to a series of land occupations requires us to improve our understanding of the spatial occupation of grazing land generated by pastoral mobility (Byambaa and de Vries, 2019). Two main types of herding mobility are used by pastoralists (Adriansen, 2008). Broad-scale movements related to different seasons that occur between camps and fine-scale movements that include daily mobility within the pastoral unit. Various indicators have been suggested by scholars to measure the pastoral space and mobilities based on studies conducted on the sedentary to semi-sedentary or transhumance pastoral systems.

We characterize and quantify pastoral areas and mobility by applying the parameters of grazing orbit, length of daily herding movement, and distances between campsites which include the number of camps. Grazing orbit is a mobility area from the center of the household or a livestock enclosure where the path that animals circumnavigate from their enclosures to grazing and water resources and back to their enclosures in a grazing day (Butt, Shortridge et al., 2009). Length of daily herding movement is an indicator of pastoral mobility and it measures the daily cumulative herd travel [31,36–39]. Pastoral mobility is also measured by the distance from camp, which considers a daily maximum distance from camp or the spatial stretch of daily herding movement [27,31,40]. Moreover, the number of camps is an indicator that measures the extent of grazing mobility (Liao, 2018b). This indicator refers to how many sites are used as camp locations during a seasonal cycle by pastoralists. Freedom in herd movements and the degree of constraints on herd mobility is measured by an *angular distribution of footprint* which refers to the mean angle in degrees from the livestock enclosure to the point of furthest travel, in a straight-line distance from the enclosure (Butt, Shortridge et al., 2009; Liao, 2018b).

5.2.2 Modelling and hypothesizing the spatial occupation of grazing land

We specified a model formulating the relations between a set of parameters we discussed in the previous section. This model presents our assumptions about the spatial occupation of grazing areas and is based on Karplus and Meir (2013) concept of pastoral spatiality developed under the Lefebvre (1974/1991) framework for the production of space. Lefebvre (1974/1991) spatial framework conceptualizes space as a triad consisting of perceived, conceived, and lived spaces interrelated to each other. These three elements produce a space linking physical and abstract aspects of any socially produced space. In his framework, a perceived space embraces the concrete physical space where we practice everyday activities. In contrast, a conceived space is a conceptualized space imagined by scientists, engineers, and planners through maps and plans creating a system where the spatial relations are imposed by order of signs and codes. A lived or representational space, in turn, is "the space of inhabitants, hence, space which is passively experienced and in which the imagination seeks to change appropriately. It overlays the physical space, making symbolic use of its objects" by which we imagine the space we live (see p.39 in (Lefebvre, 1974/1991, p. 39)).

By drawing on the Lefebvre (1974/1991) framework, Karplus and Meir (2013) defined the pastoral spatiality as an interrelated space produced through pastoral mobility (perceived space), social territoriality (conceived space), and pastoralists' ideological attachment to space through symbols and cultural codes (lived space). Byambaa and de Vries (2019) review concluded that the rationalist theory and linear cause-effect epistemologies are dominant underlying fundaments of EIA discourses. They argued that nomadic-pastoral land users need EIA theory to incorporate irrational logic and complex and unpredictable socio-ecological features of dynamic land use and they called for more adaptive or nomadic theories to be applied in EIA. Karplus and Meir (2013) concept of pastoral spatiality incorporates the needs of dynamic land use as this framework was specifically conceptualized to understand pastoral space. They conceptualize that "pastoralists' perceived space is produced as a series of temporary campsites linked by journey trails" (see p.39 in (Karplus and Meir, 2013, p. 26)). Thus, in our model, the perceived space is characterized by indicators related to pastoral mobility (Figure 5.1).

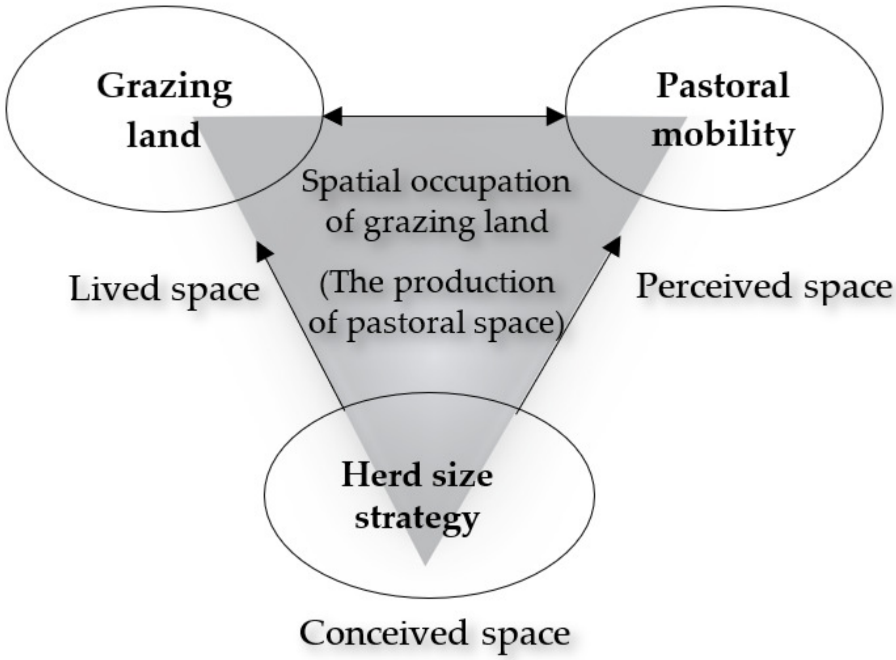

Figure 5.1. The conceptual framework of spatial occupation of grazing land tested in this study.

Furthermore, according to Karplus and Meir (2013), a pastoral conceived space is produced as social territoriality where spatial resources and social interaction are managed by means of a group of people. Our model uses the livestock population as a parameter characterizing the pastoral conceived space. Sayre, Davis et al. (2017) note that land degradation in rangelands more often results from intensifying commercial livestock production. A recent study by Hilker, Natsagdorj et al. (2014) also showed a clear connection between increases in animal population and overgrazing. Moreover, some countries successfully prevented grassland degradation by controlling the increase in livestock population (Batunacun, Wieland et al., 2019; Liu, Dries et al., 2019). Hence, the livestock population is the key indicator and rule of managing spatial resources of pasture land, and therefore, we link the herd size strategy to the pastoral conceived space in our model.

Lastly, according to Karplus and Meir (2013), "continued production and reproduction of localities lead to lived space that gives precedence to ideologies of socio-spatial bonds". Moreover, a herding pattern represented by a grazing orbit in different localities is the synergistic spatial product of social and ecological conditions in pastoralism (Butt, 2010). In fact, an effective communal land-use system in pastoralism is driven by a complex mix of community dynamics, social relations, and the biophysical characteristics of the landscape (Senda, Robinson et al., 2020), and traditional ecological knowledge

(Fernandez-Gimenez, 2000). Thus, in our model, the grazing land, which represents the grazing orbit, is linked to the lived space. We relate indicators of daily herding movements on campsites also to the lived space. This relation is necessary to understand the symbolic and cultural significance of the nomadic-pastoral lifestyle. We specify that, together, these factors relate to each other and contribute to the production of pastoral space (Figure 5.1).

Pastoral space in nomadic pastoralism is dynamic and varies in size and location due to herders' decisions to migrate between grazing areas. Thus, it is improper to observe grazing areas, herding mobility, and herd size strategy from static observations. Instead, these factors are latent variables in our model. We hypothesize that the grazing land, pastoral mobility, and the herd size strategy are interrelated key factors of the pastoral space and quantified by grazing areas, both fine and broad scale herding mobilities, the number of households, and the number of animals (Figure 5.1). As so, the proposed model is defined by these three latent variables (factors): grazing land, pastoral mobility, and herd size strategy and in addition, seven observed variables (indicators): total grazing orbit, total length of daily herding movement, total number of households on campsites, total distance between campsites, total distance between campsites including *otor*, total number of animals, and total number of sheep and goats.

Based on the above conceptual model, we hypothesize (Figure 5.1) that the grazing land and pastoral mobility are interrelated (grazing land ~~ pastoral mobility) and measured by a factor related to herd size and composition, which we name herd size strategy (grazing land ~ herd size strategy; pastoral mobility ~ herd size strategy). Herd composition is related to the foraging and feeding of livestock species and depending on livestock diet selection, herders make decisions about the location and size of grazing areas. Thus, the number of sheep and goats which characterize herd composition is an indicator that measures herd size strategy in our model. We hypothesize that the herd size strategy has a direct effect on both the grazing land and pastoral mobility. The observed variables of daily grazing patterns and households on campsites measure the grazing land (grazing land =~ grazing orbit + length of daily herding movement + number of households on campsites). Moreover, pastoral mobility is quantified in our model by the total distances between all seasonal (spring, summer, autumn, winter) grazing camps including *otor* campsites (pastoral mobility =~ distance between campsites + distance between campsites including *otor* campsites + number of households on campsites). *Otor* is a traditional mobility strategy developed by

Mongolian herders to cope with harsh winter (Xie and Li, 2008) and it improves the effectiveness of grazing reserves (Fernández-Giménez, Batkhishig et al., 2012). Moreover, *otor* provides herders with the means to maintain livestock husbandry in highly variable and uncertain environments by accessing key resources through extensive movements (Xie and Li, 2008). Therefore, *otor* is an important indicator, which measures pastoral mobility. The number of households on each of those campsites is predicted by both the grazing land and pastoral mobility as the availability of pasture land and the needs for seasonal movements depend on access to grazing areas which influence the households' decision to stay in or move out the campsites. The observed number of animals and the sheep/goat herd composition measure the herd size strategy.

5.3 Methodology and data collection

5.3.1 Study areas

The study was conducted in two areas in Mongolia. The first area, Turgen *soum*[8] of Uvs *aimag*[9] is located in western Mongolia at an average altitude of 1763 meters in a forest steppe region, approximately 1500 km from the capital city of Mongolia. The second, Delgertsogt *soum* of Dundgovi *aimag* is located at an average altitude of 1432 meters in a semi-desert steppe region in southern Mongolia. However, both areas include dry and mountain forest steppe, desert and mountain desert steppe ecoregions in their entirety (Figure 5.2). Turgen had 340 herder households and 143,960 animals in 2018, whereas Delgertsogt had 380 herder households and 185,860 animals in total (NSO, 2020). In both *soums*, households herd sheep, goats, cows (and yaks), horses, and camels and move between winter, spring, summer, autumn, and *otor* campsites. The herd composition and herding pattern differ in these two study areas due to their variations in altitude and climate conditions. Such different areas were chosen to include a representation of various movement patterns and herd composition which exist in Mongolian pastoralism.

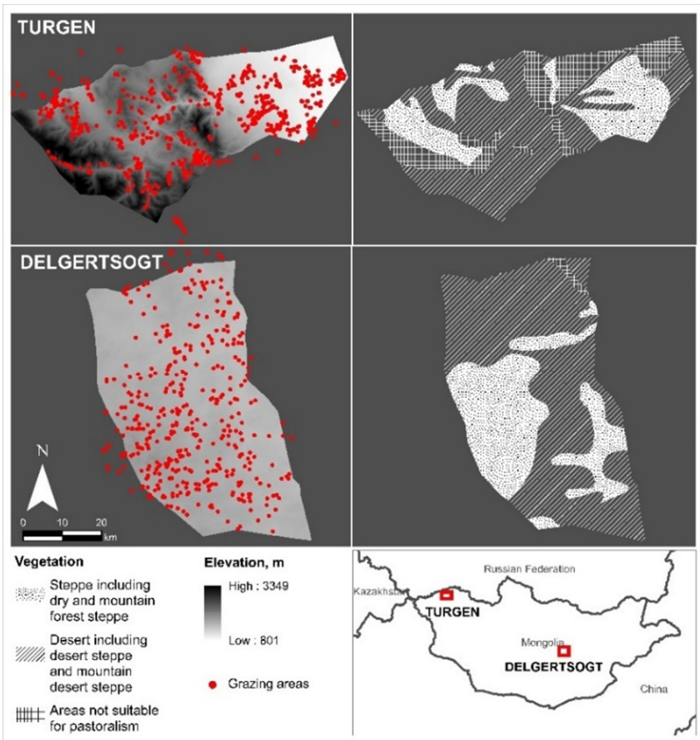

Figure 5.2. Two study sites in Turgen and Delgertsogt *soums* of Mongolia.

[8] The second-level administrative subdivision of Mongolia
[9] The first-level administrative subdivision of Mongolia

Open grazing areas are owned by the state in both zones (SGH, 1992), however, they are de facto managed as common properties (Upton, 2010). Formal possession rights are allocated to *khot ail* (groups of livestock keeping families (Bold, 1996)) in those *soums* to use grazing areas in winter and spring campsites (SGH, 2002). Moreover, land rights on grazing lands in autumn, summer, and *otor* campsites are regulated through “manifestations and interpretations of herders’ customary rights and the reworked legacy of historical institutional arrangements” (see p.1401 in (Upton, 2009, p. 1401)).

5.3.2 Data collection

Data were collected from the two study sites in Mongolia between July and September 2019. First, we used a survey questionnaire containing questions related to the movement pattern of animals. The design of the questionnaire used the indicators of pastoral land use and mobilities such as the grazing orbit, the length of daily herding movement, and the number of camps (Table 5.1). We administered the questionnaire through structured face-to-face interviews. To carry out the interviews, we visited the homes of herder households as well as various events such as community meetings and celebrations where many herders gathered. From each *soum*, we interviewed senior family members of 100 households in the Mongolian language and in total, received 200 responses from two *soums* to our questionnaire.

Table 5.1. List of collected data on herd population, mobility, and grazing areas from two sites in Mongolia.

Livestock	Number of Herder Households on Campsites	Distance between Campsites	Length of Daily Herding Movement	Grazing Orbit
Total number of animals (sheep, goats, cows (and yaks), horses, camels)	Winter campsite	Winter-Summer	Sheep and goats	Sheep and goats at winter campsites
	Summer campsite	Winter-Spring	Cattle (and yaks)	Sheep and goats at summer campsites
	Spring campsite	Winter-Autumn		Sheep and goats at spring campsites
Number of sheep	Autumn campsite	Spring-Summer		Sheep and goats at autumn campsites
Number of goats	*Otor* campsite	Spring-Autumn		Sheep and goats at *otor* campsites
		Autumn-Summer		Cattle
		Summer-*Otor*		Yaks
		Summer-Temporary campsite		

The face-to-face interviews we conducted with 200 herder households reveal that horses and camels graze freely in any pasture area. They graze within a much longer distance compared to sheep, goats, cattle, and yaks. Moreover, the herders who participated in the survey noted that horses and camels mostly graze outside their grazing orbit. Therefore, we considered the length of daily herding movement and the grazing orbit of only sheep, goats, and cattle (and yaks) in our model.

Mongolian herders used their ecological knowledge of plant-animal-environment relationships in their nomadic herding strategy (Fernandez-Gimenez, 2000). Different knowledge systems such as the pastoralists' own knowledge system were also used for understanding pastoral mobility (Adriansen, 2008). Moreover, participatory mapping was used to obtain local spatial knowledge (Rohrbach, Anderson et al., 2016). During the interviews, we also conducted participatory mapping with herders to identify the locations of their winter, summer, spring, autumn, and *otor* grazing areas using the local names printed on a map prepared in advance. Seasonal movements between winter, summer, spring, autumn pastures practiced by Mongolian herders have repeated patterns and the location of basic pasture types remains constant between years (Fernandez-Gimenez, 2000). Therefore, herders who participated in the survey had good knowledge about their seasonal pastures and they provided us information about their grazing distances, locations, number of animals, grazing distances, and households, which share pasture in their campsites during the survey. Grazing locations were then further marked on a shapefile we obtained from the local authorities to measure distances between campsites using spatial analysis. The shapefiles included locations of grazing campsites of these *soums* allocated to herders for possession rights and were used as the second source of data for this study.

5.3.3 Structural equation modeling and exploratory factor analysis

The methodological approach taken in this study is a structural equation modeling (SEM) technique. SEM is a methodology for explaining the patterns of relationships among variables and for estimating the magnitude of effects of one variable on the other. We use SEM to test and estimate complex relationships among both observed (indicators) and unobserved (factors) variables (Kaplan, 2009). Factors representing nomadic-pastoral land use are not measured directly and therefore, they are latent variables. SEM fits into the purpose of this study in examining both latent and observed variables related to pastoral space in the same analysis. We tested Karplus and Meir (2013) concept of pastoral spatiality by specifying a model of the spatial occupation of grazing land employing this concept. SEM is used for both confirmatory and exploratory purposes and it examines the extent of interrelationships among the variables (Schreiber, Nora et al., 2006). Thus, SEM also suits our objective to quantify the pastoral areas and mobility by estimating the magnitude of effects of our variables on each other.

We followed the key steps of SEM (Kline, 2011). First, we specified the model, while choosing indicators for observations and designing a questionnaire for data collection. We evaluated the model by applying exploratory factor analysis (EFA) using the Zhang, Jiang et al. (2018) EFAutilities package in R. The EFA is conducted to test the assumptions between measured variables and to identify the common factors and covariation that explain the structure among our observed variables (Watkins, 2018). We tested the relationships among all our observed variables using the datasets derived from 200 survey responses including data on horses and camels by applying EFA. However, the factor loadings of variables of horses and camels were not significant. A factor loading for a variable is a measure of how much the variable contributes to the factor (Yong and Pearce, 2013). The face-to-face interviews with the herders also verified that the movement of horses and camels are substantially different from the daily grazing patterns that herders practice. Therefore, the EFA focused on data on sheep, goats, and cattle (and yaks).

Following the model evaluation, we estimated the model using the R package lavaan (Rosseel, 2012) which applies the maximum likelihood (ML) method to calculate the fit of the model and we evaluated model fit. We assessed the goodness of fit indices of the model with the Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Some rules of acceptable criteria for goodness-of-fit indices exist although there are no well-established guidelines for adequate fit (Schermelleh-Engel, Moosbrugger et al., 2003). For the ML method, the cut-off values CFI $> .95$, TLI $> .95$, RMSEA $< .06$, and SRMR $< .08$ are suggested to assess whether the hypothesized model and the observed data fit sufficiently/significantly (Hu and Bentler, 1999). Moreover, SRMR $< .10$ and RMSEA $\leq .08$ are suggested as acceptable fit (Schermelleh-Engel, Moosbrugger et al., 2003; Vandenberg and Lance, 2000).

A fitting model represents a tool that explains causal assumptions among variables and such results should support conclusions about matters to which the theory applies (Markus, 2010). Thus, we interpreted the parameter estimates in connection with the concept of pastoral spatiality. Moreover, we interpreted the results following the Schreiber, Nora et al. (2006) guidelines and recommendations for reporting results of SEM.

5.4 Results

5.4.1 Exploratory factors

The results of the EFA show that the grazing orbit and the total length of daily herding movement load on the first factor (grazing land) ranged from 0.82 to 0.98 and this factor represents what we have called grazing land in our conceptual model (Table 5.2). The number of herder households on campsites also loads on the first factor with a value of 0.20 which is relatively significant compared to other variables.

Table 5.2. Exploratory factor analysis of the observed variables of data used in the model testing and the factor loadings
(Factor 1—Grazing land; Factor 2—Pastoral mobility; Factor 3—Herd size strategy; Estimation method—maximum likelihood; Rotation type—oblique).

Observed variables (Indicators)	Factor 1	Factor 2	Factor 3
Total number of animals	0.05	0.01	0.91
Total number of sheep and goats	0.01	0.01	0.99
Total grazing orbit	0.98	0.02	0.03
Total length of daily herding movements of sheep, goats, cattle (and yaks)	0.82	0.05	0.03
Total number of herder households on campsites	0.20	0.36	0.05
Total distance between campsites	0.01	1.00	0.03
Total distance between campsites including *otor* campsite	0.12	0.82	0.07

Distance related two variables (the total distance between campsites and the total distance between campsites including *otor* campsite) as well as the number of households on campsites load on the second factor (pastoral mobility). The factor loadings ranged from 0.36 to 1.00. The total number of animals and the total number of sheep and goats load on the third factor (herd size strategy), which had factor loadings of 0.91 and 0.99 respectively. Our results of EFA validates the structure of the three factors we applied in our model considering the conceptual framework on pastoral spatiality. Following this analysis, the fit of the model was tested, and its parameters were estimated.

5.4.2 Estimation of the model

The estimation of the hypothesized structural equation model was carried out using the Rosseel (2012) R package lavaan for SEM. We quantified the standardized factor loadings and parameter estimates of this model which we specified with R code[10] using lavaan (Figure 5.3). As presented in Table 5.3, the data we collected fitted with the model and resulted in reasonable fit indices. The relationships between the indicators of the model are shown in Table 5.4 and the correlation/covariance among the measurements are all positive in our model. Furthermore, Table 5.5 and Figure 5.3 illustrate the standardized factor loadings and parameter estimates for the structural model. Parameter estimates explain the effects of the factors and indicators on each other (Pearl, 2010).

Table 5.3. Model fitting test and fit statistics assessed with cut-off-values.

Estimator	ML
Optimization method	NLMINB
Number of free parameters	18
Number of observations	200
Model Test User Model:	
Test statistic	19.264
Degrees of freedom	10
p-value (Chi-square)	0.037
Model Test Baseline Model:	
Test statistic	1044.957
Degrees of freedom	21
p-value	0.000
User Model versus Baseline Model:	
Comparative Fit Index (CFI)	0.991 (cut-off value: CFI > .95)
Tucker–Lewis Index (TLI)	0.981 (cut-off value: TLI > .95)
Root Mean Square Error of Approximation:	
RMSEA	0.068 (cut-off value: RMSEA < .06; RMSEA ≤ .08 also acceptable)
Standardized Root Mean Square Residual:	
SRMR	0.027 (cut-off value: SRMR < .08; SRMR < .10 also acceptable)

[10] R code is included in Bayarmaa Byambaa. (2020). Pastoral space and mobility datasets [Data set]. Zenodo. http://doi.org/10.5281/zenodo.4379679

Table 5.4. Correlation between the indicators of the structural equation model of spatial occupation of grazing land.

	Indicators	1	2	3	4	5	6	7
1	Total number of animals	1.0						
2	Total number of sheep and goats	.93	1.0					
3	Total grazing orbit	.36	.36	1.0				
4	Total length of daily herding movement	.33	.31	.84	1.0			
5	Total number of households on campsites	.13	.15	.35	.29	1.0		
6	Total distance between campsites	.06	.07	.37	.34	.43	1.0	
7	Total distance between campsites inc. *otor*	.18	.20	.46	.40	.41	.86	1.0

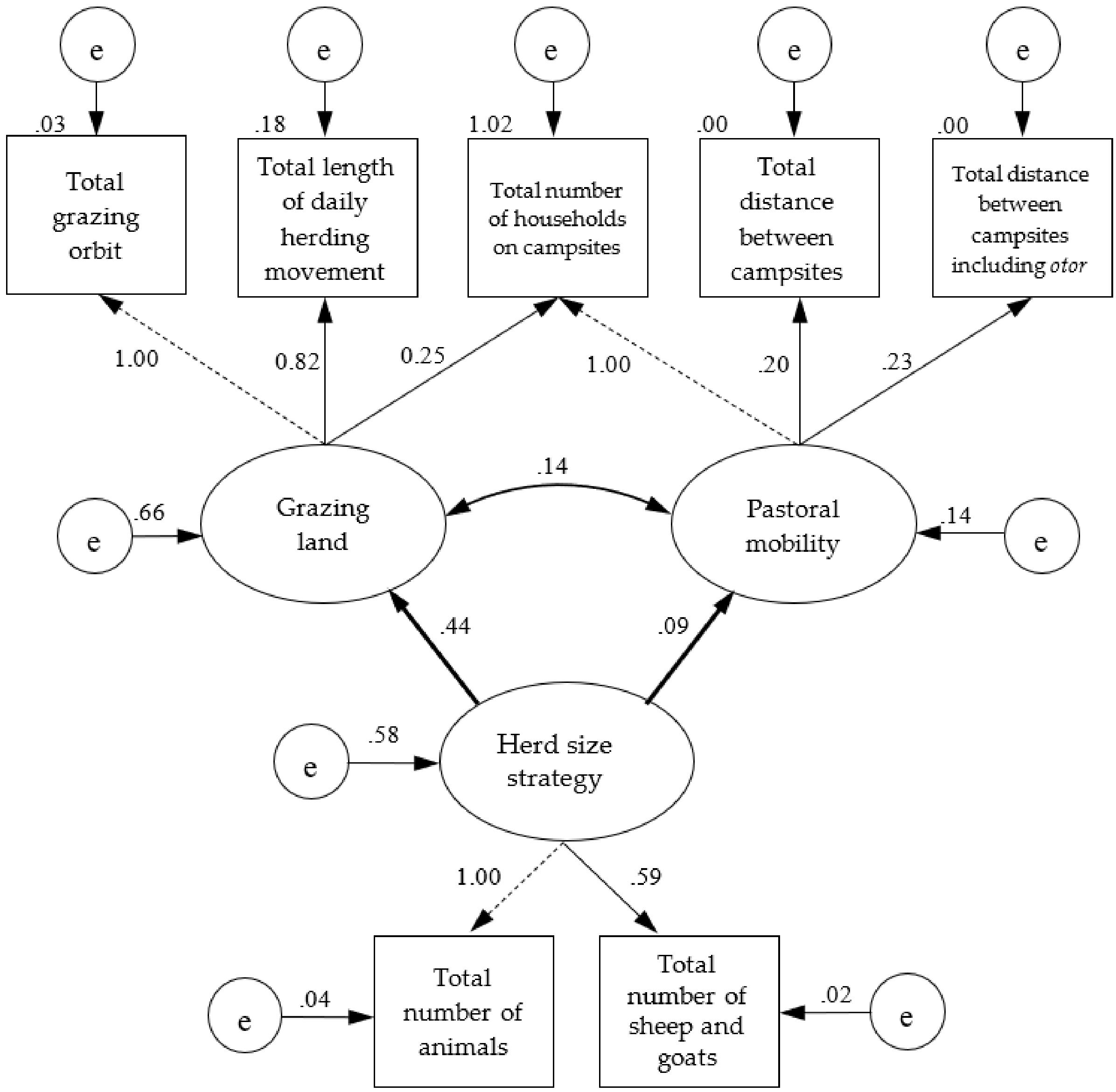

Figure 5.3. Results for the structural equation model.

Comparative Fit Index = .991, Tucker-Lewis Index = .981, Root Mean Square Error of Approximation = .068, Standardized Root Mean Square Residual = .027, e=error.

Table 5.5. Standardized parameter estimates from the hypothesized structural equation model.

lhs	op	rhs	est	se	z	pvalue	ci.lower	ci.upper	std.all
Herd size strategy	=~	Total number of animals	1.000	0.000	NA	NA	1.000	1.000	0.967
Herd size strategy	=~	Total number of sheep and goats	0.589	0.045	13.157	0.000	0.501	0.676	0.957
Grazing land	=~	Total grazing orbit	1.000	0.000	NA	NA	1.000	1.000	0.980
Grazing land	=~	Total length of daily herding movement	0.816	0.063	12.908	0.000	0.692	0.940	0.860
Grazing land	=~	Total number of households on campsites	0.255	0.098	2.611	0.009	0.064	0.446	0.197
Pastoral mobility	=~	Total number of households on campsites	1.000	0.000	NA	NA	1.000	1.000	0.338
Pastoral mobility	=~	Total distance between campsites	0.204	0.046	4.489	0.000	0.115	0.294	0.886
Pastoral mobility	=~	Total distance between campsites inc. *otor*	0.234	0.054	4.364	0.000	0.129	0.340	0.970
Grazing land	~	Herd size strategy	0.439	0.081	5.405	0.000	0.280	0.598	0.380
Pastoral mobility	~	Herd size strategy	0.089	0.042	2.110	0.035	0.006	0.171	0.176
Grazing land	~~	Pastoral mobility	0.137	0.040	3.451	0.001	0.059	0.214	0.444
Total number of animals	~~	Total number of animals	0.040	0.041	0.970	0.332	-0.041	0.120	0.064
Total number of sheep and goats	~~	Total number of sheep and goats	0.018	0.014	1.286	0.198	-0.010	0.046	0.084
Total grazing orbit	~~	Total grazing orbit	0.032	0.050	0.640	0.522	-0.065	0.129	0.039
Total length of daily herding movement	~~	Total length of daily herding movement	0.181	0.038	4.809	0.000	0.107	0.254	0.260
Total number of households on campsites	~~	Total number of households on campsites	1.016	0.103	9.889	0.000	0.815	1.218	0.785
Total distance between campsites	~~	Total distance between campsites	0.002	0.000	3.945	0.000	0.001	0.003	0.216
Total distance between campsites inc. *otor*	~~	Total distance between campsites inc. *otor*	0.001	0.001	0.979	0.327	-0.001	0.002	0.059
Herd size strategy	~~	Herd size strategy	0.577	0.074	7.813	0.000	0.433	0.772	1.000
Grazing land	~~	Grazing land	0.661	0.085	7.817	0.000	0.495	0.826	0.856
Pastoral mobility	~~	Pastoral mobility	0.143	0.065	2.201	0.028	0.016	0.270	0.969

=~—directional effects; ~~—(co)variances/correlations; ~—regression; lhs—left-hand side variable; op—the lavaan syntax operator; rhs—right-hand side variable; est—parameter values; se—standard error for the standardized parameters; ci.lower—lower end of the confidence interval; ci.upper—upper end of the confidence interval; std.all—standardized estimates on the variances of observed and latent variables.

As presented in Figure 5.3, our structural equation model consists of measurement and structural components. The measurement component is shown using thin lines and the structural component is presented using bolded lines (Schreiber, Nora et al., 2006). The latent variables are illustrated with ellipses, whereas rectangles represent our observed variables. The model shows the association between three latent and seven observed variables and predicts the changes in our measured variables with change in the latent variables. A minimum number of indicators per factor is two, and one indicator may measure more than one domain (Kline, 2011). Thus, in our model, two indicators related to the number of livestock measured the factor of herd size strategy. The number of households on campsites also loads on two factors. One loading for each factor is fixed to one to assign a metric to each factor (Kline, 2011).

According to the model, both the total number of animals and the number of sheep and goats grew, with the increase of the herd size strategy factor. Herd size strategy increased by 0.59 of the standard deviation when the total number of sheep and goats increased by one standard deviation. An increase in the herd size strategy also led to an increase in the grazing land and a slight increase in the broad-scale pastoral movements. Moreover, 58% of the changes occurring in the herd size strategy influenced the grazing land and pastoral mobility. When the grazing land increased by one standard deviation, the herd size strategy increased by 0.44 of the standard deviation. Although, there is a positive association between the herd size strategy and pastoral mobility, the effect of the herd size strategy on pastoral mobility is small compared to its effect on the grazing land.

The indicators of grazing orbit, daily herding movement, and the number of households on campsites measure the grazing land. The number of households on campsites along with the distance-related indicators measure pastoral mobility. The grazing land and pastoral mobility co-vary positively. However, their effects on each other were found to be insignificant.

5.5 Discussion

Compared to other statistical methods, complex relationships including latent construct level hypotheses can be examined using SEM (Ullman and Bentler, 2012). We modeled the spatial occupation of grazing land and analyzed the relationships between the grazing land, pastoral mobility, and the herd size strategy as unobserved latent constructs and we examined their associations with different measured variables. Structural parameters of SEM such as parameter estimates are interpreted as effects of one variable on the other (Pearl, 2010). In the following sections, we discuss the causal assumptions of our structural equation model.

5.5.1 Grazing land

The grazing land is a latent variable, which represents the lived space in the concept we used in this study. This variable characterizes fine-scale movements and home range herding patterns in our model. According to the model specification, the number of households on campsites also quantifies the grazing land together with the grazing orbit and the daily herding movement. Households on campsites are the pastoral land users who define the land cover through how they decide to exploit the land area.

In our model, the grazing orbit represents the interconnected total home range grazing areas at herders' winter, summer, spring, autumn, and *otor* campsites. However, the current methods used in EIA do not consider their connections as a series of land-use occupations. It is important that our model explains this link for EIA. Moreover, it is noteworthy that the model significantly links the pastoral land users with the pastoral areas and mobility and recognizes them as participants in the production of the pastoral space. As the scale of the grazing land and pastoral mobility is measured by how many pastoral land users share grassland resources on specific campsites, the land-use agreements and rights established between herders regulate the pastoral space in terms of how it is occupied. In fact, land users indicate their land tenure right boundaries based on their personal views on local dependency relations and social advocacy networks (de Vries, Bennett et al., 2015). Thus, considering our conceptual underpinning (Karplus and Meir (2013)) which gives precedence to ideologies of social and spatial connection, we can presume that our assumption about pastoral lived space is credible. In other words, the grazing land measured by the herding patterns and pastoral users is one of the key factors in the production of pastoral space.

Our model indicates that the grazing land has a strong positive effect on daily herding movements, this can be interpreted spatially. When the grazing orbit is larger, pastoral users practice long-distance herding, or reversely, the length of daily herding movement tends to be shorter when the grazing land is smaller. In contrast to the relationship between the grazing land and the daily herding movements, the grazing land has less effect on the number of households in the campsites. Over the last eight years, the number of herder households has increased by 17% in Mongolia (NSO, 2020). With an increase in the number of households, there is no significant increase in the grazing land while the size of rangeland has stayed the same. This implies that the number of households on a specific campsite is not influenced by the size of the grazing land.

The effects of the latent variables of grazing land and pastoral mobility on each other were found to be positive, yet not significant. Herding on a smaller grazing area did not increase broad-scale pastoral mobility. Previous studies have reported that social, economic, and institutional factors limit the pastoral management decisions including choices between broad or fine-scale pastoral mobilities [72–74]. In our study areas, herders move a minimum of four times in different seasons between three to four distinct areas each year and they kept such a customary pattern of pastoral land use in post-socialist Mongolia (Fernández-Giménez, 2001). In addition, seasonal movements are also related to climatic conditions. Thus, it is also possible that such norms of pasture use make broad-scale pastoral mobility more constant and independent of the fine-scale movements and size of grazing areas. On the other hand, it is alarming that herders are not practicing broad-scale movements even though when the number of animals increases in their grazing orbits as this might lead to overgrazing. If we turn now to the relationship between the grazing land and the herd size strategy, the effect was found to be significant. The herd size strategy has a direct positive effect on the grazing land and indirect effects on the daily herding movements of animals and the number of households on seasonal campsites. The model suggests that with the increase in the number of animals, the size of the grazing land will increase too. Moreover, the changes in the number of animals on campsites would possibly affect the number of households and the length of daily herding movements of animals.

5.5.2 Herd size dynamics

The herd size strategy in our model is a latent variable measured by the total number of animals and the total number of sheep and goats each herder household has at their campsites. This factor represents the conceived space in our model and the herd size and composition are influenced by this factor. In our study areas, pastoral land users herd five types of livestock: sheep, goats, cattle/yaks, horses, and camels. The EFA revealed that the grazing patterns of horses and camels are not correlated significantly with the factors of the model. The results suggest that particularly, the population of sheep and goats in the herd composition plays a considerable role in how the pastoral space is used by herders compared to other species. Sheep and goats have the ability to utilize a wide range of food sources as well as to cope with harsh climatic conditions (Dwyer, 2009). Thus, it is likely that herding sheep and goats in home-range grazing areas is easier for herders due to their diet behavior. Moreover, these factors further indicate that the movement of sheep and goats better characterizes the spatial pattern of customary pastoral land use compared to the movement of cattle/yaks, horses, and camels. Saizen, Maekawa et al. (2010) also noted that in contrast to other types of animals, goats have the greatest impact on grasslands in Mongolia where the data for this study have been collected.

Furthermore, the model suggests that the herd size strategy was found to have a direct effect on grazing land and pastoral mobility. In particular, the relationship between the herd size strategy and the grazing land increased while the herd size strategy was estimated to explain 44% of the variance that occurred in the grazing land. By contrast, only 9% of the changes occurring in pastoral mobility are explained by the herd size strategy. The herd size strategy has a direct positive effect on pastoral mobility; however, the effect was found to be minor. We hypothesized that the livestock population is the key indicator in managing the pastoral space and it influences the grazing pattern of animals as well as their movements. These parameter estimates support our hypothesis.

5.5.3 Pastoral mobility

Pastoral mobility represents the perceived space in our model and is measured by the total distance between campsites located in different seasonal grazing areas and used for the purpose of extensive herding including areas for *otor* migration. These indicators consider the number of campsites used by herders for seasonal migration as we observed distances between campsites separately. It is interesting that pastoral mobility is measured with *otor* migration and the number of households as this emphasizes the importance of *otor* and herder households in nomadic pastoralism.

The herd size strategy was found to have a direct positive effect on pastoral mobility; however, the effect is not significant. Mobile pastoralism has many advantages such as resilience to droughts (Freier, Finckh et al., 2014). However, research by Kerven, Robinson et al. (2016) in Kazakhstan has shown that the pastoralists are subjected to a number of limitations in using biophysical niches such as lack of access to water resources and financial constraints, thus most pastoralists' choices of distributing their livestock are compromised despite the wide availability of pasture areas. Moreover, in their study conducted in the Mongolian Altai, Lkhagvadorj, Hauck et al. (2013) revealed that herder families have reduced their seasonal migration due to high transportation costs and climate change resulted in a shortage of fodder. In the meantime, in this area, over the last 20 years, the livestock population has been increasing in response to market demand for products such as cashmere (Saizen, Maekawa et al., 2010) and decreasing due to climatic factors such as *dzud* (severe winter) which killed millions of animals (NSO, 2020). This tendency supports the weak relation between the herd size strategy and pastoral mobility. In other words, even though herders do not use all their seasonal migration campsites, the livestock number may still increase. Liao (2018a) model on herding decision making in southern Ethiopia also suggests that compared to community-level factors, households' herd size plays a lesser role in the practice of extensive herding. Moreover, Karplus and Meir (2013) noted spatial mobility as a central characteristic that distinguishes nomadic from sedentary societies and emphasized Lefebvre (1974/1991) view about social existence where he argued that every society produces its own space and those societies failing to produce their own space would disappear sooner or later. Thus, the nomadic pastoralists' society should maintain both fine and broad-scale herding mobility to sustain its social existence and nomadic identity.

Lastly, the grazing land and pastoral mobility were shown to be dependent on each other, however, the magnitude of their relationship is not significant. A study carried out by Adriansen (2008) in northern Senegal noted pastoralists' preference for moving around within a small territory and their unwillingness to employ broad-scale movements themselves whilst their herds still being quite mobile. The model indicates that broad-scale movements between seasonal migration campsites do not decrease or substantially increase when the size of grazing orbit is large, or the degree of fine-scale movements is extensive. Thus, according to our hypothesized assumptions, the broad-scale movements are relatively independent of the fine-scale movements, but still associated with each other.

5.6 Conclusions

The dynamic pastoral space occupied by herders is one of the most important parameters which needs to be understood and predicted in any impact prediction in EIA in order to identify negative impacts associated with nomadic-pastoral land use. We used the SEM technique, which combines factor and multiple regression analyses, for explaining spatial occupation of grazing land for EIA. We specified a hypothesized structural equation model of dynamic pastoral space based on Karplus and Meir (2013) concept of pastoral spatiality. We hypothesized that the grazing land, pastoral mobility, and the herd size strategy are interrelated factors and together they produce the pastoral space. Moreover, we hypothesized that these three factors are measured by grazing areas, both fine and broad scale herding mobilities, the number of households on campsites, and the number of animals. We estimated the structural relationships between land, mobility, and herd in the case of Mongolian pastoralism and quantified the direct effects of these factors on each other.

The assumptions tested in this study suggest that the herd size strategy has a direct effect on the pattern of grazing land and pastoral mobility and their effects on each other are all positive. Specifically, the findings indicate that the scale of the grazing land and pastoral mobility depends on the grazing orbit, fine and broad scale movements as well as the number of land users who are herding on particular seasonal campsites. Furthermore, the herd size strategy has a significant positive effect on the grazing land compared to pastoral mobility. This finding was unexpected and suggests that individual herder households' decision-making regarding herd size and composition has more of an effect on fine-scale pastoral movements in their home range grazing areas than broad-scale extensive mobility between their seasonal campsites. The grazing land and pastoral mobility, in turn, covary but not considerably. Nevertheless, this study suggests that pastoral mobility is still one of the fundamental characteristics of the pastoral space associated with pastoral land use and herd size strategy in Mongolia.

We hope these results contribute to broadening the perspective of EIA methods with respect to predicting impacts associated with nomadic-pastoral land use. Particularly, our findings provide evidence with regard to identifying impact zones in EIA that impacts of the project on herd size strategy at a specific campsite significantly affect the size of grazing areas, pastoral mobility, and the number of herder households. Thus, this study extends EIA's knowledge of the impact zones associated with nomadic-pastoral land use. Moreover, EIA impact prediction should consider grazing areas as a dynamic space which are shaped by herd size, composition, and mobility instead of looking at campsites as a static physical space. Therefore, EIA should distinguish impacts on pasture lands paying more attention to the details related to herding, specifically, to grazing orbits, fine and broad-scale herding movements including *otor*, livestock species, the number of animals as well as households at campsites.

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CHAPTER 6. Discussion and conclusions

6.1 EIA theories and dynamic land use

The theory and practice of impact assessment has been the subject of intense debate in academic journals questioning the adequacy of impact assessment theory and practice in addressing the environmental and social issues we face today (Banhalmi-Zakar, Gronow et al., 2018; Lawrence, 1997). Thus, there continues to be a need for the development of theory surrounding impact assessment and specifically, the need for theory associated with the effectiveness of impact assessment in different decision contexts is as strong now as it has ever been (Pope, Bond et al., 2013). More reflective practice and more coherent theory-building are required (Lawrence, 1997). Researchers are looking for evidence, analysis and insights linked to analysis on impact assessment theory and practice (Banhalmi-Zakar, Gronow et al., 2018). This study (Chapter 2) aimed at contributing to this discussion of EIA theory-building examining the needs associated with dynamic land use with respect to EIA theory in the context of nomadic pastoralism. Particularly, part of the aim of this dissertation was to understand the needs of nomadic-pastoral land users with respect to EIA theory and to investigate whether EIA addresses these needs sufficiently or appropriately.

This study found that nomadic-pastoral land users need EIA theory to incorporate inherent dynamic and irrational characteristics of nomadic-pastoral land use and to consider complex interconnected and unpredictable socio-ecological features which influence nomadic pastoralism. However, the results of this investigation showed that the theory on which EIA has been grounded insufficiently and inappropriately incorporates a conceptual basis which would be able to characterise the needs of nomadic-pastoral land users.

Various theories and models of planning and decision-making have been the theoretical foundations of EIA (Morgan, 2012; Weston, 2010). A literature review conducted in Chapter 2 of this study confirms the dominance of the rationalist and decision-making theories in EIA where the rational decision-making chooses the best solution from a range of alternatives as the result of EIA. Scholars criticise the application of the rational decision-making model to EIA for its failure at accommodating the values of those potentially affected by the project such as nomadic-pastoral land users. The logic applied in nomadic pastoralism is the opposite to the rational fundament of EIA. The nomadic pastoral systems are flexible, nonlinear and irrational. Therefore, this thesis voiced concerns that conceptually such dynamic needs of nomadic-pastoral land users cannot be appropriately and sufficiently addressed in EIA that is based on rationalist and linear cause-effect epistemologies.

Whilst investigating for the first time how conceptually EIA addresses impacts associated with nomadic-pastoral land use, this study called for more adaptive EIA theories which consider the nature of socio-ecological interactions and the characteristics of dynamic land use in nomadic pastoralism.

6.2 Methodological contributions

This thesis makes two methodological contributions to the impact assessment field. The main methodological contribution of this study (Chapter 4, 5) to EIA is related to impact prediction associated with nomadic-pastoral land use. Predicting and calculating the total impacts associated with a complex series of land occupations such as nomadic-pastoral land use is still an unresolved methodological problem (Dwyer and Istomin, 2008; Koellner and Scholz, 2006). A review conducted in this thesis concludes that the current EIA methods primarily consider static land use and therefore, insufficiently and inappropriately predict impacts related to dynamic land use. This is the first study reporting the methodological shortcoming of EIA in terms of predicting impacts with respect to dynamic land use in nomadic pastoral systems. The findings from this study explain the characteristics of dynamic land use as opposed to static physical space for EIA impact prediction methods. I argue that as the key parameters of dynamic pastoral space, the characteristics, patterns, and spatial occupation of nomadic-pastoral land use need to be understood sufficiently for EIA methods at both community and landscape levels in order to predict potential negative impacts properly.

The evidence from this study suggests that grazing areas, herd mobility, and herd size and composition have direct positive effects on each other. Daily herding movements at campsites increase and occupation of pastoral space expands when the population of livestock increases. The herd size and composition significantly affect grazing areas and the extent of fine-scale herding mobility. However, the herd size and composition have less effect on broad-scale pastoral movements which occur between herders' seasonal campsites. Likewise, the scale of grazing areas and the fine-scale pastoral mobility do not affect significantly the broad-scale extensive herding mobility. Although, the extensive pastoral movements are relatively independent of the fine-scale mobility, this study suggests that the broad and fine-scale movements covary. This finding indicates that the extensive herding movements are still a crucial part of nomadic pastoralism. Moreover, the results of this study suggest that the influence of social and economic factors on livestock distribution and herd composition increased with time in contrast to environmental drivers. Therefore, EIA should pay more attention into considerations of negative effects triggered by social and economic factors when predicting impacts related to pastoral land use.

In this study, the empirical findings from modelling the distribution of livestock species at the landscape level and spatial occupation of grazing land extends EIA's methodological knowledge of identifying impact zones for dynamic land use. Moreover, this thesis advances EIA's knowledge with regard to calculating and quantifying impacts of the project on herd size strategy, grazing areas, and fine and broad-scale pastoral mobilities that need to be analysed in impact prediction associated with dynamic land use.

Secondly, this thesis (Chapter 2) expands Retief (2010)'s broad framework approach to a four-step method for reviewing and examining EIA literature. Retief (2010)'s framework defines theory, methods and effectiveness as three main interrelated themes of environmental assessment. This method narrows down topics that need to be analysed in relation to EIA by guiding the review to these three key EIA themes. This approach is especially useful for interdisciplinary studies as it can be employed to systematically examine and link any research topic with respect to the key areas of EIA. In this study, I applied this method to identify the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness and investigated whether EIA addresses these needs using nomadic pastoralism as a test case.

6.3 Effectiveness of EIA

The concerns about EIA practices whether EIA achieves its desired outcome, the enhancement of environmental protection have resulted in the development of a substantial body of research debating the issue of EIA effectiveness (Banhalmi-Zakar, Gronow et al., 2018; Cashmore, Gwilliam et al., 2004; Loomis and Dziedzic, 2018; Sadler, 1996). The question of whether EIA is effective or not has been a topic of research from the earliest days of impact assessment (Pope, Bond et al., 2018). This thesis (Chapter 3) contributes to this growing area of the EIA field by evaluating the effectiveness of the EIA process with respect to addressing the needs of nomadic-pastoral land users in the case of Mongolia's pastoral land use.

Most studies conducted in the past focused on effectiveness of EIA in terms of its legal provisions and processes. Sadler (1996) noted that assessing the effectiveness of EIA in delivering its desired outcome, the enhancement of environmental protection, is a different, and ultimately more difficult, task. Hence, this study examined effectiveness of EIA not only in terms of its legal processes, but it also attempted to contribute to development of EIA theories and impact prediction methods that affect output of environmental protection. This is the first study which examined EIA effectiveness for nomadic-pastoral land users specifically. My findings are consistent with those of Banhalmi-Zakar, Gronow et al. (2018) and Pope, Bond et al. (2013) that reported the shortcomings of impact assessment. Limited implementation of mitigation measures directed to improve pasture land quality, lack of accurate impact prediction and poor handling of uncertainties related to dynamic land use, poor quality of EIA reports, lack of public participation, lack of consideration of social impacts as well as alternatives and cumulative effects in EIA, lack of EIA integration into territorial planning system, and poor enforcement of laws and accountability in practice are the key issues affecting EIA effectiveness. These limitations and weaknesses need to be addressed to improve EIA effectiveness for pastoralists. Moreover, this research highlights the importance of interdisciplinary studies by exploring the shortcomings of EIA with respect to understanding all types of land use, in particular dynamic land use. Development of models which explain pastoral land use, especially, spatial occupation of grazing areas, livestock distribution and herd composition for EIA in this study contributes to effort to improve effectiveness of EIA for all environmental aspects including land use.

CHAPTER 7. Opportunities for future research

7.1 Future research on modelling patterns of dynamic land use

The findings of this research concluded that the concept and patterns of dynamic land use is not fully described for other disciplines. This research examined and explained the patterns of land use in nomadic pastoralism for EIA as understanding the irrational and dynamic characteristics of nomadic-pastoral land use is a methodological issue for the field of EIA. These findings enhance not only EIA's knowledge of land use patterns and impact zones, but also improves the link between the EIA field and the domain of land use planning and management. Land management benefits from proper mitigation measures for land use defined by EIA in both urban and rural areas. The findings from this study also expand knowledge related to customary land tenure and land use patterns for land management including land use planning. The results of this study describe the complexity of nomadic-pastoral (customary and dynamic) land use by quantifying the relationships between its features such as grazing areas and herding mobility. This study also calls land use planning to address complexity of nomadic-pastoral land use sufficiently and appropriately in spatial planning in the context of customary land tenure systems.

Nomadic-pastoral land use is only one of many types of land use in pastoral systems. I believe the problem of EIA's impact prediction goes much wider than issues related to nomadic-pastoral land use. Land use characteristics in sedentary to semi-sedentary as well as in transhumance grazing systems need to be fully defined and modelled as the goals are widely different in these systems due to various soil, plant, herding strategy, and socio-economic features that shape them. More research to better understand different forms of dynamic land use will improve effectiveness of EIA in predicting impacts on the environment and herders' livelihoods in all cases of grazing systems.

Furthermore, considerations of more social and economic indicators in modelling pastoral space and herding mobility are needed. Chapter 4 emphasised the importance of comprehensive data in modelling of livestock distribution and herd composition at landscape level. However, social and economic data such as income, poverty, gender, land tenure, and access to livestock markets are not easy to collect and time series datasets are often not available. Moreover, high resolution environmental data on desertification or vegetation cover have been lacking as well for different periods of time which could be used in similar analysis of livestock distribution and herd composition conducted in this study. Therefore, spatial and temporal dynamics of land use modelled in this study should be replicated adding more social as well as high quality environmental data.

7.2 Future research on effectiveness of EIA with respect to pastoral systems

The shortcomings of EIA in addressing impacts associated with nomadic-pastoral land use explored in the case of the EIA process in Mongolia indicate that further empirical research is needed to establish a broader context for the topic of effectiveness of EIA with respect to the needs of various pastoral systems which exist in other countries. Thus, it is recommended to replicate this study in countries which practice similar pastoral activities in the similar ecological environments. Such studies could contribute to the discussion of EIA theory-building by offering evidence and insights into the effectiveness of the different EIA processes related to pastoral systems. Moreover, such studies should investigate to what extent the theories used in EIA incorporate the needs of dynamic land use and issues which should be considered in the EIA theory-building. Examining the effectiveness of the EIA processes in other countries as it relates to dynamic land use could have policy implications as well since many shortcomings of EIA are caused by poor EIA practices. For instance, insights from different countries could improve herders' participation in EIA which lack often due to gaps in legislation.

It is recommended that further research would be undertaken how other widely practised assessment tools such as strategic environmental assessment, social impact assessment, climate change vulnerability assessment, and health impact assessment address effects associated with nomadic-pastoral land use using the same set up applied in this study. More information on how different types of impact assessment incorporate dynamic land use issues would help to mitigate adverse effects of future projects on nomadic-pastoral land use to a greater degree. The structure and methods applied in this study can serve as a base for such research. Moreover, another possible area of future research would be to examine the links between spatial planning and dynamic land use. It would be interesting to assess whether local or regional level land use planning incorporate the needs of nomadic-pastoral land users sufficiently and appropriately.

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Glossary

ci.lower	Lower end of the confidence interval
ci.upper	Upper end of the confidence interval
est	Parameter values
lhs	The left-hand side variable
op	The lavaan syntax operator: "~~" represents covariance, "=~" represents factor loading, "~" represents regression, and "~1" represents intercept.
rhs	The right-hand side variable
se	The standard error for the standardized parameters
std.all	Standardised estimates on the variances of observed and latent variables.

Appendix I. Concept matrix and datasets used in Chapter 2: Literature review

Concept matrix for evaluating the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness

The key questions investigated

- Does theory on which EIA has been grounded sufficiently or appropriately incorporate the needs of pastoral-nomadic land use(rs)?
- Do the methods of EIA sufficiently or appropriately incorporate the needs of pastoral-nomadic land use(rs)?
- Does the way in which effectiveness of EIAs is determined sufficiently or appropriately incorporate the needs of pastoral-nomadic land use(rs)?

Questions and criteria included in the concept matrix		
Theories	Does the article discuss about theories? Yes (1); No (0)	
Methods	Does the article discuss about methods? Yes (1); No (0)	
Effectiveness	Does the article discuss about effectiveness? Yes (1); No (0)	
Theories applied in EIA	Decision-making theory	
	Rationalist theory	
Purpose of use of theory	To conceptualise EIA related concepts/methods	
Does the articles discuss about the following methods? Yes (1); No (0)	Methods for EIA	Matrices, weights, check lists
		Networks, impact pathways
		EIA pre-decision analysis
		EIA follow-up
		GIS/Remote sensing
		Mathematical models
		Simulation models
	Land use impact assessment (LUIA) methods	Predictive land-change models
		LCA/LUIA within life-cycle assessment
		If the method consider impact pathways?
		If the method consider dynamic land use?
Does the articles discuss about the following dimensions of effectiveness? Yes (1); No (0)	Procedural	
	Substantive/Sustainability	
	Transactive	
	Normative	
	Pluralism	
	Knowledge and learning	
	Rational	

Questions and criteria included in the concept matrix		
	Cultural (If EIA considers cultural characteristics of pastoral- nomadic land users)	
	Effectiveness criteria	
	Type of criteria	
Qualitative analysis	Do the theories mentioned in this article sufficiently or partly incorporate the needs of pastoral-nomadic land use(rs)? If yes, how?	
	Do the methods mentioned in this article sufficiently or partly incorporate the needs of pastoral-nomadic land use(rs)? If yes, how?	
	Does the way in which effectiveness of EIAs is determined in this article sufficiently or partly incorporate the needs of pastoral-nomadic land use(rs)? If yes, how?	

List of articles reviewed for evaluation of the needs of nomadic-pastoral land users with respect to EIA theory, methods and effectiveness

#	Name of journal	Name of article
1	Current Opinion in Environmental Sustainability	Opportunities to improve impact, integration, and evaluation of land change models
2	Current Opinion in Environmental Sustainability	A conceptual framework for analysing and measuring land-use intensity
3	Environment and Planning B-Planning and Design	Incorporating Spatial Autocorrelation with Neural Networks in Empirical Land-Use Change Models
4	Environment and Planning B-Planning and Design	Uncertainty in Extrapolations of Predictive Land-Change Models
5	Environmental and Ecological Statistics	Inference for finite-sample trajectories in dynamic multi-state site-occupancy models using hidden Markov model smoothing
6	Environmental Conservation	The classification of the sciences and the quest for interdisciplinarity: a brief history of ideas from ancient philosophy to contemporary environmental science
7	Environmental Conservation	Chance and randomness in design versus model-based approaches to impact assessment: comments on Bulleri et al. (2007)
8	Environmental Conservation	The analysis of ecological impacts in human-dominated environments: reply to Stewart-Oaten (2008)
9	Environmental Conservation	The assessment and interpretation of ecological impacts in human-dominated environments
10	Environmental Conservation	Land-use/land-cover change: a key to understanding land degradation and relating environmental impacts in Northwestern Sinai, Egypt
11	Environmental Conservation	A new model of geo-environmental impact assessment of mining: a multiple-criteria assessment method integrating Fuzzy-AHP with fuzzy synthetic ranking
12	Environmental Conservation	Geo-environmental impact assessment and management information system for the mining area, Northeast China
13	Environmental Conservation	Using a mathematical model to assess the sustainability of proposed bauxite mining in Andhra Pradesh, India from a quantitative-based environmental impact assessment
14	Environmental Conservation	GIS-based impact assessment of land-use changes on groundwater quality_study from a rapidly urbanizing region of South India
15	Environmental Conservation	Effectiveness of Environmental Impact Assessment follow-up as a tool for environmental management: lessons and insights from platinum mines along the Great Dyke of Zimbabwe
16	Environmental Conservation	Monitoring and predicting land use changes in the Huai Thap Salao Watershed area, Uthaithani Province, Thailand, using the CLUE-s model
17	Environmental Conservation	Ecological effects analysis of land use change in coal mining area based on ecosystem service valuing_a case study in Jiawang
18	Environmental Conservation	A review of assessment methods for river hydromorphology
19	Environmental Impact Assessment Review	he roles of EIA in the decision-making process
20	Environmental Impact Assessment Review	The application of Geographical Information Systems to determine environmental impact significance
21	Environmental Impact Assessment Review	Comparison of weight assignment procedures in evaluation of environmental impacts
22	Environmental Impact Assessment Review	Comparison of conventional and geo-spatial EIA_A shrimp farming case study
23	Environmental Impact Assessment Review	Assessing health consequences in an environmental impact assessment The case of Amsterdam Airport Schiphol
24	Environmental Impact Assessment Review	An integrated assessment model for cross-country pipelines
25	Environmental Impact Assessment Review	A proposed tool to integrate environmental and economical assessments of products
26	Environmental Impact Assessment Review	An environmental impact assessment system for agricultural R&D
27	Environmental Impact Assessment Review	Environmental impact assessment including indirect effects—a case study using input–output analysis

#	Name of journal	Name of article
28	Environmental Impact Assessment Review	Exploring the relation between evidence and decision-making A political-administrative approach to health impact assessment
29	Environmental Impact Assessment Review	The role of science in environmental impact assessment: process and procedure versus purpose in the development of theory
30	Environmental Impact Assessment Review	The precautionary principle stimulus for solutions- and alternatives-based environmental policy
31	Environmental Impact Assessment Review	Environmental assessment and planning theory: four short stories about power, multiple rationality, and ethics
32	Environmental Impact Assessment Review	Bridging the gap between theory and practice in integrated assessment
33	Environmental Impact Assessment Review	EIA scoping in England and Wales: Practitioner approaches, perspectives and constraints
34	Environmental Impact Assessment Review	Some common shortcomings in the treatment of impacts of linear infrastructures on natural habitat
35	Environmental Impact Assessment Review	Biodiversity in environmental assessment—current practice and tools for prediction
36	Environmental Impact Assessment Review	Treatment of biodiversity issues in impact assessment of electricity power transmission lines: A Finnish case review
37	Environmental Impact Assessment Review	Scoping in environmental impact assessment: Balancing precaution and efficiency?
38	Environmental Impact Assessment Review	Environmental impact monitoring in the EIA process of South Australia
39	Environmental Impact Assessment Review	The influence of incomplete or unavailable information on environmental impact assessment in the USA
40	Environmental Impact Assessment Review	Quality control and the substantive influence of environmental impact assessment in Finland
41	Environmental Impact Assessment Review	Assessing environmental vulnerability in EIA—The content and context of the vulnerability concept in an alternative approach to standard EIA procedure
42	Environmental Impact Assessment Review	Causal networks in EIA
43	Environmental Impact Assessment Review	Theoretical reflections on the connection between environmental assessment methods and conflict
44	Environmental Impact Assessment Review	Decision-oriented environmental assessment: An empirical study of its theory and methods
45	Environmental Impact Assessment Review	Terrestrial vertebrate fauna surveys for the preparation of environmental impact assessments; how can we do it better? A Western Australian example
46	Environmental Impact Assessment Review	Systematic comparative and sensitivity analyses of additive and outranking techniques for supporting impact significance assessments
47	Environmental Impact Assessment Review	Environmental impact assessment: Retrospect and prospect
48	Environmental Impact Assessment Review	Scale issues in the assessment of ecological impacts using a GIS-based habitat model — A case study for the Stockholm region
49	Environmental Impact Assessment Review	Impact assessment procedures for sustainable development: A complexity theory perspective
50	Environmental Impact Assessment Review	Impact significance determination—Designing an approach
51	Environmental Impact Assessment Review	Impact significance determination—Back to basics
52	Environmental Impact Assessment Review	Impact significance determination—Pushing the boundaries
53	Environmental Impact Assessment Review	Thresholds and criteria for evaluating and communicating impact significance in environmental statements: 'See no evil, hear no evil, speak no evil'?
54	Environmental Impact Assessment Review	Network and system diagrams revisited: Satisfying CEA requirements for causality analysis
55	Environmental Impact Assessment Review	A critical review of building environmental assessment tools
56	Environmental Impact Assessment Review	Cumulative effects in Swedish EIA practice — difficulties and obstacles

#	Name of journal	Name of article
57	Environmental Impact Assessment Review	Multi-jurisdictional environmental impact assessment: Canadian experiences
58	Environmental Impact Assessment Review	Environmental impact assessment procedure: A new approach based on fuzzy logic
59	Environmental Impact Assessment Review	Comparing GIS-based habitat models for applications in EIA and SEA
60	Environmental Impact Assessment Review	Application of the SEA Directive to EU structural funds: Perspectives on effectiveness
61	Environmental Impact Assessment Review	Strategic approaches and assessment techniques—Potential for knowledge brokerage towards sustainability
62	Environmental Impact Assessment Review	Environmental impact assessment by means of a procedure based on fuzzy logic: A practical application
63	Environmental Impact Assessment Review	Canadian and international EIA frameworks as they apply to cumulative effects
64	Environmental Impact Assessment Review	Assessing the cumulative effects of projects using geographic information systems
65	Environmental Impact Assessment Review	Environmental assessment of spatial plan policies through land use scenarios: A study in a fast-developing town in rural Mozambique
66	Environmental Impact Assessment Review	Purposes, paradigms and pressure groups: Accountability and sustainability in EU environmental assessment, 1985–2010
67	Environmental Impact Assessment Review	Ethical implications of democratic theory for U.S. public participation in environmental impact assessment
68	Environmental Impact Assessment Review	An analysis framework for characterizing and explaining development of EIA legislation in developing countries—Illustrated for Georgia, Ghana and Yemen
69	Environmental Impact Assessment Review	Opening new institutional spaces for grappling with uncertainty: A constructivist perspective
70	Environmental Impact Assessment Review	Integrating ecosystem services into environmental impact assessment: An analytic–deliberative approach
71	Environmental Impact Assessment Review	Advancing the theory and practice of impact assessment: Setting the research agenda
72	Environmental Impact Assessment Review	Using Compliance Analysis for PPP to bridge the gap between SEA and EIA: Lessons from the Turcot Interchange reconstruction in Montréal, Québec
73	Environmental Impact Assessment Review	Compensatory mitigation and screening rules in environmental impact assessment
74	Environmental Impact Assessment Review	A review of uncertainty research in impact assessment
75	Environmental Impact Assessment Review	Is the ecosystem service concept improving impact assessment? Evidence from recent international practice
76	Environmental Impact Assessment Review	Bibliometric analysis of global environmental assessment research in a 20-year period
77	Environmental Impact Assessment Review	Mitigation for one & all: An integrated framework for mitigation of development impacts on biodiversity and ecosystem services
78	Environmental Impact Assessment Review	Four conceptual issues to consider in integrating social and environmental factors in risk and impact assessments
79	Environmental Impact Assessment Review	Disparate perceptions about uncertainty consideration and disclosure practices in environmental assessment and opportunities for improvement
80	Environmental Impact Assessment Review	Coping with uncertainty in environmental impact assessments: Open techniques
81	Environmental Impact Assessment Review	Methods for land use impact assessment: A review
82	Environmental Impact Assessment Review	Subsurface activities and decision support systems: An analysis of the requirements for a social acceptance-motivated decision support system
83	Environmental Impact Assessment Review	Global megatrends and their implications for environmental assessment practice
84	Environmental Impact Assessment Review	Reforming EIA systems: A critical review of proposals in Brazil
85	Environmental Impact Assessment Review	Conceptualizing impact assessment as a learning process

#	Name of journal	Name of article
86	Environmental Impact Assessment Review	The ‘grey’ assessment practice of IA screening: Prevalence, influence and applied rationale
87	Environmental Impact Assessment Review	Theorising EIA effectiveness: A contribution based on the Danish system
88	Environmental Impact Assessment Review	Factors leading to an erroneous impact assessment A postproject review of the Calaca power plant, unit two
89	Environmental Impact Assessment Review	Visual programming languages as a tool to identify and communicate the effects of a development project evaluated by means of an environmental impact assessment
90	Environmental Impact Assessment Review	Evaluating the effectiveness of impact assessment instruments: Theorising the nature and implications of their political constitution
91	Environmental Impact Assessment Review	A qualitative method proposal to improve environmental impact assessment
92	Environmental Impact Assessment Review	Conceptualising the effectiveness of impact assessment processes
93	Environmental Impact Assessment Review	Framing effectiveness in impact assessment: Discourse accommodation in controversial infrastructure development
94	Environmental Impact Assessment Review	Understanding EIA scoping in practice: A pragmatist interpretation of effectiveness
95	Environmental Impact Assessment Review	Scenario analysis in environmental impact assessment: Improving explorations of the future
96	Environmental Modelling and Software	OPAL: An open-source software tool for integrating biodiversity and ecosystem services into impact assessment and mitigation decisions
97	Environmental Modelling and Software	Integrating case-based and fuzzy reasoning to qualitatively predict risk in an environmental impact assessment review
98	Environmental Modelling and Software	Assessing spatial predictive models in the environmental sciences: Accuracy measures, data variation and variance explained
99	Environmental Modelling and Software	Theoretical foundations of human decision-making in agent-based land use models – A review
100	Environmental Monitoring and Assessment	Identification and Classification of Key Variables and their Role in Environmental Impact Assessment: Methodology and Software Package Intra
101	Environmental Monitoring and Assessment	Environmental impact assessment: National approaches and international needs
102	Environmental Monitoring and Assessment	Fuzzy clustering analysis in environmental impact assessment — A complement tool to environmental quality index
103	Environmental Monitoring and Assessment	A model of objective weighting for EIA
104	Environmental Science and Technology	Genomics Tools in Environmental Impact Assessment
105	Environmental Science and Technology	High-Resolution Assessment of Land Use Impacts on Biodiversity in Life Cycle Assessment Using Species Habitat Suitability Models
106	Environmental Science and Technology	Quantifying Land Use Impacts on Biodiversity: Combining Species–Area Models and Vulnerability Indicators
107	Environmental Science and Technology	How Well Does LCA Model Land Use Impacts on Biodiversity?—A Comparison with Approaches from Ecology and Conservation
108	Impact Assessment and Project Appraisal	Environmental impact assessment follow-up: good practice and future directions — findings from a workshop at the IAIA 2000 conference
109	Impact Assessment and Project Appraisal	Developing and evaluating environmental impact assessment systems for small developing countries
110	Impact Assessment and Project Appraisal	Application of mitigation and its resolution within environmental impact assessment: an industrial perspective
111	Impact Assessment and Project Appraisal	Multicriteria analysis to compare the impact of alternative road corridors: a case study in northern Italy
112	Impact Assessment and Project Appraisal	International principles for best practice EIA follow-up
113	Impact Assessment and Project Appraisal	On the successful implementation of mitigation measures
114	Impact Assessment and Project Appraisal	Impact mitigation in environmental impact assessment: paper promises or the basis of consent conditions?

#	Name of journal	Name of article
115	Impact Assessment and Project Appraisal	In search of arenas for democratic deliberation: a Habermasian review of environmental assessment
116	Impact Assessment and Project Appraisal	The causality premise of EIA in practice
117	Impact Assessment and Project Appraisal	The art and science of impact assessment: results of a survey of IAIA members
118	Impact Assessment and Project Appraisal	Environmental impact assessment: the state of the art
119	Impact Assessment and Project Appraisal	The interminable issue of effectiveness: substantive purposes, outcomes and research challenges in the advancement of environmental impact assessment theory
120	Impact Assessment and Project Appraisal	Improving quality/ Common sense in environmental impact assessment: it is not as common as it should be
121	Impact Assessment and Project Appraisal	Uncertainty in environmental impact assessment predictions: the need for better communication and more transparency
122	Impact Assessment and Project Appraisal	Rationality and effectiveness: does EIA/SEA treat them as synonyms?
123	Impact Assessment and Project Appraisal	The contribution of capacities and context to EIA system performance and effectiveness in developing countries: towards a better understanding
124	Impact Assessment and Project Appraisal	Using a Delphi study to identify effectiveness criteria for environmental assessment
125	International Journal of Life Cycle Assessment	Attributional life cycle assessment: is a land-use baseline necessary?
126	International Journal of Life Cycle Assessment	Global land use impacts on biomass production—a spatial-differentiated resource-related life cycle impact assessment method
127	International Journal of Life Cycle Assessment	Land use impact assessment in the construction sector: an analysis of LCIA models and case study application
128	International Journal of Life Cycle Assessment	A comparison of three methods to assess land use impacts on biodiversity in a case study of forestry plantations in New Zealand
129	International Journal of Life Cycle Assessment	A spatially explicit data-driven approach to assess the effect of agricultural land occupation on species groups
130	International Journal of Life Cycle Assessment	Is land use impact assessment in LCA applicable for forest biomass value chains? Findings from comparison of use of Scandinavian wood, agro-biomass and peat for energy
131	International Journal of Life Cycle Assessment	The use of temporal dynamics for the automatic calculation of land use impacts in LCA using R programming environment
132	International Journal of Life Cycle Assessment	Land use impacts on biodiversity from kiwifruit production in New Zealand assessed with global and national datasets
133	International Journal of Life Cycle Assessment	Comparing direct land use impacts on biodiversity of conventional and organic milk—based on a Swedish case study
134	International Journal of Life Cycle Assessment	Adapting the LCA framework to environmental assessment in land planning
135	International Journal of Life Cycle Assessment	Baseline time accounting: considering global land use dynamics when estimating the climate impact of indirect land use change caused by biofuels
136	International Journal of Life Cycle Assessment	Global land use impact assessment on biodiversity and ecosystem services in LCA
137	International Journal of Life Cycle Assessment	UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA
138	International Journal of Life Cycle Assessment	Principles for life cycle inventories of land use on a global scale
139	International Journal of Life Cycle Assessment	Land use impacts on biodiversity in LCA: a global approach
140	International Journal of Life Cycle Assessment	Land use impacts on biodiversity in LCA: proposal of characterization factors based on functional diversity
141	International Journal of Life Cycle Assessment	Global characterisation factors to assess land use impacts on biotic production
142	International Journal of Life Cycle Assessment	Land use impacts on freshwater regulation, erosion regulation, and water purification: a spatial approach for a global scale level
143	International Journal of Life Cycle Assessment	Land use impact assessment of margarine

#	Name of journal	Name of article
144	International Journal of Life Cycle Assessment	Baseline time accounting: Considering global land use dynamics when estimating the climate impact of indirect land use change caused by biofuels
145	International Journal of Life Cycle Assessment	Land use indicators in life cycle assessment
146	International Journal of Life Cycle Assessment	Assessment of land use impacts on soil ecological functions: development of spatially differentiated characterization factors within a Canadian context
147	International Journal of Life Cycle Assessment	Key Elements in a Framework for Land Use Impact Assessment in LCA
148	International Journal of Life Cycle Assessment	Assessment of Land Use Impacts on the Natural Environment. Part 1: An Analytical Framework for Pure Land Occupation and Land Use Change (8 pp)
149	Journal of Environmental Management	Modelling spatial association in pattern based land use simulation models
150	Journal of Environmental Planning and Management	Analysis of uncertainty consideration in environmental assessment: an empirical study of Canadian EA practice
151	Journal of Environmental Planning and Management	Understanding farmers' influence on land-use change using a participatory Bayesian network approach in a pre-Alpine region in Switzerland
152	Land Degradation and Development	Knowledge management for land degradation monitoring and assessment: An analysis of contemporary thinking
153	Land Degradation and Development	Monitoring and assessment of land degradation and desertification: Towards new conceptual and integrated approaches
154	Landscape Ecology	Markov models of land cover dynamics in a southern Great Plains grassland region
155	Landscape Ecology	Assessing land-use impacts on biodiversity using an expert systems tool

Appendix II. Survey questionnaire used in Chapter 3: Case study

Evaluating the effectiveness of Mongolia's environmental impact assessment processes for nomadic-pastoral land users

Survey questionnaire

Stakeholder group: Private companies - EIA

Years of experience in EIA: > 10 years

1. When selecting your answer in the column "**By law**", please answer as if you are evaluating how this question is addressed in the existing EIA laws and regulations.
2. When selecting your answer in the column "**In practice**", please answer as if you are dealing with this question in practice.
3. Please write your comments regarding your answers in "Comments" column and answer to the questions highlighted in green.

1-Strongly disagree; 2-Disagree; 3-Somewhat disagree; 4-Neither agree nor disagree; 5-Somewhat agree; 6-Agree; 7-Strongly agree;

EIA-Environmental impact assessment
NLU/NLUs-Nomadic-pastoral land use/users
Thank you so much for completing our survey.

#	Statements	By law	In practice	Comments
1	**Stakeholder confidence**			
1	The EIA process is known by stakeholders to be objective in addressing impacts associated with NLU.			
2	There is confidence that other processes do not predetermine the EIA decision which would affect NLUs.			
3	The EIA process is understood by NLUs.			
4	Information about the EIA process, proceedings and its authority is **accessible** to NLUs.			
5	Information about the EIA process, proceedings and its authority is **clear** to NLUs.			
6	The intent of the EIA process to advise on decision-making which may affect NLUs is **acknowledged.**			
7	The intent of the EIA process is **acknowledged** with regard to **decision-making** which may affect NLUs.			
8	The intent of the EIA process to **identify** baseline conditions and **determine** impacts associated with NLUs is acknowledged.			
9	The intent of the EIA process to **advise** on decision-making which may affect NLUs is clearly **stated.**			
10	The intent of the EIA process is clearly **stated** with regard to **decision-making** which may affect NLUs.			
11	The intent of the EIA process to **identify** baseline conditions and **determine** impacts associated with NLUs is clearly stated.			
12	There is confidence that major projects or powerful proponents cannot circumvent the EIA process.			
2	**Integrative and linked to approval decision-making**			
13	The results of the EIA process are clearly accounted for in the decision (the eventual approval, rejection or approval with conditions) related to NLU.			
14	The EIA process demonstrably **informs** other subsequent or coincident environmental approval and review processes about the results on the initiative which may affect NLUs,			

15	The results of EIA for the initiative which may affect NLUs are **integrated** into other subsequent or coincident environmental approval and review processes.			
16	The EIA process is capable of integrating the knowledge and results of other processes into EIA of the initiative which may affect NLUs without unduly influencing its outcomes.			
17	An initiative which may affect NLUs may not proceed through other approval processes or receive other approvals not waiting the EIA process to complete and the initiative to get approved.			
3	**Promotes betterment and longer-term and substantive gains to environmental management and protection**			
18	The EIA process and its outcomes **minimise** adverse **environmental effects** that may result from the initiative.			
19	The EIA process and its outcomes **minimise** adverse **impacts on NLU** that may result from the initiative.			
20	The EIA process and its outcomes **eliminate** adverse **environmental effects** that may result from the initiative.			
21	The EIA process and its outcomes **eliminate** adverse **impacts on NLU** that may result from the initiative.			
22	The EIA process seeks **betterment of the environment**, when possible, by ensuring net benefits to the environment.			
23	The EIA process seeks **betterment of pasture land**, when possible, by ensuring net benefits to pasture land resources.			
24	The EIA process **seeks to identify** social and biophysical systems that interact and may be affected by assessment-subject activities.			
25	The EIA process **identifies** social and biophysical systems that interact and may be affected by assessment-subject activities.			
26	The EIA process **seeks to sustain** social and biophysical systems that interact and may be affected by assessment-subject activities.			
27	The EIA process **sustains** social and biophysical systems that interact and may be affected by assessment-subject activities.			
28	The EIA process prevents imposition of significant adverse effects onto future generations.			
29	The EIA process prevents imposition of significant adverse effects on NLU onto future generations of herders.			
30	There is **mandatory follow-up and monitoring system** with regard to ensuring compliance with approval conditions.			
31	There is **audit system** with regard to ensuring compliance with approval conditions.			
32	There is **public reporting system** with regard to ensuring compliance with approval conditions.			
33	The EIA process provides follow-up provisions to assess the efficacy of mitigation requirements and reports on environmental benefits (e.g. provision of compliance schedules, mitigation reports and post implementation audits, evaluation of immediate and longer-term gains to environmental management and protection).			
4	**Comprehensiveness**			

34	The definition of 'environment' and 'environmental effects' encompasses social/cultural and ecological/biophysical factors and their interrelationships at multiple scales.			
35	EIA is applied to each initiatives/activities if they significantly affect NLU, whether the proponent is from the public or private sector.			
36	Initiatives may be 'screened out' (exempted from EIA) if there is sufficient information to determine that impacts are insignificant, or otherwise addressed by an alternative process, but listed exemptions are limited to emergency or similar initiatives (e.g. urgent flood control works).			
37	There is a mandatory scoping stage of the EIA system that occurs early in the assessment process to focus the assessment on key issues and identify opportunities for environmental protection and improvement, and there is opportunity to deal with new information or issues identified throughout the assessment process or during project implementation.			
38	The EIA process requires identification and reasonable consideration of alternatives, including 'alternatives to' the initiative and 'alternative means' of carrying out or implementing the initiative.			
39	The EIA process assesses cumulative effects on NLU.			
5	**Evidence-based**			
40	The decisions that follow the EIA process clearly and directly reflect the evidence about NLU presented in the assessment and/or review proceedings.			
41	The EIA process is open to hearing and considering all relevant and opposing evidence.			
42	Uncertainties and assumptions about data, system behaviours and future conditions about NLU are **disclosed** in the decision.			
43	Uncertainties and assumptions about data, system behaviours and future conditions about NLU are **acknowledged** in the decision.			
44	Impact on NLU predictions are formulated in such a way that they can be tested or used for follow-up.			
45	The data and reporting from monitoring and follow-up activities are accessible to the public.			
46	The data and reporting from monitoring and follow-up activities are used in subsequent assessments and decision-making processes.			
6	**Accountability**			
47	There is a requirement for regular, independent public review of the EIA system, its performance and effectiveness (e.g. a five-year review of process, legislation and regulations).			
48	Documentation and information disclosure requirements are binding on the EIA process and its administrators, proponents and all other stakeholders.			
49	There is **open** access to information for NLUs early and throughout the EIA process.			
50	There is **easy** access to information for NLUs early and throughout the EIA process.			
51	There is access to **accurate** information for NLUs early and throughout the EIA process.			
52	There is access to **complete** information for NLUs early and throughout the EIA process.			

53	The EIA process provides information for NLUs through formats that provide extensive access using different forms such as electronic, print, languages, verbal and other.			
54	The EIA process is independent.			
55	The EIA involves multidisciplinary organisations to hear requests for exemptions and inclusions, conduct hearings (when they are required) and review assessment documents and reports.			
56	Roles and responsibilities in the assessment, review and decision-making processes are clearly identified.			
57	Roles and responsibilities for post-EIA, including implementation of the initiative and follow-up on mitigation and monitoring and reporting, are clearly identified.			
7	**Participation**			
58	There is a requirement for participation of NLUs throughout the EIA process.			
59	Participation opportunities are known to NLUs.			
60	The EIA process recognises that stakeholder participation varies in scale and method according to the nature and scale of the initiative being assessed, the stage of the process and the social–cultural context.			
61	Sufficient resources and time are provided to support participation of NLUs.			
62	The participation of NLUs in the assessment of initiatives which may affect their interest improves the quality of the proposal and affect the assessment of the initiatives.			
63	The participation of NLUs where applicable and available influences the decision.			
64	There is a requirement for the EIA process to broadly consider, use and respect multiple forms of knowledge where applicable and available (e.g. scientific, applied-technical, aboriginal, local and culture-specific).			
65	The EIA process uses multiple forms of knowledge where applicable and available (e.g. scientific, applied-technical, aboriginal, local and culture-specific).			
66	The EIA process uses knowledge of NLUs where applicable and available.			
67	Where applicable hearings and other similar deliberations are open to NLUs.			
68	The EIA process prevents unjustified limitations to open deliberation and presentation of evidence (whether through the imposition of place, time of day, time allowed, insufficient resources, or cultural or social barriers, or other unwarranted limitations).			
69	Where applicable there is a requirement for the EIA process to publically report on engagement of NLUs, including how it was undertaken and what was said, and how it was accounted for in the assessment.			
70	Where applicable there is a requirement for the EIA process to explain how participation of NLUs was accounted for in the decision.			
8	**A legal foundation for EIA**			
71	EIA is codified in law.			

72	The legal foundation for EIA provides clarity for stakeholders with respect to applicability, assessment requirements, disclosure requirements, and process components, reporting and decision-making.			
73	The EIA process contains a legal base for participation and accountability requirements.			
74	The EIA process outlines provisions for enforcement.			
75	The EIA process outlines provisions for addressing with noncompliance with assessment requirements or subsequent decisions.			
76	The EIA system provides decisions (for approvals, conditions, rejections, exemptions and inclusions) that may be appealed by NLUs where applicable based on questions of process veracity or interpretation of law.			
9	**Capacity and innovation**			
77	The EIA process is administered by competent and impartial authorities with sufficient staffing, skills and qualifications to administer the process, and to review and evaluate technical, social and scientific data.			
78	The EIA process provides sufficient financial resources to review agencies to ensure the integrity, effectiveness of, and confidence in, the process.			
79	Mechanisms exist in the process for the early consideration of assessment-subject initiatives and the provision of advice to proponents.			
80	Innovative technologies and various communication formats are used in EIA to enhance participation and capacity of NLUs where applicable and their access to information.			
81	The EIA process and its supporting institutional framework are flexible, adaptive and open to new and innovative tools and approaches to assessment and evaluation.			

Open-ended questions

1. Why NLUs are not fully confident in the EIA process?
2. How to improve NLUs' access to information about and participation in the EIA process?
3. How to improve NLUs' confidence and understanding about the intent and process of EIA?
4. What measures should be taken to increase EIA's influence in the decision-making which may affect NLU?
5. How to better coordinate the EIA process with other processes which may affect NLU?
6. How to ensure that initiatives which may affect NLU do not proceed until the EIA process is complete?
7. How to improve effectiveness of the EIA process in minimising and eliminating adverse impacts associated with NLU?
8. What are the reasons that EIA does not fully identify and address social impacts caused by environmental effects of NLU within EIA?
9. What are the reasons that EIA is not fully achieving its aim to protect quality of pasture land and ensure sustainable land use?
10. How to improve performance of environmental monitoring and auditing to ensure compliance with approval conditions set for NLU?
11. How to better identify and address social and cultural impacts caused by environmental effects associated with NLU in EIA?
12. How to ensure that EIA is applied to all initiatives which may affect NLU and make sure that such initiatives are not exempted from EIA?
13. What are the reasons that EIA does not consider a sufficient number of alternatives or does not assess cumulative impacts sufficiently?
14. How to make the EIA process more transparent and accessible to NLUs?
15. How to reduce uncertainties associated with NLU in EIA prediction?
16. How to improve the prediction of impacts associated with NLU?

17. What difficulties does the EIA process face to provide open and easy access to accurate and complete information to NLUs early and throughout the EIA process?
18. Which roles and responsibilities in the EIA process are unclear and how such unclear situation affects NLUs?
19. Which methods should be used to effectively engage NLUs in the EIA process?
20. Which new provisions should be included in the EIA laws and regulations to better address adverse impacts associated with NLU?

Appendix III. List of data used in Chapter 4: Factor analysis

List of data used for analysis of socio-environmental factors influencing the spatial and temporal dynamics of herd composition and livestock distribution in Mongolia

#	Datasets	Year	Source
1	Area		Administration of Land Management, Geodesy, and Cartography of Mongolia
2	Average elevation		Shuttle Radar Topography Mission (SRTM)
3	Centroid X		Administration of Land Management, Geodesy, and Cartography of Mongolia
4	Centroid Y		Administration of Land Management, Geodesy, and Cartography of Mongolia
5	Average population	1995-1999	National Statistics Office of Mongolia
6	Average population	2010-2013	National Statistics Office of Mongolia
7	NDVI average	1981-1985	GIMMS3G
8	NDVI average	1995-1999	GIMMS3G
9	NDVI average	2010-2013	GIMMS3G
10	Average number of horses	1981-1985	National Statistics Office of Mongolia
11	Average number of horses	1995-1999	National Statistics Office of Mongolia
12	Average number of horses	2010-2013	National Statistics Office of Mongolia
13	Average number of camels	1981-1985	National Statistics Office of Mongolia
14	Average number of camels	1995-1999	National Statistics Office of Mongolia
15	Average number of camels	2010-2013	National Statistics Office of Mongolia
16	Average number of cattle	1981-1985	National Statistics Office of Mongolia
17	Average number of cattle	1995-1999	National Statistics Office of Mongolia
18	Average number of cattle	2010-2013	National Statistics Office of Mongolia
19	Average number of sheep	1981-1985	National Statistics Office of Mongolia
20	Average number of sheep	1995-1999	National Statistics Office of Mongolia
21	Average number of sheep	2010-2013	National Statistics Office of Mongolia
22	Average number of goats	1981-1985	National Statistics Office of Mongolia
23	Average number of goats	1995-1999	National Statistics Office of Mongolia
24	Average number of goats	2010-2013	National Statistics Office of Mongolia
25	Herder households	2012	National Statistics Office of Mongolia
26	Herder households	2013	National Statistics Office of Mongolia
27	Herder households	2014	National Statistics Office of Mongolia
28	Average herder HH	2012-2013	National Statistics Office of Mongolia
29	Fraction of the areas under mining licence	2014	Mineral Resources Information Technology Centre Mineral Resources and Petroleum Authority of Mongolia
30	Fraction of the areas under strictly protected areas	1981	Ministry of Environment and Tourism of Mongolia
31	Fraction of forest areas	1981	Ministry of Environment and Tourism of Mongolia
32	Fraction of the areas under urban areas	2014	Mineral Resources Information Technology Centre Mineral Resources and Petroleum Authority of Mongolia
33	Fraction of the areas under crop land	2018	Administration of Land Management, Geodesy, and Cartography of Mongolia

#	Datasets	Year	Source
34	Fraction of the areas under lake	1983	Environmental Information Centre Ministry of Environment and Tourism of Mongolia
35	Fraction of areas under no-go zones	1981, 1983, 2008, 2014, 2018	Mineral Resources and Petroleum Authority of Mongolia Ministry of Environment and Tourism of Mongolia Administration of Land Management, Geodesy, and Cartography of Mongolia
36	Poverty headcount ratio (P0)	2011	National Statistics Office of Mongolia

Appendix IV. Survey questionnaire and results of Chapter 5: Model development

Survey questionnaire for modelling spatial patterns of nomadic-pastoral land use

Name of *soum*	**Name of winter shelter**	**Number of family members**		

Total number of animals	Sheep	Goat	Cattle	Horse	Camel

Questions	**Instuction**	**Uvulj**	**Hav**	**Zusl**	**Namar**	**Otor**
General information		Uvulj uu	Havar jaa	Zusla n	Namarj aa	Otor
How many years has your family been using this camp?	Date →					
How did you acquire your camp/pastureland?	1 Inheritance 2 Purchase 3 Given by *soum* (year) →	1 ☐ 2 ☐ 3 ☐	1 ☐ 2 ☐ 3 ☐	1 ☐ 2 ☐ 3 ☐	1 ☐ 2 ☐ 3 ☐	1 ☐ 2 ☐ 3 ☐
Which land use rights do you have on your land? **1 – Ownership; 2 – Possession; 3 – Use; 4 – Customary; 5 – Other;**		1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Is there a clear fixed boundary between pasturelands you and your neighbours use?		yes ☐ no ☐	yes ☐ no ☐	yes ☐ no ☐	yes ☐ no ☐	yes ☐ no ☐
Number of households in your hot ail?	→					
Water access for your animals?	1 Well inside camp grazing areas 2 Well outside camp grazing areas 3 Surface water inside camp grazing areas 4 Surface water outside camp grazing areas	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐
Are you a member of a herder group?	Yes ☐ No ☐					
How many conflicts did you have over the last 20 years over land and water use?						
Spatial pattern		Uvul	Hav	Zusl	Namar	Otor
Number of camps	→					
Location of Otor?	1 Within the territory of your soum	2 Within your neighbouring soums		3 Within the territory of your aimag		
	4 Within your neighbouring aimags	5 Outside your neighbouring aimags				
Distance between: km→	U-H	U-N	U-Z	H-Z	H-N	N-Z
	Temp. place 1	H-H1	H-H2	H-H3	Otor1	Otor2
Location of temporary place?	1 Within the territory of your bagh			3 Within your neighbouring soums		
	2 Within the territory of your soum					
How big is the grazing area of your hot ail?	Length, km →					
	Width, km →					

Questions	Instuction	Uvulj	Hav	Zusl	Namar	Otor
Does your grazing areas of your hot ail overlap with other hot ail pasture (coverage in percentage)?						
How big is the grazing area of your camp?	Length, km →					
	Width, km →					
Does your grazing areas at camps overlap (coverage in percentage)?	U-H	U-N	U-Z	H-Z	H-N	N-Z
How much pastureland is required at each camp to maintain your livestock sufficiently?	Length, km →					
	Width, km →					
Does your pasturelands at each camp overlap? (approximately in percentage)	U-H	U-N	U-Z	H-Z	H-N	N-Z
Do you use all pasture areas at each camp every year? (Does area of pasture change?) 1-Yes; 2- Every year areas I use change depending on pasture quality, water availability or other factors		1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
What is the length of your daily herding loop?	Sheep, goat, km →					
	Horse, km →					
	Cattle, km →					
	Yak, km →					
	Camel, km →					
What is the desired length of your daily herding loop?	Sheep, goat, km →					
	Horse, km →					
	Cattle, km →					
	Yak, km →					
	Camel, km →					
The maximum distance you travel for herding per day?	Sheep, goat, km →					
	Horse, km →					
	Cattle, km →					
	Yak, km →					
	Camel, km →					
Do you graze outside of your soum boundary?	Sheep, goat, km →					
	Horse, km →					
	Cattle, km →					
	Yak, km →					
	Camel, km →					
Distance to water point for your animals?	km →					
Temporal pattern	Temp. area	Uvul	Hav	Zusl	Namar	Otor
How many times do you move to this camp per year?						
When do you move to your Uvuljuu, Havarjaa, Zuslan, Namarjaa? Date→						

Questions	Instuction	Uvulj	Hav	Zusl	Namar	Otor
When do you go for Otor? When do you move to an temporary place? **Date→**						
Number of grazing days at each camp per year?						
How many times do your animals go to water points per day?	Sheep, goat →					
	Horse →					
	Cattle →					
	Yaks →					
	Camel →					
	Temp. area	Uvul	Hav	Zusl	Namar	Otor
Why do you move to this camp? ***(multiple answer possible)*** **1 To use my reserved pasture** **2 Water is accessible at this camp during this time** **3 This camp is suitable during this time of the year** **4 To access market to sell animal products** **5 If I hear that it has been raining at this place and pasture capacity (new grass)/water level increased** **6 Other**	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐
Why do you move within the grazing areas of your camp? ***(multiple answer possible)*** **1 To feed my animals** **2 To access water** **3 If I hear that it has been raining at this place and pasture capacity (new grass)/water level increased** **4 Other**	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐	1 ☐ 2 ☐ 3 ☐ 4 ☐
Which other factors influence herding movements? ***(multiple answer possible)*** **1 Moving less between camps due to transportation costs** **2 There is a little benefits of moving between camps as pasture capacity is not good at those camps due to lack of precipitation** **3 There is a little benefits of moving between camps as pasture capacity if often not good at those camps due to use of pasturelands by other herders** **4 Movements between camps became difficult as there are less people who would help in moving out and it (children go to university, etc.)**						1 ☐ 2 ☐ 3 ☐ 4 ☐

Answers can have approximate distances.

Hav (Havarjaa) – Spring place; Zusl (Zuslan) – Summer place; Namar (Namarjaa) – Autumn place; Uvul (Uvuljuu) – Winter shelter

Thank you for your help

Survey results of data collection on spatial patterns of nomadic-pastoral land use

Total animal	No of sheep and goats	Grazing orbit (sheep, goats, cattle/yaks)	Length of daily herding movement (sheep, goats, cattle/yaks)	Number of households on campsites	Distance including otor	Distance between campsites
414	170	26	22	14	148	138
638	500	25	18	23	195	175
481	220	31	22	23	385	305
747	180	25	21	22	301	201
725	460	19	13	25	374	304
2010	1600	26	20	16	369	329
1255	990	20	18	25	231	231
835	600	20	18	22	163	143
1575	1000	29	20	14	116	101
656	600	19	20	17	183	183
466	440	28	22	23	279	219
588	400	31	30	8	67	67
585	600	17	8	32	159	139
460	450	24	22	23	124	124
190	200	18	10	6	108	108
748	630	21	18	10	164	164
131	120	24	16	20	202	142
520	330	31	32	23	132	132
882	530	19	16	36	158	78
710	500	26	20	47	132	117
1071	850	28	31	18	146	146
1510	800	48	35	19	97	97
702	500	38	40	17	87	77
475	400	25	30	29	174	174
1202	770	56	40	33	176	176
719	700	30	20	39	193	193
696	600	20	16	33	25	25
162	80	16	14	12	102	102
138.8	150	17	12	20	184	164
355	370	25	21	12	110	110
2158	1300	32	30	27	169	129
130	70	36	36	5	281	271
1085	600	27	22	27	219	204
1860	1700	42	30	82	258	208
448	40	19	20	6	100	100
1253	1000	25	20	6	232	232
1295	1040	21	18	33	127	47
1160	500	44	30	9	97	97
230	210	36	26	41	82	82
2370	400	38	35	24	118	118
873	620	18	18	17	288	288
400	230	20	18	18	223	203
680	550	21	20	12	100	70
561	350	32	27	15	190	170
720	400	20	16	21	267	267
1860	1400	22	19	22	178	163
405	370	21	16	14	241	186
894	570	30	20	13	170	150
671	510	30	25	24	233	218
506	440	33	20	33	340	280
573	450	25	18	31	188	171
1026	800	36	26	21	193	180
157	100	34	28	9	332	232

Total animal	No of sheep and goats	Grazing orbit (sheep, goats, cattle/yaks)	Length of daily herding movement (sheep, goats, cattle/yaks)	Number of households on campsites	Distance including otor	Distance between campsites
155	160	15	10	14	121	121
1355	950	43	35	50	367	287
222	200	33	25	48	28	18
945	650	31	25	24	175	155
640	400	35	24	25	183	168
1398	700	30	24	68	165	123
990	700	27	20	27	245	165
995.5	585	26	33	21	178	178
1200	700	30	33	24	246	146
1020	700	35	32	22	212	122
1920	1000	35	28	22	279	179
930	700	35	30	28	162	132
1200	1100	33	22	23	232	217
1545	1100	39	45	37	71	71
1850	1300	33	27	30	189	179
588	470	31	24	35	153	123
2010	900	40	31	8	133	123
1360	1200	36	28	24	157	107
632	600	22	10	23	199	169
1050	700	40	31	36	98	88
323	320	26	14	18	306	236
898	570	32	26	38	338	298
957	680	28	22	38	363	318
909	650	26	19	22	197	177
918	720	22	10	52	312	282
1095	900	41	28	31	232	212
890	800	26	16	36	257	257
1060	900	35	26	38	296	216
1255	1000	40	26	29	289	189
348	330	29	19	40	202	187
744	640	32	22	41	155	145
390	400	21	10	40	253	223
1468	1300	21	22	14	150	150
915	650	24	20	41	114	84
164	85	22	24	16	179	179
1094.8	1032	21	22	31	223	223
465	0	8	15	34	114	114
311.8	202	27	26	23	100	100
153	160	16	12	29	139	139
1040	500	28	26	14	158	135
840	650	37	26	29	169	0
416	338	33	27	32	194	0
817.5	625	48	46	33	118	0
643.7	473	26	26	19	102	0
266.5	205	35	34	9	263	0
881	600	29	18	27	169	0
1371	1100	34	25	10	248	0
747	578	16	16	18	13	13
416	400	15	6	21	12	12
300.2	281	19	17	24	6	6
3285	2000	33	29	22	173	73
779.4	514	21.5	21	22	121	21
2342.1	1645	31	18	17	123	23
634.2	588	36	25	29	189	89
122.9	129	8	5	14	10	10
485.5	505	20	16	15	8	8
431.4	280	10	12	16	12	12
207.4	201	27	25	20	33	33

Total animal	No of sheep and goats	Grazing orbit (sheep, goats, cattle/yaks)	Length of daily herding movement (sheep, goats, cattle/yaks)	Number of households on campsites	Distance including otor	Distance between campsites
945.7	517	18	14	25	113	13
801.2	454	13	16	10	11	11
341	283	37	12	25	44	24
188.7	179	20	8	10	11	11
321.9	325	11	5	11	29	9
1036.4	735	22	13	17	113	13
62.6	68	33	13	11	29	9
295.1	260	21	7	8	32	12
201.9	156	10	6	5	20	20
1546.2	952	35	25	13	120	20
97.7	103	10	4	8	6	6
664.5	475	21	15	11	11	11
779.4	558	20	22	16	32	12
360.8	304	14	6	14	28	8
777.9	668	25	25	5	34	14
295.1	260	28	22	5	30	10
855.3	723	19	13	12	35	15
187.8	173	15	15	16	134	34
1870	871	22	21	27	187	87
2492.1	1112	19	16	27	67	47
304.7	256	21.5	17	11	120	20
248.3	262	10	5	24	118	18
979.4	523	17	16	12	14	14
1218	1262	20	15	9	112	12
872	885	15	6	4	115	15
2573.7	1224	23	7	22	175	75
323.4	276	13	10	12	8	8
369.7	281	11	10	4	6	6
8387.4	4364	35	25	14	131	31
1093.6	522	26	20	11	112	12
970.3	748	20	16	13	112	12
284.6	267	16	13	5	9	9
306.7	273	12	12	7	104	4
1011.7	780	25	20	6	109	9
382.2	341	14	6	16	110	10
187.8	66	14	13	17	108	8
1024.8	756	28	23	15	32	12
999.3	673	22	19	16	112	12
1870.5	1567	32	22	12	119	19
532.4	436	28	24	13	37	17
976	800	20	16	17	32	12
255	210	12	13	30	5.5	5.5
430	450	12	6	20	13	13
193	110	14	13	20	27	7
510	400	15	6	13	26	6
801	500	18	15	14	112	12
288	310	8	6	15	8.5	8.5
1945.9	711	33	25	13	112	12
722	500	13	11	15	107	7
450	300	19	13	10	105	5
195	210	10	5	10	105	5
3070	2300	25	27	25	145	45
308	300	10	16	23	28	8
557	470	19	14	17	30	10
934	700	20	16	17	30	10
1178	1100	28	26	9	20	20
215.3	209	20	16	11	113.5	13.5
1150	1000	28	24	22	110	10

Total animal	No of sheep and goats	Grazing orbit (sheep, goats, cattle/yaks)	Length of daily herding movement (sheep, goats, cattle/yaks)	Number of households on campsites	Distance including otor	Distance between campsites
640	500	19	14	21	106	6
1720	1000	19	14	11	112	12
1100	900	20	16	14	32	12
429	400	15	6	7	68	48
190	200	20	8	16	38	18
280	300	10	6	15	34	14
1178	900	18	15	15	30	10
400	300	22	20	16	32	12
1643	1400	30	20	18	111	11
500	530	12	6	16	17	17
637	102	12	12	10	8	8
1540	900	13	11	36	9.5	9.5
936	700	16	12	10	29	9
1120	570	12	8	31	164	64
69	73	10	4	9	2	2
740	700	20	8	7	24	4
216.9	192	13	9	11	28	8
312	246	11	15	11	6	6
230	250	30	10	11	28	8
1630	1500	33	28	9	112	12
464	400	16	14	11	8	8
1735	1100	32	27	19	121	21
439	400	19	14	17	179	79
481	463	15	10	11	12	12
592.7	552	20	16	10	30	10
610.3	603	20	8	17	35	15
1142	1040	26	19	16	193	93
419.6	413	12	5	10	8	8
733.1	426	17	16	15	32	12
678.4	462	18	18	10	128	28
1237.1	1060	28	23	10	112	12

Code performed to estimate the standardised factor loadings and parameter estimates of the structural equation model in the Chapter 5: Model development

The following code was performed to estimate the standardised factor loadings and parameter estimates of the structural equation model developed in the Chapter 5 using the R package lavaan.

```
PastoralSpace.model <-'Herd strategy =~ Total number of animals + Total
                       number of sheep and goats

                       Grazing land =~ Total grazing orbit + Total
length
                       of daily herding movement + Total number of
herder
                       households on campsites

                       Pastoral mobility =~ Total number of herder
                       households on campsites + Total distance
between
                       campsites + Total distance between campsites
                       including otor campsite

                       Grazing land ~ Herd size strategy

                       Pastoral mobility ~ Herd size strategy

                       Grazing land ~~ Pastoral mobility'

fitPastoralSpace.model <- sem(modelPastoralSpace.model, data =
data.Mongolia) summary(fitPastoralSpace.model, fit.measures = TRUE)
parameterEstimates(fitPastoralSpace.model, standardized=TRUE)
```