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Nutag, Mal, Malchin: Exploring the Functional and Adaptive Nature of Pastoral Traditional Ecological Knowledge System in East Ujimchin, Inner Mongolia

Ouerle Chao

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Ph.D. Programme in Environmental Science and Technology
Institut de Ciència I Tecnologia Ambientals, ICTA
Universitat Autònoma de Barcelona, UAB

Directed By
Dr. Victoria Reyes-García   Dr. Xiaoyue Li

Academic Tutor
Dr. Victoria Reyes-García

Ouerle Chao Ph.D. thesis, July 2025

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ᠮᠠᠯᠴᠢᠨ ᠠᠷᠠᠳ ᠢ ᠤᠯᠠᠮᠵᠢᠯᠠᠯ ᠪᠠᠷ ᠪᠠᠢᠭᠤᠯᠤᠯᠲᠠ ᠳᠤ ᠂ ᠪᠣᠯᠤᠨ ᠲᠤᠰᠬᠠᠢ ᠳᠤ ᠨᠡᠢᠭᠡᠮ ᠦᠨ ᠤᠯᠠᠮᠵᠢᠯᠠᠯ ᠤᠨ ᠰᠤᠷᠭᠠᠯ ᠢ ᠲᠤᠰᠬᠠᠢ ᠳᠤ ᠲᠦᠷᠦ ᠮᠠᠯᠴᠢᠨ ᠪᠠᠨ ᠪᠠᠢᠭᠤᠯᠤᠯᠲᠠ ᠶᠢᠨ ᠃ ᠲᠡᠭᠡᠳ ᠪᠡᠷ ᠲᠡᠷᠡ ᠬᠠᠮᠲᠤᠷᠠᠯ ᠰᠢᠨᠵᠢᠯᠡᠭᠰᠡᠨ ᠪᠠᠢᠳᠠᠯ ᠪᠠᠢᠭᠤᠯᠤᠯ ᠢ ᠬᠠᠮᠲᠤ ᠪᠠᠷ ᠤᠳᠤᠷᠢᠳᠤᠯᠭ᠎ᠠ ᠂ ᠰᠤᠷᠭᠠᠯ ᠳᠤ ᠬᠤᠪᠢ ᠬᠦᠮᠦᠨ ᠦ ᠪᠠᠢᠭᠤᠯᠤᠯᠲᠠ ᠶᠢᠨ ᠪᠤᠷᠳᠤᠭ ᠢ ᠰᠤᠳᠤᠯᠵᠤ ᠂ ᠰᠢᠨᠵᠢᠯᠡᠯ ᠪᠠᠷ ᠲᠤᠰᠬᠠᠢ ᠬᠡᠯᠡᠯᠴᠡᠬᠦ ᠪᠠᠨ

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[illegible] n=22) [illegible]

ᠬᠦᠮᠦᠨ ᠦ ᠬᠡᠷᠡᠭᠴᠡᠭᠡ ᠬᠠᠩᠭᠠᠬᠤ ᠬᠡᠷᠡᠭᠰᠡᠯ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ᠂ ᠬᠦᠮᠦᠨᠯᠢᠭ ᠬᠡᠷᠡᠭᠰᠡᠯ ᠪᠠᠢᠨ᠎ᠠ᠃ ᠰᠤᠳᠤᠯᠭ᠎ᠠ ᠳᠤ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠬᠠᠩᠭᠠᠬᠤ ᠪᠣᠯᠤᠨ᠎ᠠ ᠳᠠᠭᠠᠨ ᠤ ᠬᠡᠮᠵᠢᠶ᠎ᠡ ᠶᠢ ᠪᠣᠯᠪᠠᠰᠤᠷᠠᠭᠤᠯᠬᠤ ᠪᠡᠷ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠪᠣᠯᠤᠨ᠎ᠠ ᠳᠠᠭᠠᠨ ᠦ ᠬᠦᠮᠦᠨ ᠦ ᠬᠡᠷᠡᠭᠰᠡᠯ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠢ ᠬᠦᠮᠦᠨ ᠦ ᠬᠦᠮᠦᠨ ᠦ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠪᠡᠷ ᠪᠣᠯᠤᠨ᠎ᠠ᠃

ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠰᠤᠳᠤᠯᠤᠯ᠂ ᠬᠦᠮᠦᠨ ᠦ ᠬᠦᠮᠦᠨ ᠦ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠬᠦᠮᠦᠨ ᠪᠣᠯᠤᠨ᠎ᠠ᠂ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠬᠠᠷᠢᠯᠴᠠᠭ᠎ᠠ ᠪᠡᠷ ᠬᠦᠮᠦᠨ ᠦ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠬᠡᠷᠡᠭᠰᠡᠯ ᠪᠣᠯᠤᠨ᠎ᠠ᠂ ᠬᠦᠮᠦᠨ ᠦ ᠬᠦᠮᠦᠨ ᠪᠣᠯᠤᠨ᠎ᠠ᠃ ᠬᠦᠮᠦᠨ ᠦ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠬᠡᠷᠡᠭᠰᠡᠯ ᠪᠣᠯ ᠬᠦᠮᠦᠨ ᠦ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠤ ᠬᠦᠮᠦᠨ ᠪᠡᠷ ᠬᠦᠮᠦᠨ ᠦ ᠬᠠᠷᠢᠯᠴᠠᠭᠠᠨ ᠪᠣᠯᠤᠨ᠎ᠠ᠃

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Summary

Rangelands are among the world's most extensive and ecologically significant terrestrial ecosystems. They play essential roles in carbon storage, biodiversity conservation, and the supply of critical natural resources, while supporting the livelihoods of millions of people. Among the populations most intimately connected to these landscapes are pastoralists. Through their traditional ecological knowledge (TEK), pastoralists follow the natural rhythms of rangeland ecosystems, playing a central role in their stewardship and sustainability. Despite this critical role, there is a mismatch between the realities of rangelands, pastoralists, and the policies designed to manage their relations. In particular, many interventions assume environmental stability and uniform land use, without considering the climate variability, spatial heterogeneity (or patchiness in vegetation, soil, and resource distribution), and the broader ecological and socio-economic uncertainties that define rangeland ecosystems. Even more troubling is the undervaluation of millions of pastoralists and their knowledge in managing these ecosystems. Pastoral traditional knowledge is deeply embedded in local lifeways and research suggest this knowledge is crucial for managing rangeland variability in adaptive and sustainable ways. Yet, these knowledge systems are often sidelined or replaced by externally driven models, compromising both the adaptive capacity of pastoral communities and the ecological functioning of certain rangeland ecosystems that have co-evolved with traditional management practices.

In this context, this Ph.D. thesis explores the functionality and adaptability of pastoral TEK systems. It adopts a dual-scale approach. On the one side, a global perspective is provided through a systematic literature review, on the other side, in-depth ethnographic fieldwork was conducted over nine months in three *gacha*s of the East Ujimchin county in Inner Mongolia, China. Integrating analyses at both global and local scales enables the identification of broader patterns in pastoral TEK functionality while also revealing the locally grounded ways in which TEK is implemented, maintained, and adapted within the East Ujimchin context. Data collection included participant observation, semi-structured interviews (n = 47, including 43 in-person and 4 online), and participatory mapping workshops conducted in three communities with 30 households. Quantitative data were gathered through household (n = 200) and individual surveys (n = 227), focusing on the current application of herd breeding, herd sharing, and weather forecasting proverbs.

The thesis is organized into five chapters. It begins with an introductory chapter that presents the conceptual framework and research rationale (Chapter 1). It is then followed by a systematic literature review that offers a global perspective on functions of pastoral TEK (Chapter 2). The empirical foundation of this thesis centers on an ethnographic case study conducted in East Ujimchin Banner, Inner Mongolia, and is presented in two substantive chapters. Chapter 3 explores how traditional practices such as mobility, herd sharing, and herd breeding have historically enabled herders to adapt to environmental changes in the past and how they continue to support adaptation in the face of contemporary socio-environmental challenges. Chapter 4 investigates traditional weather forecasting knowledge through proverbs and how these are recognized, used, and transformed today. The final chapter (Chapter 5) brings together the thesis's theoretical and methodological contributions, while outlining directions for future research and evidence-based policy recommendations.

This thesis offers a new perspective to understand TEK's functional characteristics. It shows that pastoral TEK systems serve not only ecological purposes but also play crucial economic and social-cultural roles. This is particularly evident in the systematic review of 152 case studies from around the world, which shows that while ecological functions are most frequently documented in the literature, pastoral TEK also supports herd productivity, livelihood security, resource optimization, and the preservation of cultural identity and heritage (Chapter 2). Similar findings emerge in the East Ujimchin case study, where I found that traditional practices such as mobility, herd sharing, and herd breeding each serve multiple purposes, from ecological to social-cultural (Chapter 3). Moreover, the various elements within TEK systems are not isolated pieces of knowledge, but instead operate in a complementary and interconnected way. As explored in both the literature review and case study (Chapters 2 and 3), different knowledge domains support one another to achieve shared outcomes. Complementarity across knowledge domains is articulated through the concept of functional complementarity, which helps explain how herders draw on multiple knowledge systems simultaneously to maintain flexibility and navigate environmental and social uncertainty.

This thesis also highlights the value of oral traditions in uncovering hidden dimensions of TEK. As shown in Chapter 4, weather-related proverbs serve as a carrier of Mongolian weather wisdom. These proverbs are more than symbolic expressions, they function as practical forecasting tools that inform daily herding decisions. Through analyzing them, key prediction periods, ecological indicators, and the types of climatic events being forecasted were identified.

In East Ujimchin, there is a gradual erosion of the recognition and use of certain TEK elements, particularly among younger herders (Chapter 3 and 4). However, despite these concerning trends, many core components of the TEK system remain active and relevant (Chapters 3 and 4). Importantly, this thesis documents clear signs of renewal and innovation. Herders are actively incorporating new experience and observations, such as changing animal behaviors or pasture conditions, into their existing knowledge frameworks, as shown in Chapter 3. Additionally, some traditional practices have not only persisted but have also evolved to serve new functions in response to emerging situations.

Overall, this thesis contributes to a growing body of literature that examines pastoralist's TEK and its contemporary relevance and future potential. Supporting TEK is not only about cultural preservation, but also about recognizing a mode of knowledge production and resilience that offers valuable lessons for navigating uncertainties in a rapidly changing world.

Keywords: adaptation; functional complementarity; multifunctionality; pastoralism; traditional ecological knowledge

Resum

Les terres de pastura (rangelands) són alguns dels ecosistemes terrestres més extensos i ecològicament significatius del món. Juguen un paper essencial en l'emmagatzematge de carboni, la conservació de la biodiversitat i el subministrament de recursos naturals crítics, alhora que donen suport als mitjans de vida de milions de persones. Entre les poblacions més íntimament vinculades a aquests paisatges es troben els pastors. Mitjançant el seu coneixement ecològic tradicional (TEK, per les seves sigles en anglès), els pastors segueixen els ritmes naturals dels ecosistemes de pastura, exercint un paper central en la seva cura i sostenibilitat. Tot i aquest paper fonamental, existeix una desconnexió entre la realitat de les terres de pastura, els pastors i les polítiques dissenyades per gestionar aquestes relacions. En particular, moltes intervencions parteixen de la base d'una estabilitat ambiental i un ús del sòl uniforme, sense tenir en compte la variabilitat climàtica, l'heterogeneïtat espacial (o la distribució irregular de la vegetació, el sòl i els recursos), i les incerteses ecològiques i socioeconòmiques més àmplies que defineixen aquests ecosistemes. Encara més preocupant és la infravaloració de milions de pastors i del seu coneixement en la gestió d'aquests ecosistemes. El coneixement tradicional pastoral està profundament arrelat en els modes de vida locals, i la recerca suggereix que aquest coneixement és crucial per gestionar la variabilitat de les terres de pastura de manera adaptativa i sostenible. Tot i així, aquests sistemes de coneixement sovint són marginats o substituïts per models impulsats externament, cosa que compromet tant la capacitat adaptativa de les comunitats pastorals com el funcionament ecològic de certs ecosistemes de pastura que han coevolucionat amb les pràctiques de gestió tradicional.

En aquest context, aquesta tesi doctoral explora la funcionalitat i l'adaptabilitat dels sistemes de TEK pastoral. Adopta un enfocament a dues escales: d'una banda, es proporciona una perspectiva global mitjançant una revisió sistemàtica de la literatura; de l'altra, es va dur a terme un treball de camp etnogràfic en profunditat durant nou mesos en tres gacha del comtat d'East Ujimchin, a Mongòlia Interior, Xina. Integrar les anàlisis tant a escala global com local permet identificar patrons amplis en la funcionalitat del TEK pastoral i, alhora, revelar les formes localitzades amb què aquest coneixement s'implementa, es manté i s'adapta en el context d'East Ujimchin. La recollida de dades va incloure observació participant, entrevistes semi-

estructurades (n = 47, incloent-hi 43 presencials i 4 en línia), i tallers de cartografia participativa realitzats en tres comunitats amb 30 llars. Les dades quantitatives es van obtenir mitjançant enquestes a llars (n = 200) i a individus (n = 227), centrades en l'aplicació actual de la cria de ramats, l'intercanvi de ramats i els refranys de predicció meteorològica.

La tesi s'organitza en cinc capítols. Comença amb un capítol introductori que presenta el marc conceptual i la justificació de la recerca (Capítol 1). A continuació, s'inclou una revisió sistemàtica de la literatura que ofereix una perspectiva global sobre les funcions del TEK pastoral (Capítol 2). El nucli empíric de la tesi se centra en un estudi de cas etnogràfic realitzat a East Ujimchin Banner, Mongòlia Interior, i es presenta en dos capítols substantius. El Capítol 3 explora com pràctiques tradicionals com la mobilitat, l'intercanvi de ramats i la cria han permès històricament als pastors adaptar-se als canvis ambientals, i com aquestes pràctiques continuen donant suport a l'adaptació davant els desafiaments socioambientals contemporanis. El Capítol 4 investiga el coneixement tradicional de predicció meteorològica a través de refranys, i com aquests són reconeguts, utilitzats i transformats avui en dia. El capítol final (Capítol 5) recull les contribucions teòriques i metodològiques de la tesi, alhora que apunta cap a futures línies de recerca i recomanacions de polítiques basades en l'evidència.

Aquesta tesi ofereix una nova perspectiva per entendre les característiques funcionals del TEK. Mostra que els sistemes de coneixement ecològic tradicional pastoral no només tenen propòsits ecològics, sinó que també compleixen funcions econòmiques i socioculturals importants. Això és especialment evident en la revisió sistemàtica de 152 estudis de cas d'arreu del món, que demostra que, tot i que les funcions ecològiques són les més documentades, el TEK pastoral també dona suport a la productivitat dels ramats, la seguretat dels mitjans de vida, l'optimització de recursos i la preservació de la identitat i el patrimoni cultural (Capítol 2). Resultats similars emergeixen en l'estudi de cas d'East Ujimchin, on s'ha trobat que pràctiques tradicionals com la mobilitat, l'intercanvi de ramats i la cria tenen múltiples propòsits, des d'ecològics fins a socioculturals (Capítol 3). A més, els diversos elements dins dels sistemes de TEK no són peces de coneixement aïllades, sinó que operen de manera complementària i interconnectada. Tal com s'explora tant en la revisió de la literatura com en l'estudi de cas (Capítols 2 i 3), diferents àmbits de coneixement es recolzen mútuament per assolir resultats compartits. Aquesta complementarietat entre àmbits s'articula a través del concepte de complementarietat funcional, que ajuda a explicar com els pastors utilitzen múltiples sistemes de coneixement de manera simultània per mantenir flexibilitat i fer front a la incertesa ambiental i social.

Aquesta tesi també posa en relleu el valor de les tradicions orals per descobrir dimensions ocultes del TEK. Tal com es mostra en el Capítol 4, els refranys relacionats amb el temps actuen com a portadors de la saviesa meteorològica mongola. Aquests refranys no són només expressions simbòliques, sinó que funcionen com a eines pràctiques de predicció que informen les decisions quotidianes de pastura. L'anàlisi dels refranys ha permès identificar períodes clau de predicció, indicadors ecològics i els tipus d'esdeveniments climàtics als quals fan referència.

A East Ujimchin, s'observa una erosió progressiva en el reconeixement i ús de certs elements del TEK, especialment entre els pastors més joves (Capítols 3 i 4). Tot i aquestes tendències preocupants, molts components clau del sistema de TEK segueixen actius i vigents (Capítols 3 i 4). És important destacar que la tesi documenta senyals clars de renovació i innovació. Els pastors estan incorporant activament noves experiències i observacions —com els canvis en el comportament animal o les condicions dels pasturatges— dins dels seus marcs de coneixement existents, com es mostra al Capítol 3. A més, algunes pràctiques tradicionals no només han persistit, sinó que també han evolucionat per assumir noves funcions davant de situacions emergents.

En conjunt, aquesta tesi contribueix a un corpus creixent de literatura que examina el TEK dels pastors i la seva rellevància contemporània i potencial futur. Donar suport al TEK no és només una qüestió de preservació cultural, sinó també de reconèixer una forma de producció de coneixement i resiliència que ofereix lliçons valuoses per afrontar les incerteses d'un món en ràpida transformació.

Paraules clau: adaptació; complementarietat funcional; multifuncionalitat; pastoralisme; coneixement ecològic tradicional

Resumen

Los pastizales (rangelands) se encuentran entre los ecosistemas terrestres más extensos y ecológicamente significativos del mundo. Desempeñan un papel esencial en el almacenamiento de carbono, la conservación de la biodiversidad y el suministro de recursos naturales críticos, al tiempo que sustentan los medios de vida de millones de personas. Entre las poblaciones más estrechamente vinculadas a estos paisajes se encuentran los pastores. A través de su conocimiento ecológico tradicional (TEK, por sus siglas en inglés), los pastores siguen los ritmos naturales de los ecosistemas de pastizales, desempeñando un papel central en su gestión y sostenibilidad. A pesar de esta función crítica, existe una desconexión entre las realidades de los pastizales, los pastores y las políticas diseñadas para gestionar sus relaciones. En particular, muchas intervenciones suponen una estabilidad ambiental y un uso uniforme del suelo, sin tener en cuenta la variabilidad climática, la heterogeneidad espacial (o la distribución desigual de la vegetación, el suelo y los recursos), y las incertidumbres ecológicas y socioeconómicas más amplias que caracterizan a los ecosistemas de pastizales. Aún más preocupante es la subvaloración de millones de pastores y de su conocimiento en la gestión de estos ecosistemas. El conocimiento tradicional pastoral está profundamente arraigado en los modos de vida locales, y la investigación sugiere que este conocimiento es crucial para gestionar la variabilidad de los pastizales de manera adaptativa y sostenible. Sin embargo, estos sistemas de conocimiento a menudo son marginados o reemplazados por modelos impulsados externamente, lo que compromete tanto la capacidad adaptativa de las comunidades pastorales como el funcionamiento ecológico de ciertos ecosistemas de pastizales que han coevolucionado con las prácticas de gestión tradicional.

En este contexto, esta tesis doctoral explora la funcionalidad y la capacidad de adaptación de los sistemas de conocimiento ecológico tradicional pastoral. Adopta un enfoque a doble escala: por un lado, se proporciona una perspectiva global a través de una revisión sistemática de la literatura; por otro, se llevó a cabo un trabajo de campo etnográfico en profundidad durante nueve meses en tres gacha del condado de East Ujimchin, en Mongolia Interior, China. Integrar los análisis a escala global y local permite identificar patrones generales en la funcionalidad del conocimiento pastoral, al tiempo que revela las formas locales en que dicho conocimiento se implementa, mantiene y adapta en el contexto de East Ujimchin. La recolección de datos incluyó

observación participante, entrevistas semiestructuradas (n = 47, incluyendo 43 presenciales y 4 en línea), y talleres de mapeo participativo realizados en tres comunidades con 30 hogares. Se recopilaron datos cuantitativos a través de encuestas a hogares (n = 200) y encuestas individuales (n = 227), centradas en la aplicación actual de la cría de ganado, el sistema de intercambio de animales y los refranes relacionados con la predicción del clima.

La tesis está organizada en cinco capítulos. Comienza con un capítulo introductorio que presenta el marco conceptual y la justificación de la investigación (Capítulo 1). Luego se incluye una revisión sistemática de la literatura que ofrece una perspectiva global sobre las funciones del conocimiento pastoral (Capítulo 2). La base empírica de esta tesis se centra en un estudio de caso etnográfico realizado en East Ujimchin Banner, Mongolia Interior, y se presenta en dos capítulos principales. El Capítulo 3 explora cómo prácticas tradicionales como la movilidad, el intercambio de animales y la cría de ganado han permitido históricamente a los pastores adaptarse a los cambios ambientales, y cómo estas prácticas siguen respaldando la adaptación frente a los desafíos socioambientales contemporáneos. El Capítulo 4 investiga el conocimiento tradicional sobre la predicción del clima a través de refranes, y cómo estos son reconocidos, utilizados y transformados en la actualidad. El capítulo final (Capítulo 5) reúne las contribuciones teóricas y metodológicas de la tesis, al tiempo que propone líneas futuras de investigación y recomendaciones de política basadas en evidencia.

Esta tesis ofrece una nueva perspectiva para entender las características funcionales del conocimiento ecológico tradicional. Demuestra que los sistemas de conocimiento pastoral no solo cumplen funciones ecológicas, sino que también desempeñan roles económicos y socioculturales cruciales. Esto es particularmente evidente en la revisión sistemática de 152 estudios de caso de todo el mundo, que muestra que, si bien las funciones ecológicas son las más documentadas en la literatura, el conocimiento pastoral también apoya la productividad del ganado, la seguridad de los medios de vida, la optimización de recursos y la preservación de la identidad y el patrimonio cultural (Capítulo 2). Hallazgos similares emergen en el estudio de caso de East Ujimchin, donde se observa que prácticas tradicionales como la movilidad, el intercambio de animales y la cría de ganado cumplen múltiples funciones, desde lo ecológico hasta lo sociocultural (Capítulo 3). Además, los distintos elementos dentro de los sistemas de conocimiento no son piezas aisladas, sino que funcionan de manera complementaria e interconectada. Como se explora tanto en la revisión de la literatura como en el estudio de caso (Capítulos 2 y 3), diferentes dominios de conocimiento se apoyan mutuamente para lograr objetivos comunes. Esta complementariedad entre dominios se articula a través del concepto de complementariedad funcional, que ayuda a explicar cómo los pastores recurren a múltiples sistemas de conocimiento simultáneamente para mantener flexibilidad y afrontar la incertidumbre ambiental y social.

Esta tesis también destaca el valor de las tradiciones orales para descubrir dimensiones ocultas del conocimiento tradicional. Como se muestra en el Capítulo 4, los refranes meteorológicos son portadores de la sabiduría climática mongola. Estos refranes no son solo expresiones simbólicas, sino que funcionan como herramientas prácticas de predicción que orientan las decisiones diarias de pastoreo. Su análisis permitió identificar los periodos clave de predicción, los indicadores ecológicos y los tipos de fenómenos climáticos que anticipan.

En East Ujimchin, se observa una erosión gradual en el reconocimiento y uso de ciertos elementos del conocimiento ecológico tradicional, especialmente entre los pastores más jóvenes (Capítulos 3 y 4). Sin embargo, a pesar de estas tendencias preocupantes, muchos componentes fundamentales del sistema de conocimiento siguen activos y vigentes (Capítulos 3 y 4). Es importante destacar que esta tesis documenta señales claras de renovación e innovación. Los pastores están incorporando activamente nuevas experiencias y observaciones —como los cambios en el comportamiento animal o en las condiciones de los pastizales— dentro de sus marcos de conocimiento existentes, como se demuestra en el Capítulo 3. Además, algunas prácticas tradicionales no solo han persistido, sino que también han evolucionado para cumplir nuevas funciones frente a situaciones emergentes.

En conjunto, esta tesis contribuye a un creciente cuerpo de literatura que examina el conocimiento ecológico tradicional pastoral, su relevancia actual y su potencial futuro. Apoyar este conocimiento no solo implica preservar una cultura, sino también reconocer un modo de producción de conocimiento y resiliencia que ofrece valiosas lecciones para enfrentar las incertidumbres de un mundo en rápida transformación.

Palabras clave: adaptación; complementariedad funcional; multifuncionalidad; pastoralismo; conocimiento ecológico tradicional

摘要

草原生态系统是世界上最广泛和生态意义最重大的陆地生态系统之一。它们在碳储存、生物多样性保护和关键自然资源供应方面发挥着重要作用，同时支撑着数百万人的生计。在与这些景观联系最为紧密的人群中，牧民占据着核心地位。通过其传统生态知识（TEK），牧民遵循草原生态系统的自然节律，在生态系统的管理与可持续性方面发挥着关键作用。尽管他们的作用至关重要，但草原、牧民与为管理这些关系而制定的政策之间却存在着不匹配的现象。尤其是，许多干预措施假设环境是稳定的，土地利用是统一的，而忽视了定义草原生态系统的气候变率、空间异质性（即植被、土壤和资源分布的不均匀性），以及更广泛的生态与社会经济不确定性。更令人担忧的是，数百万牧民及其知识在生态管理中被低估。牧民的传统知识深深植根于地方生活方式中，研究表明，这些知识对于以适应性和可持续的方式管理草原变异性至关重要。然而，这些知识系统常常被边缘化，或被外来主导的模型所取代，从而削弱了牧民社区的适应能力，并影响了与传统管理实践共同演化的某些草原生态系统的生态功能。

在这一背景下，本博士论文探讨了牧民传统生态知识系统的功能性与适应性。本研究采用双重尺度的方法：一方面，通过系统性的文献综述提供全球视角；另一方面，在中国内蒙古东乌珠穆沁旗的三个嘎查中开展了为期九个月的深度民族志田野调查。整合全球与地方两个层面的分析，有助于识别牧民知识功能性中的广泛模式，同时揭示其在东乌珠穆沁地方情境中的具体实施、维持与演变方式。数据收集方法包括参与式观察、半结构化访谈（共 47 人，其中 43 人面对面，4 人在线），以及在三个社区中与 30 户家庭共同开展的参与式制图工作坊。此外，还通过家庭（n = 200）与个人（n = 227）调查收集了量化数据，重点关注牧民在牲畜育种、共享放牧以及气象谚语预测方面的实践应用。

本论文共分为五章。第一章为引言，介绍了概念框架与研究动机。第二章为系统性文献综述，从全球视角探讨了牧民传统知识的功能。第三章与第四章构成本论文的实证基础，聚焦于在内蒙古东乌珠穆沁旗进行的民族志案例研究。第三章分析了诸如牧场迁移、牲畜共

享与育种等传统实践，如何在历史上帮助牧民应对环境变化，以及这些实践在当前社会—环境挑战中如何继续支持适应。第四章则聚焦于牧民的气象预测知识，分析了通过谚语所传达的知识是如何被认知、使用与转化的。最后，第五章总结了本论文在理论与方法论上的贡献，并提出未来研究方向与基于证据的政策建议。

本论文为理解传统生态知识的功能特性提供了新视角。研究表明，牧民的传统知识系统不仅具有生态意义，还在经济与社会文化层面发挥着关键作用。这一点在对全球 152 个案例的系统性回顾中尤为突出，尽管文献中记录最多的是生态功能，但传统知识同样有助于提高牲畜生产力、保障生计安全、优化资源配置以及维护文化身份与遗产（第二章）。类似的发现也出现在东乌珠穆沁的案例研究中，传统实践如迁徙放牧、牲畜共享与育种，不仅服务于生态目的，也发挥着社会文化功能（第三章）。此外，传统知识系统中的各个组成部分并非孤立存在，而是以互补和互联的方式共同运作。正如文献综述与案例研究（第二与第三章）所示，不同知识领域之间相互支撑，以达成共同目标。知识领域之间的这种互补性可以通过“功能互补性”这一概念加以解释，它有助于揭示牧民如何同时运用多种知识系统，以保持灵活性并应对社会与环境的不确定性。

本论文还强调了口述传统在揭示传统知识隐性维度中的价值。正如第四章所展示的，与天气相关的谚语是蒙古气象智慧的承载体。这些谚语不仅是象征性的表达，也作为实用的预测工具，为日常放牧决策提供信息。通过对这些谚语的分析，论文识别出了关键的预测时段、生态指标及所对应的气象事件类型。

在东乌珠穆沁地区，传统生态知识的某些组成部分，尤其是在年轻牧民群体中，正在逐步失去其认知与使用基础（第三与第四章）。然而，尽管存在这一令人担忧的趋势，本论文同时也记录到许多核心知识成分依然活跃且具有现实意义（第三与第四章）。尤为重要的是，本研究发现了清晰的更新与创新迹象。牧民正在积极地将新的经验与观察（如动物行为或草地状况的变化）纳入其现有的知识体系中（见第三章）。此外，一些传统实践不仅得以延续，而且在应对新情境中演化出新的功能。

总的来看，本论文为牧民传统知识的当代表达与未来潜力提供了有力支持，并为相关研究提供了新贡献。支持传统知识的保存与发展，不仅是文化层面的保护问题，更是对一种知识生产与应对不确定性能力的认可，这种能力为应对快速变化的世界提供了宝贵经验。

关键词：适应；功能互补性；多功能性；牧民文化；传统生态知识

Acknowledgements

First and foremost, I send my deepest love to the Mongolian homeland and our ancestors who made this brilliant culture possible and entrusted us with this treasured heritage. May the blessings of our homeland and ancestors stand forever.

To the Ujimchin Mongolians, thank you for welcoming me into your homes with warm bowls of milk tea and even warmer hearts. You treated me as your own granddaughter, daughter, and sister — sharing not only your stories and knowledge, but your love and deep care for our Mongolian culture. You may call yourselves “just” herders, but through your everyday lives, you carry the brilliance of our culture with grace and strength, even in these turbulent times, and strive to pass it on to the next generation. There is so much I have learned from you, and even more I hope to understand. This is only the beginning.

To my father, Nuden Xiarnuud Cholmen, just like your name, you have always been a guiding light in my life — steady and wise. Your words, “Wear your Mongolian deel, it will save you one day,” have stayed with me through every journey. They remind me that identity is not just carried in memory but worn with pride. Your belief in the strength of our roots has shaped who I am more than you’ll ever know.

To my mother, Xiarnuud Tanhuaar, just like your name, you have always been a quiet force of strength in my life — graceful and enduring. You taught me what it means to be a Mongolian woman, to be wise without show, patient without pause, and strong without needing to be loud. Your words, “be humble, my daughter”, echo in my heart in moments of triumph. From you, I learned that steady commitment is its own kind of brilliance.

To my brother, Nuden Xiarnuud Baigal, you have always brought lightness into my life — with your care, your positivity, and your humor. In moments of stress or doubt, you remind me how to laugh, how to breathe, and how to keep going with a smile. I’m lucky to walk through life with a brother like you.

To my husband, in moments when I doubted myself, you were there to remind me of my strengths, pushing me to see beyond my doubts. I am also deeply appreciative of your genuine interest in learning about and respecting our Ujimchin culture. You have embraced it with an open heart, showing great appreciation and contributing to it in your own unique way. Your efforts to understand and engage with our heritage enrich not only my life but also our shared experiences. I am always grateful for your intellectual companionship, patience, and constant belief in me.

To my husband’s family, your kindness, warmth, and groundedness reminded me so much of home. Your endless words of encouragement have reached me across distance and difference, like a steady hand on my back. Thank you for walking beside me with such care.

To Viki, thank you for guiding me into the world of TEK research and for the tremendous support you’ve offered throughout this journey. You introduced me to LICCI and the LASEG team, welcomed us to beautiful Betesa, and helped shape not only my research but also how to be a good researcher. Even during your hospital leave, you still found ways to support and think of me, something I will never forget. I’m truly thankful to have had you as a mentor.

To Xiao, thank you for always making me believe in myself and for reminding me, time and again, that the deepest understanding of my work comes from within. I’ll never forget the days we spent together in East Ujimchin, the fieldwork, the yurt nights with the soft sound of a calf outside. Your guidance always came at just the right time.

To Zsolt, thank you for being such a pivotal mentor during my research stay in Hungary. Your dedication and the slow, intentional approach you take with your work have inspired me and directed my future goals to become a meaningful pastoralist researcher. I am truly grateful for all the knowledge you’ve shared and for the lasting impact you’ve had on my life and career. Köszönöm szépen!

To my Barcelona and Vácrátót friends, your warmth, friendship, and the joy of spending time together have truly been one of the highlights of my journey. I’m so lucky to have met you all and to have shared laughter, conversations, and adventures with you. Thank you for making this experience even more memorable!

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Main Acronyms and Abbreviations

CBD	Convention on Biological Diversity
CEEAH	Ethics Committee of the Universitat Autònoma de Barcelona
COP	Conference of the Parties
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
LICCI	ERC-Funded project "Local Indicators of Climate Change Impacts"
PTK	Pastoral Traditional Knowledge
SES	Social-Ecological System
SSI	Semi-Structured Interview
TEK	Traditional Ecological Knowledge
TWFK	Traditional Weather Forecasting Knowledge
UNCCD	United Nations Convention to Combat Desertification
UN	United Nations

Common Mongolian Words

agi orbah: refers to last year's *Artemisia frigida* Willd.

baigal: nature

bodargan: local name for *Atraphaxis manshurica* Kitag.

chagan huar: local name for *Hibiscus trionum* L.

chahildeg: local name for *Iris lactea* Pall.

dzud: a severe winter disaster causing mass livestock mortality due to cold, snow, or lack of forage

gobi: arid, desert-like pastures used in spring

hamhool: local name for *Salsola collina* Pall.

hilgan: local name for *Stipa grandis* P. Smirn.

huraazh barhaar, nuuzh bar: proverb meaning "It is better to move and risk than to stay and risk"

mal: livestock

malchin: herder

meqid sariin hargaa: celestial event involving moon and star alignment

nutag: ancestral homeland; conveys emotional, spiritual, and ecological ties to land

nutag sergeh: ancestral land regeneration

oodegen: Mongolian gerbil

oson tarag: water-fat in livestock

sergeh: to awaken, revive

shaag: local name for *Aneurolepidium chinense* (Trin.) Kitag

taan: local name for *Allium polyrhizum* Tirzc. ex. Rege

tavan hoshuu mal: "five main livestock species": sheep, goats, cattle, horses, camels

tsagaan sar: Mongolian New Year

ubligqi: cultural transmitters or elder mentors of traditional knowledge

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All photographs were taken by Ouerle Chao, unless otherwise noted. For any figure depicting identifiable individuals, consent was obtained prior to inclusion.

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Chapter 1 Introduction

Photo credit: Jesse Segura (2023)

1. Background and Motivation

There is an urgent need for scientists and policymakers to recognize the critical importance and dynamic functioning of rangeland ecosystems and collaborate with pastoralists to develop sustainable solutions for today's environmental and social crises. As the United Nations Convention to Combat Desertification (UNCCD) Executive Secretary Ibrahim Thiaw remarked during the 16th Conference of the Parties (COP16) in 2024, "*When we cut down a forest, when we see a 100-year-old tree fall, it rightly evokes an emotional response in many of us. The conversion of ancient rangelands, on the other hand, happens in 'silence' and generates little public reaction … Pastoralist communities are frequently overlooked, lack a voice in policy-making that directly affects their livelihoods, are marginalized, and are even often seen as outsiders in their own lands*."

This oversight is particularly concerning given the crucial role rangeland ecosystems play globally. Covering more than half of the Earth's surface, rangelands are vital for biodiversity conservation, global food security, and climate regulation. Rangelands support one-sixth of humanity's food supply and store about one-third of the world's terrestrial carbon (Ahlström et al., 2015; Seid et al., 2016; UNCCD, 2024). Beyond their global ecological and economic importance, rangelands are also home to approximately 300 million pastoralists, representing a wide range of culturally diverse groups who have coexisted with and carefully stewarded these landscapes for millennia (Reid et al., 2008). While pastoralists depend on rangelands for their livelihood, their relationship with the land is not purely extractive, it is also based on respect, reciprocity, and responsibility (Beach & Stammler, 2006; Manzano et al., 2021; Chao et al., 2023).

Pastoralism functions as a dynamic system connecting nature, livestock, and pastoralists in a triangular balance (Zinsstag et al., 2016; Boyanbaatar, 2018). Nature forms the foundation of pastoralism, livestock are its roots, and pastoralists serve as both caretakers and active stewards of the land. Nature provides physical resources—such as forage and water—as well as intangible elements like climate, seasonal rhythms, clouds, and rainfall. For pastoralists, livestock are not only a source of livelihood, but also essential partners that help them understand nature and collaboratively maintain ecological balance. In this relationship, pastoralists do not seek to dominate or control nature or animals; rather, they attune themselves to their natural rhythms, recognizing and respecting the inherent characteristics of both. Through careful observation, experiential learning, and knowledge transfer, pastoralists have developed highly flexible and adaptive strategies that allow them to navigate uncertainties (Reid et al., 2014; Sharifian et al., 2022).

Just as pastoralists have long understood, rangeland ecosystems do not have one stable condition—they are constantly changing (Nori & Scoones, 2019). Embracing the complexities and uncertainties of these systems is crucial, which contrasts with the idea of seeking a 'stable' and 'unified' model for pastoralism globally (Manzano et al., 2021; Scoones, 2024). However, rangelands are often mistakenly viewed as degraded, desertified, or unproductive wastelands, particularly from an external perspective (Arjjumend, 2024). Similarly, livestock are often seen as inevitable contributors to climate change (Ripple et al., 2013), and the traditional knowledge and practices of pastoralists are perceived as mere relics of the past, expected to vanish with modernization (Reyes-Garcia, 2015). These perceptions stem from deep misunderstandings about how rangeland ecosystems function as well as the complex interdependent relationship between these ecosystems, livestock, and pastoralists.

Historically, these misunderstandings have had a significant influence on global rangeland management policies. Such policies have often sought stability and imposed top-down control, leading to interventions such as forced settlement programs (Meshack & Griffin, 2002), grazing bans (Singh et al., 2022), fenced-off areas (Odendaal, 2011), fixed stocking rates (Ellis & Swift, 1988), and mass tree planting (Briske et al., 2024). These planned interventions imposed on local problems have frequently had negative consequences, undermining the ecological integrity of rangelands, undermining pastoralists knowledge systems, and disrupting pastoralist livelihoods. Since the 1980s, scholars such as Behnke, Scoones, and Kerven (1993) and Ellis and Swift (1988) started to recognize rangelands as non-equilibrium systems, characterized by inherent ecological variability and unpredictability. The literature on pastoralism has since recognized pastoralists' experiences as valuable sources of knowledge on adapting to change, using these insights to inform decision-making in regions inhabited by tens of millions of pastoralists globally (Nori & Scoones, 2019). In parallel, during this time, the growing study of traditional ecological knowledge (TEK) gained prominence in academia, recognizing its value in local livelihoods, biodiversity conservation, ecosystem functioning, and the resilience of social-ecological systems (Gadgil et al., 1993; Berkes et al., 2000; Fernandez-Llamazares et al., 2015; Garnett et al., 2018; Reyes-Garcia & Benyei, 2019).

Yet, despite increasing recognition of their value, rangelands are continually shrinking globally due to agricultural expansion (Wimberly et al., 2017), land grabbing (Singh et al., 2022), conservation restrictions, and infrastructure development (Hazard & Adongo, 2015). Rangeland management policies continue to enforce rigid land-use models. Rooted in colonial legacies, the combined forces of policies, educational systems, market economies, urbanization, and globalization—alongside environmental and other socio-ecological changes—pose significant challenges for pastoral communities. These challenges often hinder their ability to maintain the practices and lifestyles handed down by their ancestors, as highlighted by a substantial body of literature documenting the erosion of traditional knowledge systems (Aswani et al., 2018; Fernández-Llamazares et al., 2023). However, despite these formidable pressures, TEK shows significant resilience, continually adapting and evolving. This allows pastoral communities to dynamically respond to environmental, economic, and social transformations. While the global narrative often highlights erosion and loss, it is equally important to recognize and acknowledge the persistence and adaptability of TEK in the face of modern challenges.

Emphasizing these positive narratives can empower local communities to take pride in their heritage and feel less marginalized within the dominant global discourse. This, in turn, can help mobilize bottom-up efforts to preserve, revitalize, and apply their rich cultural knowledge and practices. Conversely, placing too much focus on the loss of knowledge risks leading to its 'museumification'—stripping communities of agency and framing their traditions as static relics of the past, rather than recognizing them as dynamic, evolving systems (Berkes et al., 2000; Reyes-García et al., 2014).

Within this context, this Ph.D. thesis aims to show a more complete reality of the traditional knowledge systems and lifeways of pastoralists. It stresses that TEK is a living, dynamic, and responsive knowledge system that continues to shape how pastoralists manage uncertainty, maintain ecological balance, and adapt to ongoing environmental and social changes. In doing so, this thesis contributes to the expanding literature that calls for a deeper understanding of TEK's diverse contributions—not only ecological and economic, but also social-cultural—and emphasizes that these multiple values are what enable TEK to persist in the face of transformation.

Specifically, this thesis examines the role TEK systems play within the Ujimchin community, and explores their contemporary relevance—how they endure, adapt, and continue to support herders in responding to present-day challenges. The Ujimchin community offers a compelling case for investigating the multifunctionality and adaptability of pastoral TEK for three key reasons. First, Ujimchin herders maintain a rich body of knowledge and practice deeply rooted in landscape and animal care. Second, approximately 70% of the Mongolian population in East Ujimchin Banner — around 30,000 people — continue to depend on traditional pastoralism, making TEK a living and applied system. Third, since the late 1990's, the region has experienced rapid transformations, including major rangeland policy reforms, economic development, increasing climate variability, and technological change, providing a unique opportunity to observe how TEK is persisting and adapting to increasing stochasticity.

This chapter proceeds as follows. Section 2 presents the theoretical background, providing key concepts related to TEK, its diverse functions, and adaptive nature. Section 3 explains the methodological framework used in this thesis, presents data collection strategies, and reflects on the researcher's positionality. Section 4 introduces East Ujimchin Banner as the case study, including its ecological context, local knowledge systems, historical rangeland policies, and observed environmental changes. Finally, section 5 outlines the thesis's specific research objectives and provides a detailed overview of the thesis structure.

2. Theoretical Background

2.1 Traditional Ecological Knowledge

Throughout their long history of interacting with natural surroundings, local communities have developed a deep sense of gratitude and appreciation for the living and non-living entities that support, accompany, and sustain them. These values, in turn, have fostered the development of local knowledge and practices centered on care, reciprocity, and stewardship of their environments. These values, knowledge, and practices are commonly referred to as TEK (Berkes, 2000).

Despite its ancient roots, scientific interest in TEK only emerged around the 1950s, initially arising from the field of ethnoecology. Early studies documented the way local communities manage the environment around them (Conklin, 1957) as well as how they understand and categorize the plants and animals (Bulmer, 1970; Berlin et al., 1974; Hunn, 1977). Others also recorded local knowledge of plant and animal behavior (Feit, 1973; Berkes, 1988). However, much of this early work often remained descriptive.

By the 1980s, growing concerns about global environmental degradation and biodiversity loss—alongside the rise of environmental movements—led more researchers to view TEK not only as a repository of environmental knowledge but also as a critical resource for guiding sustainable resource use and conservation efforts (Posey, 1985; Berkes, 1988). This growing academic interest was echoed by international policy initiatives. Notably, the 1980 World Conservation Strategy proposed by the International Union for Conservation of Nature (IUCN) and the 1992 Convention on Biological Diversity (CBD) formally recognized the importance of local knowledge systems in the conservation and sustainable use of biodiversity. Both emphasized that working with local communities is key to effective biodiversity conservation (Reyes-García, 2023).

More recent efforts by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), such as the Assessment on the Diverse Values and Valuation of Nature (2022) and the Transformative Change Assessment (2024), have once again emphasized the importance of including diverse knowledge systems, especially TEK, in decision-making for a just and sustainable future (McElwee et al., 2020). The fact that these calls continue to be made decades after the 1992 CBD suggests that, although TEK is increasingly acknowledged in academic and policy circles, its full recognition as a valid and equal knowledge system in practice remains limited.

Due to colonial legacies, Western scientific knowledge has long been positioned as superior—or even the only legitimate—way of knowing (Quijano, 2024). Traditional knowledge, by contrast, is often dismissed as outdated or as something that would naturally fade away with the rise of modern science and development. The former typically begins with hypotheses or theories, relying on controlled experiments and measurable results to develop general principles that are broadly applicable (Agrawal, 1995). TEK, in contrast, is primarily experiential, cumulative, and place-based, derived from long-term observations and continuous interactions of local communities with particular environments (Berkes, 2008). Rather than separate different knowledge domains, TEK integrates ecological, social, cultural, and spiritual dimensions into a holistic framework, allowing local communities to adapt flexibly and respond effectively to complex local realities (Berkes & Berkes, 2009). Perhaps the most fundamental difference between these systems lies in their view of nature. For many local communities, nature is not just a resource provider, but a living system imbued with spirit and agency and humans are an inseparable part of it (Kapyrka & Dockstator, 2012). This relational understanding fosters a sense of respect, responsibility, and accountability toward it (Chao et al., 2023). Western science, on the other hand, often views nature as something external to humans, an object to be studied, managed, and controlled (Escobar, 1995; Berkes, 2012).

Many researchers argue that the dominance of Western science was not merely about producing more accurate or valid knowledge; it was deeply entangled with an ideological framework that served the interests of colonialism and capitalism (Deloria, 1995; Mignolo, 2009; Grosfoguel, 2011). The delegitimization of traditional knowledge reinforced the authority of scientific institutions while advancing broader political and economic agendas. By framing traditional knowledge systems as inferior or irrelevant, external actors—the states, development agencies, NGOs, or corporations—have justified their own interventions as necessary or even benevolent. Under narratives of "saving," "modernizing," or "developing" local communities, these interventions have frequently enabled the appropriation of natural resources and the imposition of externally derived management models, despite communities' longstanding histories of ecological stewardship (Escobar, 1995; Scott, 1998).

2.2 The Adaptive Nature of TEK

Throughout history, local communities worldwide have sustained both their livelihoods and the environments they depend on by navigating various forms of ecological and social uncertainties. A key reason for this resilience is the adaptive nature of their knowledge systems (Berkes et al., 2000; Gómez-Baggethun & Reyes-García, 2013; Athayde et al., 2017). Because the production of knowledge is based on real-life experiences, these knowledge systems continuously learn from crises and mistakes (Olsson & Folke, 2001; Berkes & Turner, 2006). For instance, farmers may shift planting and harvesting times in response to changing rainfall patterns caused by ongoing climate change (Bryan et al., 2009). Pastoralists might alter grazing routes to cope with rangeland degradation or policy-driven land use change (Allsopp, 2009). Fishing communities may modify their practices to account for changes in fish migration or spawning linked to warming waters (Cinner et al., 2012).

TEK is not a single, fixed body of information, but is made up of many different types of knowledge and practices (Reyes-García et al., 2013; Sharifian et al., 2022). It is common for some parts of that knowledge to become more relevant or actively used over time, while others may fade. However, they should not be understood merely as lost. Some communities describe this process as knowledge that is "sleeping" (Hobson et al., 2010), or as being safeguarded by ancestors until the time is right for it to be reawakened (Risling Baldy, 2018).

Beyond reorganizing itself internally to new challenges, TEK systems can also renew themselves by interacting with other knowledge systems, such as Western scientific knowledge. For example, Reyes-García et al. (2014) found that garden keepers in Spain formed a new form of knowledge with the combination of traditional farming knowledge and modern practices and techniques. Similarly, others have documented comparable patterns of coexistence and complementarity between traditional and scientific knowledge (Eyssartier et al., 2011; Fanteso & Yessoufou, 2022). In the Andean region, traditional agricultural practices such as terracing and crop rotation are increasingly being combined with drip irrigation technology. This integration has improved water efficiency and crop yields in the face of the region's growing water scarcity and climate pressures (Brown, 2023). Likewise, in Arctic regions, local communities are integrating traditional forest management knowledge with satellite-based monitoring tools. While traditional practices guide local observation and decision-making, satellite imagery offers real-time data on deforestation and illegal logging (Sibanda, 2024).

However, in the face of today's rapid and often externally driven changes such as economic development, technological advancement, aggressive land-use transformations, and top-down conservation or development schemes, the natural adaptability of TEK is increasingly disrupted and challenged (Reyes-García et al., 2013; Gaup Eira et al., 2018; Fernández-Llamazares et al., 2021; Okui et al., 2021). This has led to a growing awareness of the fragile and eroding status of

TEK systems, resulting in the publication of numerous studies reporting negative trends in knowledge loss. Aswani et al. (2018) found that 77% of the 92 collected studies on TEK reported significant declines, and Tang and Gavin (2016) reported a similar result, noting that TEK degradation was by far the most common trend (89% of 152 studies). Overall, knowledge related to natural resources, such as medicinal and edible plants, has been reported as especially vulnerable to loss (Reyes-García et al., 2013). In addition, a consistent finding across many studies is the correlation between age and knowledge levels, with elders typically being more knowledgeable than younger generations (Sujarwo et al., 2014; Ianni et al., 2015). Although some of this generational difference could be attributed to the fact that elders have had more time to accumulate knowledge, it is also likely a reflection of deeper structural shifts. Younger people today are increasingly integrated into formal education systems and market-based livelihoods, which often operate on values, priorities, and epistemologies that differ significantly from those embedded in TEK.

2.3 The Diverse Functions of TEK

Researchers have widely recognized TEK as a critical source of insight into biodiversity conservation, landscape management, ecosystem monitoring, and sustainable resource use. For example, previous research shows that lands managed by local communities contain over one-third of the world's remaining intact forests (Garnett et al., 2018; Seebens et al., 2024), and provide habitat for approximately 60% (more than 2,500 species) of the world's terrestrial mammals (O'Bryan et al., 2021). Rather than merely being passive inhabitants of biodiverse regions, Indigenous Peoples and local communities are active stewards and protectors of these landscapes (Kimmerer, 2013). Increasing evidence suggests that the patterns of biodiversity and ecosystems we see today are not solely the result of natural processes but also the outcome of long-standing human management (Garnett et al., 2018; Molnár et al., 2020; Molnár et al., 2024). Many communities utilize a broad set of strategies such as controlled burning, rotational use of land or enrichment planting to shape and maintain productive, diverse, and resilient environments. In fact, in several cases, the removal or displacement of such communities has led to ecological degradation and biodiversity loss (Bliege Bird & Nimmo, 2018; Knight et al., 2022).

In terms of stewardship practices, existing literature suggests how traditional practices offer valuable approaches for managing nature in ways that support ecological balance while maintaining community well-being (Berkes et al., 2000). In many pastoralist communities, for example, people move their herds across different grazing areas to avoid exhausting the land and to let it recover (Oba & Kotile, 2001). These practices come from a belief that nature can only give so much, so people feel a responsibility to give back in return. This idea of balance and care for the future is often reflected in many local communities' customary rules and social norms, which guide their everyday actions when, where, and how much they can hunt, fish, cut wood, or gather plants (Field & Ostrom,1992).

Beyond its ecological contributions, TEK can also bring significant economic benefits to local communities. It contributes to the well-being of communities by supporting subsistence activities and reducing dependence on external inputs. For example, local communities often hold rich knowledge of the nutritional and medicinal values of local plants and animal products. In the Peruvian Andes, for instance, communities use native potato varieties not only for food security but also for medicinal purposes, contributing to both health and economic resilience (Souto & Ticktin, 2012). Similarly, in parts of Indonesia, local knowledge of medicinal plants enables communities to treat common illnesses using home remedies, reducing reliance on pharmaceutical products (Sujarwo et al., 2014). This allows them to meet health and dietary needs using locally available natural resources and reduces their reliance on costly pharmaceutical or imported goods (Reyes-García et al., 2011). In addition, TEK plays a crucial role in risk management by helping communities mitigate and adapt to severe events such as droughts, floods, or seasonal shifts and ultimately lower the economic risks associated with them. These forms of knowledge are essential for local adaptation strategies and are often more immediately applicable than formal scientific models in remote or resource-scarce contexts.

As global challenges such as climate change, biodiversity loss, and socio-political instability intensify, there has been increasing interest in the contribution of TEK to the resilience of social-ecological systems (SESs) (Adger et al., 2005). Resilience here refers to a system's ability to absorb disturbances and adapt to change while maintaining its essential functions and structure (Folke, 2006). Top-down, centralized systems, including those based primarily on Western scientific knowledge, often struggle to respond effectively to rapidly changing conditions, partly due to slower decision-making processes that require bureaucratic procedures, lengthy assessments, and hierarchical approval before any action can be taken. Moreover, these systems tend to approach uncertainties through a linear and reductionist view that fails to reflect local complexities (Nori & Scoones, 2019). For example, in pastoral regions, rangeland degradation is often framed narrowly because of overgrazing by livestock (Zerga, 2015). However, this diagnosis overlooks the layered and interconnected nature of the problem. In reality, the degradation of rangelands stems from a combination of factors: inappropriate land policies that restrict mobility, increasing pressures from mining or agricultural expansion, market demands, and changing weather patterns driven by climate change (Nori & Scoones, 2019). By contrast, TEK is better suited to engage with such complexity. It recognizes that multiple drivers interact over time and space. Consequently, when these different knowledge systems are combined, they can strengthen the resilience of SESs by fostering collaborative problem-solving and enabling more inclusive and adaptive forms of governance (Colding et al., 2003).

Additionally, TEK supports SESs' resilience by maintaining diversity in knowledge, practices, and worldviews. This diversity allows communities to draw from a wide range of strategies to respond to different kinds of environmental and social disturbances (Folke, 2004). For example, when facing a challenge like drought, many local communities do not rely on a single fixed response. Instead, they might shift planting calendars, choose drought-resistant crop varieties, or apply traditional water-saving techniques such as terraced irrigation or underground water storage (Nikolaou et al., 2020). In a similar way, their methods of weather prediction are also diverse. Rather than depending solely on satellite data or meteorological models, they may read animal behavior, wind direction, sun, and moon position, or even the softness of brown sugar to forecast coming changes (Rautela & Karki, 2015). This diversity in knowledge and practices is underpinned by a fundamentally different worldview, one in which humans are seen not as separate from nature, but as participants in a shared destiny. This relational perspective may foster a deeper sense of responsibility toward the environment and can serve as a powerful foundation for more sustainable behaviors and long-term environmental stewardship (Chao et al., 2023).

3. Methodology

This chapter explains the methodology used in this thesis, which combines academic knowledge with personal experience. As a member of the Ujimchin community, I approached this research not only as a researcher, but also as someone with cultural ties and long-standing familiarity with the people and place. Given the cultural and epistemological context of the study, a holistic and decolonial approach was necessary. What follows is a narrative-based reflection that weaves together research methods with lived experience.

3.1. Positionality

As researchers, our perspectives are inevitably shaped by the unique trajectories of our lives—our memories, identities, and lived experiences. These subjective elements influence how we perceive, interpret, and engage with the knowledge we encounter. This becomes especially important to acknowledge when conducting research within one's own community. Although I identify as an Indigenous woman, I have spent much of my life, since high school, living, studying, and working in cities and countries far from home, which brings both complexity and the possibility of bias into my perspectives. In this section, I reflect on my cultural background and educational experiences, and how they have shaped my approach to research.

My name, *Ogloo*, means 'Morning' in Mongolian. It stands for new beginnings, hope, and a fresh start each day, something my parents really wanted for me. This has greatly shaped how I see life. My brother's name, *Baigal*, means "Nature." My parents wanted him to be calm and generous. My mother's name, *Tanhuaar*, means "Flower," fitting her gentle and nurturing nature. My father, *Cholmen*, is named after the brightest star at dawn, guiding us through the dark, just as he has always guided our family. My mother always wanted me to be a typical Mongolian woman, reserved and wise, and my father always encouraged me to wear our traditional Mongolian dress every day. Growing up in a family that deeply values nature and Mongolian heritage, I learned to respect the land and the people who care for it.

Pursuing higher education beyond the Ujimchin mountains, as advised by our elders, marked the beginning of a new chapter in my life. My journey took me to big cities and foreign countries, where I was exposed to diverse cultures, academic disciplines, and ways of thinking. This experience was transformative. It expanded my understanding of the world and, perhaps unexpectedly, deepened my appreciation for my own cultural roots. Interacting with students and researchers from various backgrounds gave me a broader view of global challenges and helped me see how traditional knowledge systems, like ours, have unique and valuable insights to offer in addressing them.

Being a member of the Indigenous community I study has provided many advantages. My existing relationships and the trust I share with herders allowed me to access knowledge that might not have been shared with outsiders. My insider identity helped me easily understand local expressions, subtle gestures, and the cultural logic behind decisions. It also allowed me to ask questions in a way that felt natural and culturally appropriate, and to interpret answers with deeper sensitivity.

However, insider status also comes with certain challenges. One common bias I became aware of in myself was the tendency to take things for granted—to assume I already knew what people meant, without asking further. For example, I know that Ujimchin herders often choose male sheep with black noses, eyes, mouths, and legs for breeding. Because this practice is so normalized in my own understanding, I initially failed to ask the obvious but important follow-up question: Why this particular type? What is the reasoning behind it? To overcome this, I made an effort to pause when something felt too familiar or unquestioned. I asked myself "Why?" and "Do I really understand this, or am I just assuming I do?" I regularly cross-checked my interpretations with both herders and family members, and I conducted follow-up interviews after my initial data analysis to explore the meanings behind some findings in more depth. This process of reflexivity helped me recognize moments where my familiarity with the culture could limit, rather than enhance, my understanding and pushed me to engage more critically with my own knowledge.

Another bias of mine that I had to consider was a natural inclination to protect the identity and image of my community. This made it challenging at times to engage critically with certain perspectives, especially those that seemed to contradict traditional values. For instance, when speaking with a herder who strongly supports modern agricultural methods, such as switching all his/her livestock to high-yield meat cattle and wool-producing sheep and building a large commercial feeding center, I noticed my initial reaction was dismissive. I found myself perceiving his/her knowledge as somehow less "authentic" or less connected to the cultural roots I wanted to highlight. Throughout my thesis, this emphasis on the positive and enduring aspects of TEK is clear. While I did not always actively challenge this bias, I believe that acknowledging it here is important. I fully acknowledge this is a limitation of this thesis. At the same time, I see it also as part of my political and emotional stance as an Indigenous researcher working on her community.

3.2. Holistic Approach

When I was young, the stones and shrubs on the grassland were part of our everyday play. But whenever we moved a stone from its place, we were scolded—because we were told the stone, like us, belonged to this land and could grow homesick. Every spring and winter, our family would prepare to slaughter sheep. I used to feel sad watching them, but my mother would tell me not to speak sorrowfully, because the animals would feel it too. The morning tea she made always began with a bowl offered to the sky and earth, as a gesture of respect. Even when I went away to school in town, I still remember her words when I carried an umbrella in the rain: "What a bad omen! You're scaring away the rain." These memories are the reflection of how Ujimchin herders understand everything around them, land, sky, animals, and even the weather is alive and responsive. They believe that every action we take can have consequences that ripple through both the human and more-than-human worlds. This way of seeing the world lies at the heart of many TEK systems globally, and it guided how I approached this research.

To comprehensively capture and show the interconnectedness of pastoralists' knowledge systems, I chose to adopt a holistic approach in this Ph.D. thesis. I tried to engage with TEK not only as ecological wisdom, but as a way of life that is embedded in their stories, their rituals, and how they herd and make everyday decisions. Researchers Queeneth Nokulunga Mkabela (2006), Linda Tuhiwai Smith (1999), and Marie Battiste (2000) have all stressed the necessity for researchers studying Indigenous knowledge systems to apply a more holistic and decolonizing methodology to fully document the social, spiritual, political, and economic components of these complex knowledge systems.

Temporally, my fieldwork was from autumn through to the summer, November 2022 to August 2023, completing a full annual cycle of herding life. Spatially, I met and spoke with herders in a wide range of settings: in their houses, on open pastures, during festivals and weddings, at sacred *Ovoo* ceremonies, and even in livestock shelters while they sheared wool. This exposed me to as many settings and seasons as possible to understand TEK more holistically. Herders start their day by stepping outside to check the weather, deciding which direction to move their herd. They choose pastures based on the season and the condition of their herd, whether fat or thin. As they follow their herd, they closely observe the animals for any signs of distress or illness, such as limping or abnormal breathing, and conduct thorough check-ups if needed. In the course of their daily routine, herders apply their knowledge of weather, plants, and livestock health instinctively. This integration of knowledge is why my Ph.D. research naturally extended beyond mere mobility practices to include herd management, weather forecasting, and socio-cultural practices.

3.3. Story-telling

For East Ujimchin herders, storytelling permeates everyday life. It occurs during herding, in meetings with neighbors, in playful moments with grandchildren, during encounters with strangers, and around the dinner table. As Linda Tuhiwai Smith (1999) discusses in her work Decolonizing Methodologies, the essence of stories extends beyond mere narration. Stories serve as carriers of collective cultural memory, crucial for transmitting the values and beliefs of a community across generations. Russell Bishop (1999) stresses storytelling as a powerful research tool that respects cultural nuances, allowing storytellers to maintain control over their narratives, thus representing diverse perspectives authentically. According to Bishop, the local community itself is seen as a living narrative, composed of many individual stories that continually evolve with the community members' lives.

With this understanding, this Ph.D. thesis treated every story told by herders as relevant and listened to with respect and appreciation. While data collection was not initially intended to be conducted through storytelling, during informal discussions, interviews, mapping workshops, herders often preferred to communicate their knowledge and experiences in this format. One example occurred when I asked, 'How many days did you spend on a single spot (pasture)?' Here is one-third of the story one of the herders told me:

> *Many years ago, an old herder didn't go back to his original land from winter camps. He told his neighbors that they should move, but he was not going to. So, he stayed the whole spring at the winter camp. Actually, the winter camps had no grass left because everyone was there. However, when he came back at the end of the spring, his sheep and lambs were*

all so fat and chubby. Later, he said that his herd ate 'agi orbah', which means there was agi (Artemisia frigida Willd.*) that had grown last year and it was hidden under baogi grass. He found out that the Agi was under it and it was still green and nutritious, so he spent the winter not moving. Therefore, we always observe the plants and everything. There is a grass called 'ulaan botoo'; the good ones have green in them, even in winter when you pick it up and see. If your herds eat it, it's good for their health. There is shaag grass (Aneurolepidium chinense* (Trin.) Kitag) *which has two types: round and flat shaped. It's good for horses and easy to get fat if they eat it. I used to join horse racing competitions, so I needed to fatten up my horse before the race. I brought my horse to the place where there was plenty of round shaag grass. We didn't have specific grains and stuff back then. So, the next morning, my horse was different than other horses; he was strong. And I didn't tell anybody about this (Story shared by participant, 2023).*

The stories that I listened to were diverse in content. Some told about history, others were about big successes or important lessons. Some showed love for animals, while others talked about how upset people are with changes happening today. Some stories were fun, and others were sad. But every story showed me what the storyteller thinks and feels, and what they believe in. Listening to these stories helped me really understand who I was talking to. In addition to stories, herders shared many proverbs during the conversations, especially on the topic of weather forecasting. Proverbs are often short and wise sayings that express a truth or piece of wisdom. By treating these proverbs as significant data, I was able to delve deeper into these hidden forms of traditional wisdom and uncover layers of meteorological understanding that are not immediately apparent in casual conversation.

3.4. Methods for Data Collection

Building on these approaches, I employed a mixed-method approach for data collection and analysis. I combined qualitative and quantitative research methods and used a range of data sources, including both primary and secondary data. As a researcher working within my own Indigenous community, my positionality enabled deeper engagement and trust during data collection. This research also builds on the broader framework of the LICCI (Local Indicators of Climate Change Impacts) project, which aims to document how local communities perceive and respond to environmental change. Detailed descriptions of the research methods and sampling strategies used in this thesis are presented in the following chapters. This section provides an overview of the data collected. Primary data analyzed in this thesis includes information derived from online interviews, participant observation, semi-structured interviews, participatory mapping workshops, household/individual surveys, and follow-up interviews (Table 1). Secondary data used in this thesis consists of peer-reviewed publications that synthesize the state of knowledge on the diverse functions of pastoral TEK, as detailed in Chapter 2.

Table 1. Overview of the main data collection methods and primary data gathered, with corresponding chapter.

Method	**Type**	**Sample size**	**Main data collected**	**Chapter**
Online interviews	Qualitative	n = 4 individuals	Preliminary understanding of how herders traditional forecast weather; proverb collection	4
Participant observation	Qualitative	/	herding practices, interactions with nature, community dynamics, and cultural practices	3, 4
Semi-structured interviews	Qualitative	n = 43 individuals	Detailed accounts of past applications of mobility, herd breeding, herd sharing, and weather forecasting knowledge.	3, 4
Participatory community mapping workshops	Qualitative	n = 3 workshops	Past gacha-level mobility practices prior to 1984	3
Participatory household mapping workshops	Qualitative	n = 30 workshops	Current household-level mobility practices	3

Household surveys	Quantitative	n = 200 households	Current application of herd sharing practice	3
Individual surveys	Quantitative	n = 227 individuals	Current application of herd breeding and weather forecasting knowledge	3, 4

Living with various herders' families during the research period allowed me to reconnect with the herders. Engaging in daily activities such as herding, domestic chores, meals, and cultural celebrations brought me back to the lifestyle that I had been away from for a long time. As a member of the community, I had long established a foundation of trust and familiarity with the herders. Importantly, I understood the subtle intricacies of our cultural dialogue, which is particularly important given the characteristic communication style of the Ujimchin herders.

If you know the herders in the area long enough, you will know the "*gorben gui*" or "three no's" characteristic of them. If you ask, "Do you know...?", they typically reply, "I don't know"; "Have you heard of...?" would often get the answer "I never heard of it"; and "Can you...?" is replied with "No, I cannot." This conversation pattern isn't just a quirk; it's a cultural shield against superficial engagement. It means that to have a meaningful engagement with them, especially about their herding knowledge, one must ask questions that demonstrate a genuine and informed interest. This is crucial because the herders have little patience for outsiders who know nothing of their ways and just as little for those who presume too much familiarity. Growing up in the area has taught me how to maintain this delicate balance, how to engage deeply without overstepping cultural boundaries. They are not fond of flattery or excessive praise about their culture. Instead, they value and open up more in conversations that challenge their knowledge and ways of being in a respectful and insightful manner.

The primary data for my research were all collected in Mongolian. All interviews for this research were audio-recorded and conducted in Mongolian. The recordings were transcribed verbatim in

Mongolian, and a local community member fluent in both Mongolian and English translated the transcripts into English. During the translation process, she left culturally specific or ambiguous terms untranslated. I then reviewed these sections to ensure accuracy and preserve cultural nuance. When clarification was needed, I contacted participants directly—either by phone or, when possible, in person.

4. Case Study: East Ujimchin

4.1. Study Area

East Ujimchin Banner is situated within the Shilingol League in northeastern Inner Mongolia, China (Figure 1). The administrative structure of Inner Mongolia is organized into *aimag* (league), which are further subdivided into *huxuu* (banner). Each banner is made up of several *sumu* (township), and these, in turn, consist of *gacha* (the smallest administrative unit).

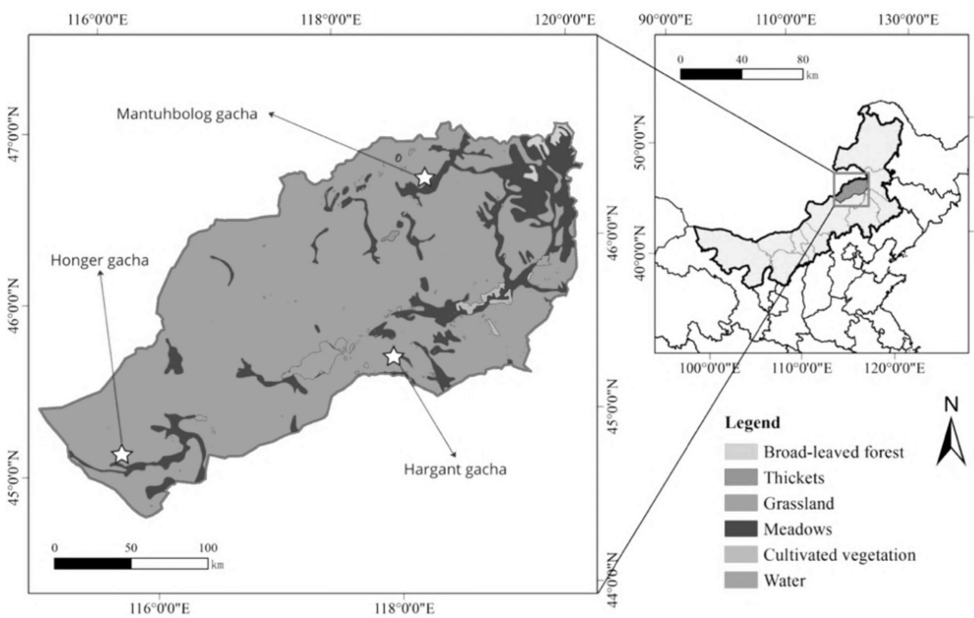

Figure 1. Map of the study area showing the locations of the selected sites - *Honger, Hargant, and Mantuhbolog gacha.*

Rooted in the Mongolian word for 'grapes,' Ujimchin translates as 'grape people.' According to local oral history, the grape mountains in the Altai-Hanggai region were the ancestral land of the Ujimchin Mongolians (Belguntai, 2006) (see Figure 2). Until today, Ujimchin herders place their saddles and cooking pots in the direction of their origin, to remember their history. With a population of 46,419 people, Mongolians make up 74.7% of the banner's total population (East

Ujimchin Bureau of Statistics, 2020). The banner's 4,611,300 hectares overall rangeland area (East Ujimchin Banner Government Office, n.d.) is nearly equivalent to the size of the Netherlands.

East Ujimchin lies at elevations between 800 and 1,500 meters above sea level, sloping from higher ground in the north toward the south and west (East Ujimchin Banner Government Office, n.d.). The region falls within the northern temperate continental climate zone and is characterized by a semi-arid climate (Li et al., 2016). It experiences four distinct seasons. Spring is unpredictable, characterized by fluctuating conditions that include snow, rain, and frequent windy days. Summer generally features high temperatures with regular rainfall. In contrast, autumn is relatively cool, with minimal rainfall and stable weather. Winter is intensely cold, often marked by significant snowfall. Annual precipitation ranges from 200 to 350 mm, while evaporation can exceed 3,000 mm. The average annual temperature is around 1.6°C, with extremes ranging from 39.3°C in summer to -40.5°C in winter (East Ujimchin Banner Government Office, n.d.; Uriyaanhan, 2018). These climatic and environmental conditions shape a temperate steppe ecosystem dominated by species such as Stipa grandis, Stipa krylovii, Leymus chinensis, Cleistogenes squarrosa, Artemisia frigida, Caragana microphylla, and Agropyron cristatum (Li et al., 2016).

4.2. Traditional Ecological Knowledge of East Ujimchin Herders

Mongolian *nuudel maljil* (nomadism) represents a traditional socio-ecological system characterized by three interconnected core components: *baigal* (nature), *tavan hoshuu mal* (the five primary livestock species: sheep, goats, cattle, horses, and camels), and *malqin* (herder) (Boyanbaatar, 2018). Among these, nature is the foundation. Mongolian herders believe that an imbalance in nature can lead to catastrophic events. They think that different and legitimate ways of being, such as humans, animals, stones, and rivers, are conceived as a collection of energies that influence and balance each other mutually.

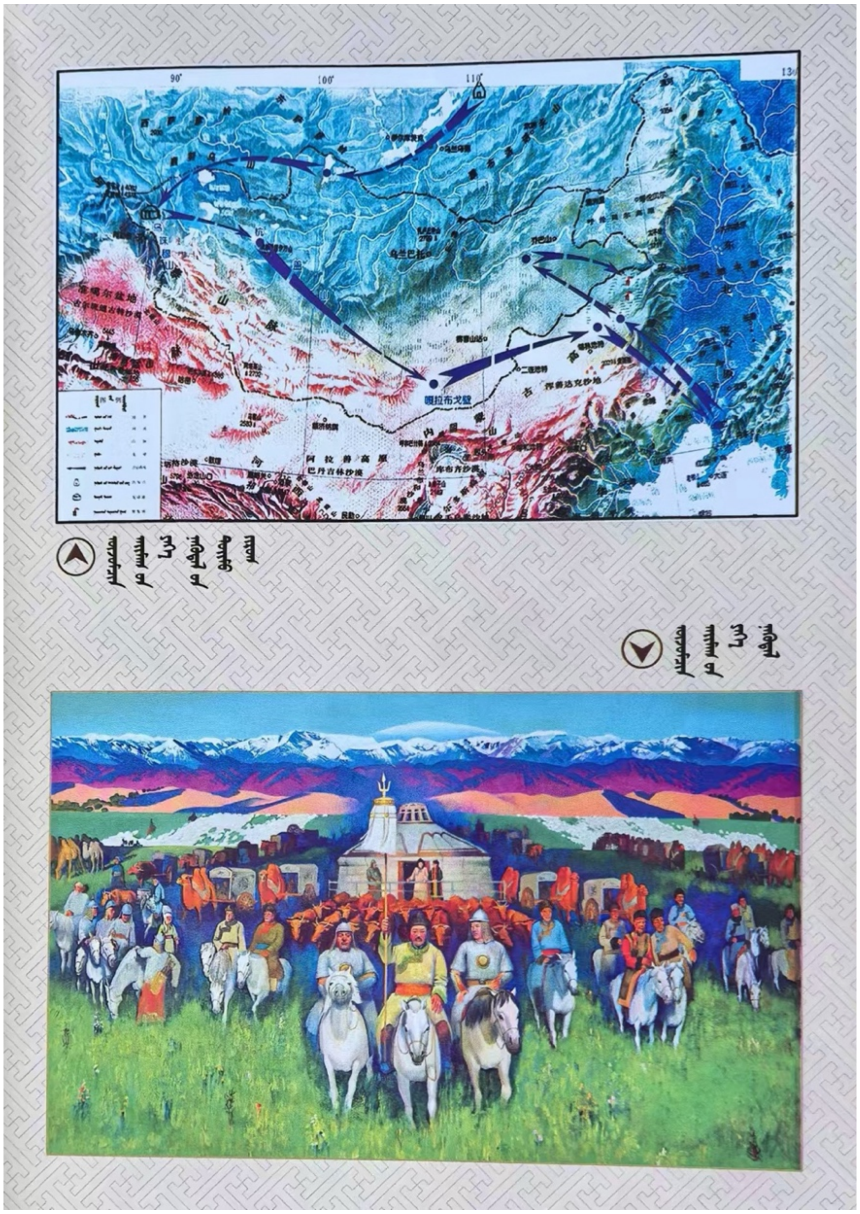

Figure 2. Migration route of Ujimchin Mongolians (from Ulji, 2013).

Through centuries of close interaction with their environment, herders have developed a deep understanding of natural cycles and ecological processes. Their practices are aligned with what they refer to as the "rules of nature," aiming to prevent environmental degradation and maintain ecological balance (Chao et al.,2023). Mobile grazing is one of the key practices that reflects this close relationship with nature. Traditionally, herders manage all five types of livestock and follow a highly strategic and organized movement, respecting the rules of nature. Such movement is crucial for the sustainability of grassland ecosystems, as it allows vegetation periods of rest and recovery (Fernández-Giménez & Le Febre, 2006; Sharifian et al., 2023).

On a yearly basis, East Ujimchin Banner experiences a wide range of climatic challenges. The northeastern region frequently faces harsh winter snowfalls and summer floods due to its mountainous terrain. In spring, strong winds are common across the region, and the western desert zone is particularly prone to sandstorms. The northern part of the banner also experiences seasonal wildfires, especially in spring and autumn. To cope with this complex and unpredictable environment, herders rely on more than just mobility strategies. They also utilize their forecasting knowledge, sophisticated understanding of the landscapes, knowledge of waterways, plant species and their nutritional values, as well as the strengths and weaknesses of each type of livestock.

Livestock in East Ujimchin are more than a means of subsistence; they are central to Ujimchin identity and survival in local uncertainties. To ensure that livestock adapt to the extreme temperatures and resource scarcity of the area, herders have been practicing selective breeding for generations. They choose male livestock based on traits like coat color, hair density, and other physical characteristics, which indicate the animal's ability to thrive in the local environment (Boyanbaatar, 2018). For example, sheep with black ears, snout, eyes, and neck are often preferred to sheep without these characteristics as they have better resilience against the region's harsh climate (Belguntai, 2006).

As noted earlier, pastoral life is inherently uncertain, with herders frequently encountering environmental challenges and hazards (Reid et al., 2014). Consequently, collaboration and reciprocal support systems among herders are not merely beneficial, but rather essential for their survival in these variable environments (Fernández-Giménez et al., 2008). In response to adversities such as harsh winters or other natural disasters, East Ujimchin herders engage in 'herd sharing'—a practice where herders share female livestock with those who have suffered losses, enabling them to rebuild their livestock. This arrangement is also beneficial in situations where a family faces labor shortages and cannot manage their full livestock effectively. In such cases, herders entrust their young female livestock to another reliable family. Typically, the receiving family receives the wool and milk produced, as well as a share of any offspring, as compensation.

This practice not only acts as a crucial safety net but also strengthens social bonds, ensuring that herders can maintain their way of life in the face of ongoing challenges (Uriyaanhan, 2018).

4.3. Major Historical Rangeland Policies in the Area

Until 1958, livestock and land in East Ujimchin were managed collectively within larger communal units known as *sums*. After 1958, management shifted to a more localized *gacha* level, though it remained collective. In 1984, land tenure reform was implemented, transitioning from collective management to a market-oriented system based on privately owned land, with the aim of improving efficiency and grassland management (Xie & Li, 2008). While initially enhancing household economic conditions, the reform also heightened the vulnerability of pastoral SES to environmental variability and climate change. Many scholars have noted that this policy has contributed to increased grassland degradation and has adversely impacted herder livelihoods through reduced mobility and fragmented grazing patterns (Xie & Li, 2008; Han, 2011).

Since the privatization of land, the central government has also intensified efforts to enhance the economic conditions in pastoral regions by promoting the transition from traditional mobile pastoralism to a more sedentary one. This policy shift, driven by state narratives that characterized nomadic lifestyles (居无定所) as backward, sought to fundamentally transform traditional pastoral practices. The "12th Five-Year Plan for the Construction of National Nomadic Settlement Project" explicitly linked traditional mobile pastoralism to poor living conditions and to increased vulnerability to natural disasters (National Development and Reform Commission, 2012). Following these settlement policies, by 2010, most formerly nomadic households in Inner Mongolia had adopted more sedentary lifestyles, residing in permanent brick structures on allocated land parcels. As of 2010, only about 3000 households, comprising 12,000 herders, maintained their mobile pastoralist practices (National Development and Reform Commission, 2012).

In tandem with these changes, a major grazing ban policy was introduced in the early 2000s, targeting severely degraded grasslands (Li & Huntsinger, 2011). The ban included both partial and complete restrictions on livestock grazing, with the goal of reversing desertification and restoring ecological balance. In many cases, the policy was accompanied by ecological migration programs, which relocated herders from traditional grazing areas to urban settlements. While the policy aimed to promote grassland recovery, it often disrupted long-standing grazing practices and pastoralist livelihoods, leading to socio-economic challenges and loss of cultural identity (Li et al., 2016).

In addition, the local government has implemented several livestock incentive programs to boost the productivity and economic viability of herding. Starting in 1958, these programs primarily focused on crossbreeding local herds with imported commercial breeds. A significant example was the effort to replace local Ujimchin fat-tail sheep with the Australian Merino breed, known for the quality of their wool and high market value. This effort, which continued for nearly 25 years, ultimately failed after the land tenure reform (Uriyaanhan, 2018). Between 1965 and 1985, the Ujimchin white horses were also targeted for replacement due to their perceived 'lack of market value.' Similarly, from 2005 to 2007, the local government ordered the replacement of the Ujimchin cattle breed with Simmental cattle, known for the value of its meat. The Ujimchin white goat is characterized by cold resilience, attributable to its long, heavy, and soft cashmere and large body size. However, in 2009, the local government criticized this breed for its 'low wool production' and 'harmful effects on vegetation and pastures' (Uriyaanhan, 2018). As a result, herders were incentivized to replace it with other breeds with higher wool yields. Ironically, only five months later, the national government officially recognized the Ujimchin goat as a valuable national breed. Introducing external breeds and undervaluing local breeds has not only affected the lineage makeup of local livestock but also disrupted traditional breeding practices that were finely tuned to the ecological and climatic realities of East Ujimchin (Uriyaanhan, 2018).

5. Specific Objectives and Structure of the Thesis

The aim of this thesis is to understand the diverse roles that TEK systems play within pastoralist communities, and to explore their contemporary relevance—how such knowledge endures, adapts, and continues to support herders in responding to present-day challenges. This overarching aim unfolds into three specific research objectives, each addressed in a core chapter of the thesis:

- To examine how pastoral TEK helps herders globally to adapt and thrive amid changing environmental and socio-economic pressures (Chapter 2).

- To investigate the resilience of TEK systems among herders in East Ujimchin Banner, Inner Mongolia, China, with a focus on the intrinsic resilience mechanisms embedded within TEK (Chapter 3).
- To explore the traditional weather forecasting knowledge of herders in East Ujimchin by collecting, interpreting, and analyzing the persistence of weather-related proverbs (Chapter 4).

This thesis is organized into three parts and five chapters. The first part, i.e., this chapter, provides a comprehensive introduction to the research topic, methodological approach, and background of the case study (Chapter 1). It includes an overview of East Ujimchin Banner, focusing on its historical context, policy environment, local ecological knowledge systems, and the environmental changes currently affecting the region. The second part contains a systematic literature review that explores the diverse domains of pastoral TEK and the diverse roles it plays in helping pastoral communities adapt to socio-ecological changes (Chapter 2). The third part consists of two empirical chapters based on fieldwork conducted in East Ujimchin. The first of these chapters focuses on traditional mobility practices, herd breeding strategies, and herd sharing systems, examining how these practices have adapted or persisted in the face of contemporary pressures (Chapter 3). The second empirical chapter explores traditional weather forecasting knowledge through the collection and analysis of proverbs (Chapter 4). I end the thesis with a final chapter that presents the main conclusions (Chapter 5).

The empirical chapters contain some overlapping background and methodological details, which may appear repetitive. However, I have chosen to maintain the format in which they have been published (or sent for publication) to maintain internal cohesion within the chapter. As of January 2025, the literature review has been published, while the two empirical chapters have been submitted to peer-reviewed journals. All three papers were co-authored, with me as the lead author.

Chapter 2 synthesizes global insights on the dynamic functions of Pastoral TEK using a systematic review of 152 case studies across 62 countries. Through a functional lens, this chapter explores how pastoral TEK contributes to ecological, economic, and socio-cultural resilience among pastoralist communities, emphasizing its multifunctionality and adaptability in the face of environmental and socio-economic pressures. Additionally, it explores the overlapping and synergistic functions across different knowledge domains. This chapter corresponds to the article "Exploring the dynamic functions of pastoral traditional knowledge," published in *Ambio* (2025).

Chapter 3 explores the resilience of TEK among herders in East Ujimchin Banner, Inner Mongolia. Focusing on the continuity and adaptation of three key practices—mobile grazing, herd breeding, and herd sharing— it examines how these practices persist, evolve, and serve multiple functions under shifting socio-environmental conditions. The chapter also investigates the evolving role of each practice in shaping herders' lives, both historically and in the present. This chapter corresponds to the article "Understanding the Traditional Knowledge Systems Through a Resilience Lens – Case Study in East Ujimchin Banner, Inner Mongolia," which has been accepted, pending major revision, in *Ecology & Society*.

Chapter 4 explores the role of traditional weather-related proverbs as carriers of climate knowledge among herders in East Ujimchin Banner. I collected and analyzed 28 weather-related proverbs to examine their characteristics, recognition, usage, and perceived reliability across different sociodemographic groups. In this chapter, I argue that these proverbs not only support local climate adaptation but also reinforce autonomy and cultural continuity. This chapter corresponds to the article "Everything is Talking to Us: Understanding Traditional Weather Forecasting Knowledge through Proverbs in East Ujimchin Banner," under review in *Weather, Climate, and Society* in April 2025.

Chapter 5 serves as a comprehensive discussion of the research findings presented throughout the thesis. This concluding chapter synthesizes the key results from the preceding chapters, drawing on both theoretical and methodological perspectives to address the primary research question. Additionally, the chapter identifies the limitations of the thesis, suggests areas for future research, and proposes potential policy implications stemming from the research findings.

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Chapter 2

Exploring the Dynamic Functions of Pastoral Traditional Knowledge

Photo credit: Jesse Segura (2023)

This chapter corresponds to the article:

Chao, O., Li, X. & Reyes-García, V. Exploring the dynamic functions of pastoral traditional knowledge. *AMBIO* (2025). https://doi.org/10.1007/s13280-025-02131-x

Abstract

Pastoral traditional knowledge is increasingly recognized for its inherent adaptability in addressing contemporary challenges and increasing the resilience of pastoral communities. To deepen our understanding of how this knowledge system demonstrates adaptive characteristics, we employ a functional lens to examine its dynamic nature in this systematic review. Our analysis, based on insights from 152 case studies worldwide, shows that this knowledge system has various domains and serves diverse functions, including ecological, economic, and socio-cultural functions, with further subfunctions. Ecologically, pastoral traditional knowledge predominantly enhances climate adaptation and resilience; economically, it helps maintain herd productivity and sustain livelihood support; and socio-culturally, it is crucial for preserving the cultural identity and heritage of pastoral communities. Furthermore, our findings highlight that each knowledge domain shows multifunctional characteristics. Our analysis also helps identify common functions across eight knowledge domains, each contributing to areas such as sustainable resource management and climate adaptation, though to varying degrees.

Keywords: Knowledge Functions, Pastoral Traditional Knowledge, Resilience, Pastoralism, Traditional Ecological Knowledge

1. Introduction

Rangelands, covering around 25–45% of the earth's land surface, are remarkably diverse, including semi-arid savannas, grasslands, mountainous regions, and arid deserts (Reid et al., 2014). Within these varied landscapes, pastoral communities have developed rich and distinctive bodies of knowledge shaped by intimate and enduring interactions with the local environment (Reid et al., 2014; Sharifian et al., 2023; Tugjamba et al., 2023). These knowledge systems are rooted in traditions that have accumulated over generations and continue to evolve (Reyes-García et al., 2014). The dynamic nature of pastoral traditional knowledge (PTK) plays a crucial role in the survival of pastoral communities, enabling them to navigate various challenges and enhancing their resilience, understood as their capacity to absorb disturbance, maintain functionality, and adapt in response to change (Folke, 2006; Arjjumend, 2018; Ahmed et al., 2023).

Currently, pastoral communities face numerous challenges. Climatic variability has a considerable impact on pastoralists' traditional ways of living and the natural environment they depend on. With advancing climate change, pastoralists are witnessing greater unpredictability in climatic patterns, more intense droughts, increasing land degradation, and declining pasture quality (Ifejika Speranza, 2010; Ahmed et al., 2023). Socio-economic pressures such as market influence, urbanization, and extraction of natural resources have been exacerbating pressure on the already overloaded adaptive capacity of pastoral communities (Galvin, 2009). Beyond this, policies or conflicts regarding land ownerships also put further restrictions on traditional grazing for access to fundamental resources, aggravating these vulnerabilities (Xie & Li, 2012). These ecological and socio-economic challenges threaten not only the ecological balance but also directly influence the livelihood and cultural continuity of pastoral societies.

Despite these challenges, pastoral communities persistently employ and renew their traditional knowledge, continually learning from and adapting to changing environmental conditions and socio-economic landscapes. In addressing the challenges posed by climate variability, pastoral communities have developed a diverse range of adaptive strategies that reflect the depth of their traditional knowledge. These include predicting weather patterns by observing animal behavior, plants, and natural phenomena, as well as employing practices such as herd mobility, herd diversification, and herd sharing (Arjjumend, 2018; Radeny et al., 2019; Ochieng' et al., 2020). For example, shamans of the Tukano people of Colombia monitor species abundance by randomly scheduling hunting excursions. Monitoring ecosystem changes is another key function of many traditional knowledge practices that can be seen amongst the Sahel herders who observe grazing pressure and the condition of pastures to inform their decisions on when to rotate or move their herds (Berkes et al., 2000). The practice of herd mobility also exemplifies how pastoralists manage rangeland ecosystems in a way that is sustainable. This key practice involves strategic movements of herds to alternate grazing areas, the movement being crucial for allowing time for degraded pastures to recover (Dominguez et al., 2010; Stammler-Gossmann, 2010).

Besides its ecological significance, PTK also helps communities achieve significant economic benefits. For example, pastoralists have a rich understanding of the nutritional values of different plants. This includes knowing which plants induce milk production, which plants are the best for weight gain, and which others improve general livestock health (Sharifian et al., 2023). Using this specialized knowledge of forage/plants, pastoralists make informed decisions about when and where to graze their livestock (Fernández-Giménez, 2000; Molnár, 2017). Moreover, the geographical dispersion of pastoralist settlements across extensive grasslands, often isolated from one another, necessitates a reliance on the social-cultural dimensions of PTK. For instance, kinship-based social networks are instrumental in enabling pastoralists to exchange experiences, share resources, and mitigate risks (Salpeteur et al., 2015; Chao et al., 2023). Diversifying livestock species and breeds also functions as a risk management strategy, allowing pastoralists to manage various climate conditions as certain species or breeds show better drought tolerance, whereas others are more adapted to the cold (Ghorbani et al., 2013).

Beyond ecological and economic functions, PTK also plays essential roles in the preservation of the socio-cultural fabric of pastoral communities. The traditional knowledge, practices, and culture developed by pastoral communities in the management of their environments and existence primarily provide additional support to the socio-cultural continuity in the pastoral communities (Oteros-Rozas et al., 2013; Stolton et al., 2019). For example, the traditional customary laws and governance systems that regulate access to communal resources, such as pastures, can facilitate conflict resolution among different groups or families (Sundstrom et al., 2012; Kaoga et al., 2021). Moreover, herd breeding also brings forth these socio-cultural functions, as the selection of breeding stock is sometimes ritualistic and associated with traditional ceremonies and festivals, which enhance community ties and preserve heritage (Gandini &Villa, 2003; Ahozonlin & Dossa, 2020).

From climate-related knowledge to social-cultural wisdom, the application of the various components of PTK to tackle different challenges suggests the diverse functions that the knowledge system can play in pastoral life. While taken as a whole, the PTK system plays various functions at different levels of pastoral life, each knowledge domain within the system also shows multifunctional characteristics. For instance, the practice of herd mobility is not only instrumental in sustaining herd health, but it also serves as a crucial strategy for pasture preservation (Wario et al., 2016). Similarly, cultural practices are also multifaceted, playing a vital role not just in the maintenance of cultural identity and community cohesion but also in prompting ecological sustainability (Dominguez et al., 2010; Ghorbani et al., 2013; Chao et al., 2023). Similarly, traditional forage/plants-related knowledge, not only contributes to livestock productivity and, therefore, determines economic stability but also supports ecological management through fostering sustainable grazing practices (Sharifian et al., 2023). Moreover, this knowledge sometimes holds cultural importance, appearing in traditional healing practices and rituals (Frascaroli et al., 2014).

In addition to the multifunctional characteristics within each domain of PTK, different knowledge domains synergistically contribute to achieving common objectives and outcomes. Traditional knowledge systems are holistic and complex (Berkes et al., 2004; Berkes, 2012). Different types of knowledge do not exist and operate in an isolated way; rather, they are interconnected. For instance, if unexpected weather changes occur, communities rely not solely on their knowledge about climate and weather (Radeny et al., 2019); they also utilize their knowledge about landscapes (Wangdi & Norbu, 2018), forage/plants (Fernández-Giménez et al., 2021), livestock (Shukurat et al., 2012), and even spiritual rituals (Roncoli et al., 2001) to adapt to the changes from different angles holistically.

To dig deeper into how PTK helps pastoralists adapt and thrive amid changing environmental and socio-economic pressures, we decided to apply a functional lens in this study. The function of knowledge, within this context, refers to the deliberate use of knowledge to achieve specific objectives as well as the actual impacts or outcomes of the knowledge. Specifically, we review the literature 1) to document the domains of PTK, 2) to explore the diversity of functions PTK serves in the lives of pastoralists, 3) to investigate whether a single PTK domain can serve multiple functions, and 4) to examine whether different PTK domains share common functions. The current literature acknowledges the contribution of the multifunctional nature of PTK in climate adaptation (Reid et al., 2014) and sustainable management of rangeland and livestock (Oba, 2012), but to date, no study has explicitly and systematically reviewed PTK through a functional lens.

2. Methodology

2.1 Selection of Publications

Our review used primary sources from peer-reviewed literature on PTK from the Web of Science and Scopus. The search was conducted in July 2022 and included publications up to that date. To ensure a comprehensive exploration of PTK and its functions, we developed a detailed search string that encompassed terms that explain the dynamic functions of PTK. This choice helped us to explore how PTK serves multiple purposes in different contexts, especially under different environmental and socio-economic pressures. The search string used was TS= ((traditional OR Indigenous OR local OR past OR old OR folk OR aborigin) AND (pastoral* OR nomad* OR herd* OR shepherd OR flock) AND (ecology* OR environment* OR rangeland OR grassland) AND (knowledge* OR practice* OR strategy*)) AND TS= (adapt* OR cop*).

The initial search yielded 1076 documents (WoS = 432; Scopus = 644). After removing overlapping documents based on DOI, title, and abstract comparisons (n = 318), we thoroughly screened 758 publications for relevance to our review, focusing on title, abstract, and methods. During the screening process, we followed strict criteria to ensure the quality and relevance of selected studies. We included only peer-reviewed studies that provided empirical evidence of PTK and had a clear focus on PTK. Studies that only partially addressed PTK were included if the relevant section to PTK provided detailed insights. Publications were restricted to those available in English or Chinese. The inclusion of Chinese-language studies is tied to the first author's ability to speak Chinese. This linguistic focus, however, introduces a potential bias by excluding significant works published in other languages, especially from other regions where pastoralism is prevalent, such as Africa and Central Asia. While the concept of adaptation was a significant aspect of our search, its explicit mention was not a prerequisite for inclusion. This approach allowed us to consider a broader spectrum of documents that offered valuable insights into the diverse functions of PTK, extending beyond mere adaptive responses. Ultimately, 149 papers met our criteria and were included in the review. The list of publications included is presented in the supplementary material (Table S1).

2.2 Data Collection

During the data collection phase, each document was assigned a unique ID. For those documents containing multiple case studies, data for each case were collected separately. We recorded the geographical location of each case study and its climate zone using the Köppen-Geiger climate classification system. We also documented the characteristics of the study populations. This included noting their ethnic names, as mentioned in the original articles, and assessing whether they were identified as Indigenous groups by the authors of the publication.

Additionally, we documented the types of livestock managed and the various pastoral practices of these communities. We distinguish among *nomadism*, characterized by the regular movement of herds to new pastures; *transhumance*, involving seasonal migration between fixed pastures; *agro-pastoralism*, which combines crop farming with pastoralism; and *sedentarism*, indicating settled herding with limited livestock movement. Verbatim statements referring to PTK and its application were recorded from each selected paper. While all selected statements were directly relevant to the following aspects: the application of PTK, the motivations for its application, and the outcomes of associated knowledge practices, some relevant quotes might be unintentionally excluded.

2.3 Data Analysis

To document PTK domains, we conducted qualitative thematic analysis and coded the verbatim statements referring to PTK in Nvivo (Table S2). We categorized the extracted data into several knowledge domains based on a classification framework from Sharifian and colleagues (2022), which organizes PTK into the following domains: livestock, forage/plants, landscape, climate/weather, and social-cultural knowledge. During the coding process, we created additional cross-knowledge practices based on frequency of occurrence. For example, in our study, we distinguish 'herd mobility practice' and 'herd diversification practice' from the broader 'livestock-related knowledge' domain. This distinction is based on our understanding that these domains not only involve knowledge of the livestock but also encompass a comprehensive understanding of landscape, forage/plants, and climate/weather.

To investigate the diverse functions of PTK within pastoralist communities, we coded quotes from the selected cases using the qualitative data analysis software Nvivo (Table S2). Each quote was coded based on its thematic content and relevance to specific functional categories. Initially, all quotes relevant to PTK and its applications were classified into three main categories used in social-ecological systems research (Folke et al., 2002; Boström, 2012): ecological function, economic function, and social-cultural function.

Within the three functional categorizations, we identified 10 subfunctions of PTK using an inductive qualitative content analysis. To develop these subcategories, we thoroughly reviewed the verbatim statements of PTK functions extracted from the publications and applied Nvivo coding to identify emerging themes.

Furthermore, to ensure accuracy and reliability, following the initial coding process by the lead author, the two other co-authors independently reviewed the codes assigned by the primary coder. To address coding discrepancies identified during the independent reviews, including whether to separate 'herd mobility practice' and 'herd diversification practice' from the livestock-related knowledge domain, we had a meeting during which we examined each issue raised by the second and third authors. In cases where a consensus could not be reached, the first author made the final decision.

Additionally, we quantitatively assessed the distribution of the coded functions among different domains using the R program, specifically ‘dplyr’ for descriptive analysis and ‘ggplot2’ for data visualization. Specifically, to assess the diverse functions of PTK, we first counted the mentions of knowledge that contributes to ecological, economic, and social-cultural functions. Then, for each main functional group, we calculated the percentage of different knowledge domains contributing to that group. Furthermore, we conducted a detailed analysis to understand the weight of different subfunctions within the three main functions. We categorized the knowledge that play ecological functions into sub-ecological groups. The same approach was applied to the economic and social-cultural function categories.

Using ‘dplyr’, we evaluated the distribution of different functions across various PTK domains and analyzed how these knowledge domains contribute to various functions by calculating the percentage distribution within each sub-functional group. The common functions among these domains were also assessed. This involved calculating the frequency and percentages with which different domains (livestock, forage/plants, landscape, climate/weather, social-cultural, mobility, herd diversification, and other) contributed to the same function. Visualization with ‘ggplot2’ offered insightful representations, including pie charts and bar charts to depict PTK functions and stacked bar charts to illustrate the distribution of functions within each domain.

Additionally, to comprehensively understand the distribution of case studies, practiced pastoral types, and pastoral knowledge domain across varying climate zones, spatial analysis was conducted using ArcGIS Pro.

3. Results

3.1 Overview of the Case Studies

Our review included 149 papers and 152 case studies from 62 countries, spanning all five main climate zones (Fig. 1). Case studies documented in our review were predominant in the dry climate, representing 38% (58 cases) of the total case studies. Following closely, cases in the temperate climate accounted for 24% (37 cases). The continental (22 cases) and tropical climates (23 cases) also represented a considerable portion of the dataset, with approximately 15% of the cases in each climate zone. Lastly, 12 cases (8%) were found in the polar climate.

In terms of pastoral practices, transhumance was the most prevalent, comprising 66% (101 cases) of the cases, followed by nomadism with 28% (42 cases). Agro-pastoralism and sedentarism together accounted for 6% (9 cases). In the analysis of pastoralism types across climate zones, nomadic groups were predominantly found in dry climates, representing 44% (27 cases) within this climate zone. Transhumance, however, was the leading pastoral practice in a variety of climates, with majorities in the temperate (33 cases, 83%), continental (13 cases, 59%), tropical (18 cases, 64%), and polar climates (9 cases, 64%). In contrast, sedentary practices and the combination of transhumance and agro-pastoralism were less prevalent and did not dominate any specific climate zone.

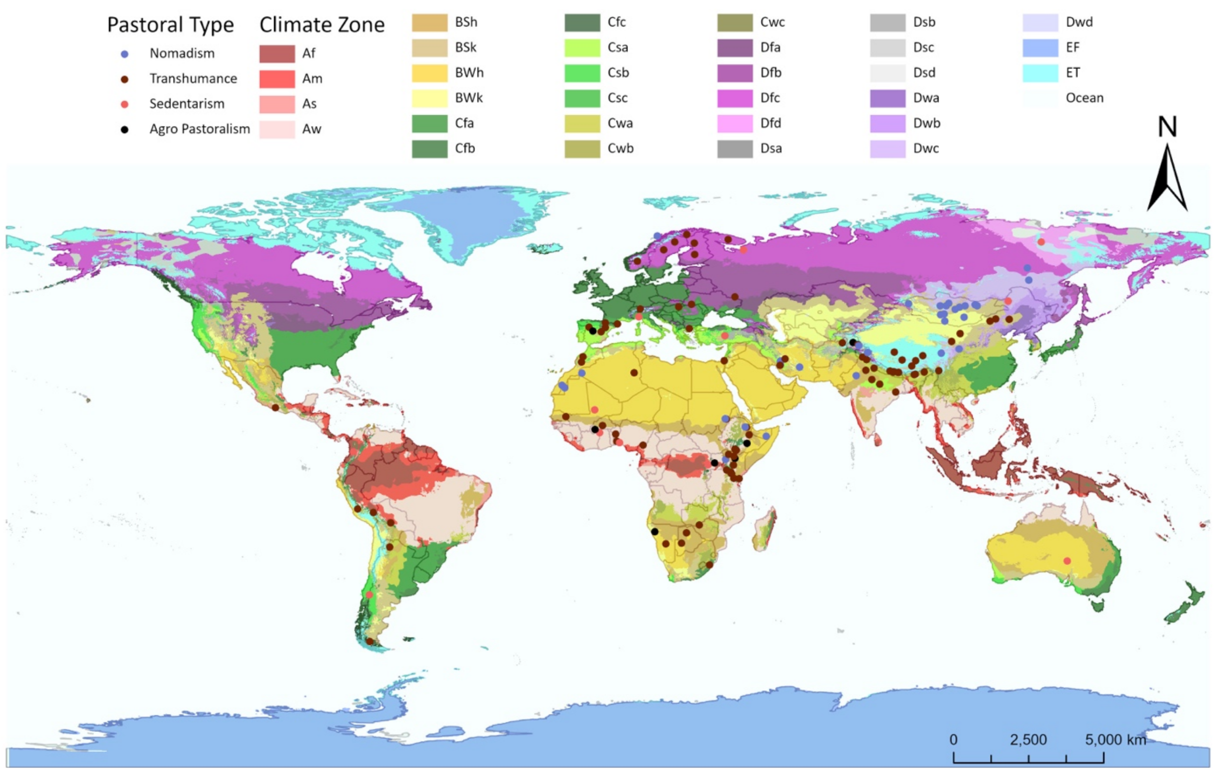

Figure 1 Global distribution of the case studies (n = 152) and pastoralism types, integrated with the Köppen-Geiger climate classification.

Our compilation included case studies from 81 different ethnic groups, of which 75 were identified as Indigenous Peoples in the original reference. While the dataset featured a range of ethnic groups, some of the more prominent ones were Mongolian (17%), Tibetan (5%), Sámi (3%), Borana (3%), and Maasai (3%). In the studied cases, pastoral communities managed different animals: cattle were reported in 65% of cases, sheep in 73%, goats in 66%, camels in 29%, horses in 29%, reindeer in 9%, and yaks in 15%. Interestingly, 28 cases (18%) exclusively focused on single-species herds, predominantly cattle. In contrast, most communities (n = 124; 82%) employed mixed herding strategies. The mixed herding strategy was most prevalent in dry climates, where we found 55 cases of mixed herding and three cases of single-species herding. Similarly, the temperate and polar climates also tended to favor mixed herding strategies (37 vs. 30 cases for temperate and 12 vs. 9 in polar). In continental and tropical climates, there was a more balanced distribution between single-species and mixed-species herds.3.2 Domains of PTK

Results from our analysis expanded upon the initial framework proposed by Sharifian et al. (2022), who identified five key knowledge domains: livestock, forage/plants, landscape, climate/weather, and social-cultural knowledge, by adding two new domains to this classification: herd mobility practice and herd diversification practice (Table 1). The distribution of different knowledge domains examined across case studies showed significant variation (Fig. 1). More than half of the case studies (84, 55%) reported only one or two knowledge domains, while 39% (59 cases) documented three to four domains. Notably, only 9 cases (6%) documented a range of five to six knowledge domains.

Among the knowledge domains documented, herd mobility was the practice most frequently reported, identified in 82% of cases (124 cases) across all climate zones. For example, nomadic movement was widely practiced by herders in Mongolia (Tugjamba et al., 2021). Knowledge associated with other types of mobility, such as the rotational grazing practiced by the Sámi people in Finland, was also recorded (Turunen et al., 2016).

Climate and weather-related knowledge was the second most highly cited knowledge domain, reported in 41% of the cases (n = 63). This knowledge was particularly crucial and widely applied in the dry climate zone (40%). Since many of the pastoralist communities resided in regions with highly variable climates, they developed knowledge to predict the upcoming weather through observing natural phenomena, as well as changes in animal behavior and plants (Oteros-Rozas et al., 2013; Klein et al., 2014; Guoping et al., 2021). These observations included changes in rainfall, snow patterns, wind behavior, and growing seasons (Fernández-Giménez & Fillat, 2012; Ghazali et al., 2021).

Social-cultural knowledge was highlighted in 29% of the cases (n = 44), with the presence of local institutions being the most frequently mentioned component. For example, in Nariyan, Iran, the Indigenous institution known as chakaneh enabled pastoralists to share responsibilities and resources, such as livestock management and access to grazing lands (Ghorbani et al., 2013).

Similar local institutions were also found in some other pastoralist communities (Postigo, 2020; Fernández-Giménez et al., 2021).

Many pastoral communities had deep connections with plant species in general and pastures in particular, which allowed them to identify whether a pasture was good or bad, and the functions of different plants. Forage/plants-related knowledge was mentioned in 26% of the cases (n = 40), particularly in the temperate climate zone (38%). For example, pastoralists in Shilingol League, Mongolia, had an extensive understanding of plant characteristics relevant to herding, including their seasonal edibility for different livestock (Huang et al., 2009).

Similarly, pastoral communities held rich livestock-related knowledge, or knowledge emphasizing the understanding of the specific needs and characteristics of livestock. This knowledge was reported in 40 cases (26%) and was particularly prominent in the dry climate zone (41%). As an example, the Borana pastoralists in Ethiopia had knowledge about the camel's unique capabilities, including its resilience to water scarcity, feed shortages, heat stress, and drought conditions (Megersa et al., 2014). Tibetan pastoralists in Yunnan, China, were adept at recognizing signs of disease or nutritional deficiencies in their livestock through behavioral and physical cues (Haynes & Yang, 2012).

Knowledge domains relatively less often examined in the literature included landscape-related knowledge and herd diversification practices. Landscape-related knowledge was found in 33 cases (22%). Pastoralists routinely observed and learned about their surroundings while herding. For instance, people living in Ansó, Spain, were cognizant of the changes happening in their landscape, such as the increase in shrub and forest cover (Fernández-Giménez, 2015). Herd diversification practice appeared in 24 cases (15%). The Maasai pastoralists in Kenya, for instance, advocated for herd diversification, arguing that this strategy optimized resource use and helped mitigate risks (Kaoga et al., 2021).

Table 1a. Pastoral Traditional Knowledge Domains.

Knowledge Domains	Definition	Frequency and Percentage	Example quote and reference
Livestock-related knowledge	This knowledge includes understanding the nutritional needs, well-being, grazing preferences, and unique characteristics of the livestock.	40 cases; 26%	*"They learn step by step how to identify their livestock from the rest, how to guard them and keep them healthy, how to herd them by using different signals and sounds."* (Malhotra et al., 2022, p 10)
Forage/plants-related knowledge	This knowledge involves the identification of plants, a detailed understanding of their characteristics, and their utilization.	40 cases; 26%	*"They also plant bechna (*Panicum miliaceum L.*, millet), a cereal crop widely used as fodder and food. The Tuareg mostly appreciate millet's nutritional value as fodder for sheep and goats."* (Miara et al., 2022, p 6)
Landscape-related knowledge	This knowledge refers to the traditional insights and techniques developed for interacting with and understanding specific landscapes.	33 cases; 22%	*"The Evenki topographic typology is a detailed collection of concepts that define mountains, hills, inclines, slopes, rivers basins, types of soil, snow specificities, etc. The socio-economic importance of topographic landscapes is huge to the nomads, as accessibility of these landscapes constitutes their richness."* (Lavrillier & Gabyshev, 2021, p 1913)
Climate/weather-related knowledge	This knowledge refers to information about the local climate, weather patterns, and seasonal variations that impact pastoral activities	63 cases; 42%	*"Some respondents indicated that they use different forecasting methods to predict the rain, such as bird movements, certain species of trees, wind patterns, phenology, presence and absence of certain animals, wind movements, moon and sun as indicators of whether they will have rain or not."* (Inman et al., 2020, p 11)

Table 1b. Pastoral Traditional Knowledge Domains (continued).

Knowledge Domains	Definition	Frequency and Percentage	Example quote and reference
Social-cultural knowledge	This knowledge is about the cultural traditions, social institutions, and community dynamics specific to pastoral societies.	44 cases; 29%	*"Adaptation strategies were mainly facilitated by local communal institutions, such as reciprocity and trust. The communal institutions were critical for climate adaptation in the remote Tibetan pastoral areas where local markets and economies were less developed."* (Wang et al., 2016, p 7)
Herd mobility practice	This practice refers to the movement of livestock groups from one location to another for different purposes.	124 cases; 82%	*"The second traditional management strategy is called "taking otor" in the Mongolian Language. During severe droughts, which affect large areas, herders would move temporarily over long distances to unaffected or less severely affected areas, perhaps even outside of the Alxa Left Banner. When local conditions improved, they returned to their original land."* (Zhang et al., 2013, p 184)
Herd diversification practice	This knowledge focuses on the trade-offs of diversifying the composition of the livestock.	23 cases; 15%	*"The herd's composition and diversity makes it possible for the animals to graze on several species of plants at the same time, which decreases pressure on the palatable plants in one area and also prevents the extinction of unpalatable species."* (Ghorbani et al., 2013, p 12)
Other	This domain includes knowledge that does not fit in any of the domains, such as holistic knowledge.	17 cases; 11%	*"By distributing livestock among a number of people in different places, pastoralists have been able to reduce the risks of livestock mortality during drought. This livestock loan system, called mafisa, is unique in southern Africa"* (Reed et al., 2007, p 252)

3.3 Diverse Functions of PTK

Our analysis suggests that PTK covers different ecological, economic, and social-cultural functions in pastoral systems (Fig. 2). PTK ecological functions refer to the roles and significance of PTK in interacting with and sustaining nature. PTK ecological functions include various subfunctions such as monitoring ecosystem health, preventing unsustainable resource use, predicting weather and climate variations, and maintaining biological diversity in the ecosystem.

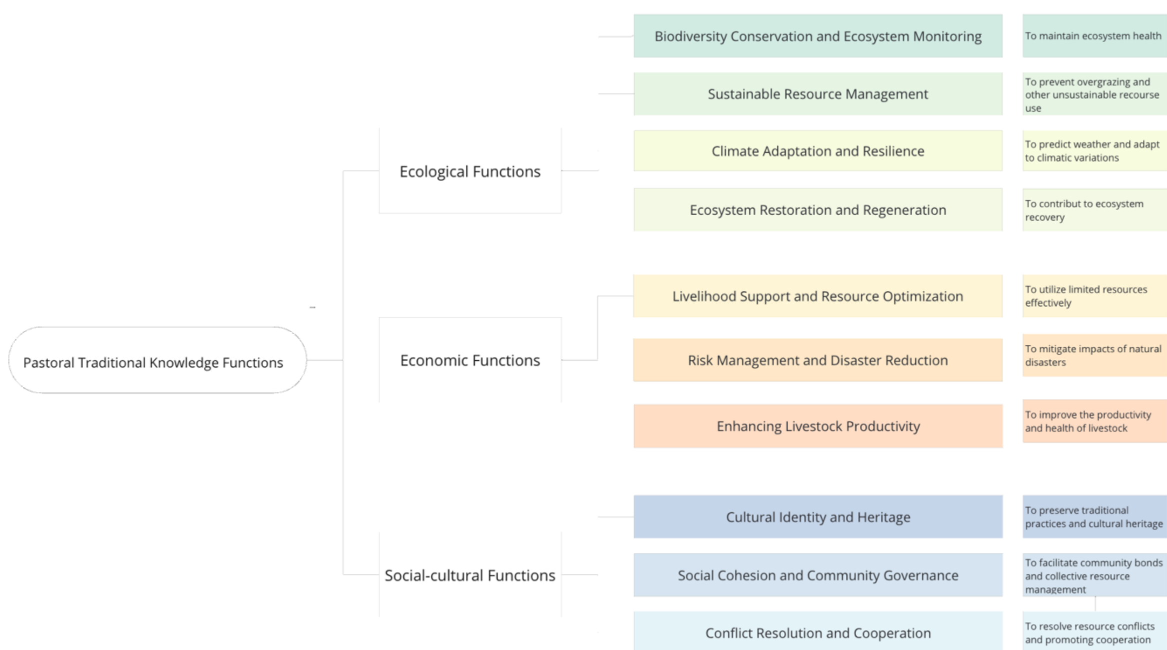

Figure 2 Flow chart presenting a classification of PTK functions

Within the dataset analyzed, a total of 252 citations were applied to support ecological functions. Upon examining the distribution of these citations among different knowledge domains, it was apparent that the domain of herd mobility practice was particularly significant. Thirty-one percent of the citations (n = 78) that described ecological functions belonged to herd mobility practice. For example, some communities used herd mobility to allow pasture regeneration, while others mainly used it to sustainably manage natural resources (Stammler-Gossmann, 2010).

Climate and weather-related knowledge was also prominently associated with ecological functions. Twenty-two percent of the citations that described ecological functions were found in this domain. For example, in various communities, weather forecasting knowledge was used to adapt to climate variations (Radeny et al., 2019; Inman et al., 2020). Finally, landscape-related knowledge made up 13% (n = 32) of citations that supported ecological functions. Controlled fire practice, for example, was used in many pastoral communities to encourage grass growth (Bollig & Österle, 2008).

PTK's economic functions referred to its role in enhancing the efficiency and sustainability of pastoralists' livelihoods. We identified three different subfunctions in this group: utilizing limited resources effectively, mitigating the impacts of natural disasters, and improving livestock productivity and health. Among all the recorded citations, 139 were identified as supporting economic functions among pastoral communities. The domain of herd mobility emerged as the most prominent within this economic category, with 43% (59 citations) attributed to the herd mobility practice. Pastoralists in Greece, for instance, maintained herd health and maximized herd productivity by moving them to different grazing areas to access fresh vegetation (Siasiou et al., 2020). Although forage/plants-related knowledge was not prominently featured for its ecological function, this knowledge domain made up 18% (26 citations) of PTK economic functions (Fig. 3). For example, the Rabari pastoralists in India utilized *Prosopis juliflora* leaves as medicine for herd skin infections to mitigate the loss of livestock productivity due to untreated ailments (Duenn et al., 2017). Livestock-related knowledge accounted for 11% (16 citations) of the economic functional group. For example, Sámi and Tibetan herders had the knowledge and skills to evaluate the clinical signs of their herd to prevent disease (Riseth et al., 2020; Haynes & Yang, 2012).

The social-cultural functions of PTK contributed to the maintenance of pastoral communities' cultural integrity and social structures. This functional characteristic stressed PTK's role not only in preserving traditional culture but also in enhancing the social bond of the community and promoting cooperation. Among the recorded citations, 59 were documented as fulfilling social-cultural functions. Social-cultural functions drew on social-cultural knowledge, which formed nearly half of this functional category (48%, 29 citations). However, it was interesting to note that livestock-related knowledge, accounting for 11% of all social-cultural functions, and landscape-related knowledge, representing 10%, also contributed meaningfully to the social-cultural fabric. For example, the tsamdro management practice of Brokpa pastoralists in Bhutan, which involved the use of dry-stack stone walls and wooden fences to manage livestock, reduced grazing conflicts, thus playing a crucial role in fostering social harmony within these communities (Wangdi & Norbu, 2018). Additionally, the deliberate choice by pastoralists to favor traditional livestock breeds was a way to sustain local pastoral culture and identity in many communities (Fernández-Giménez, 2015).

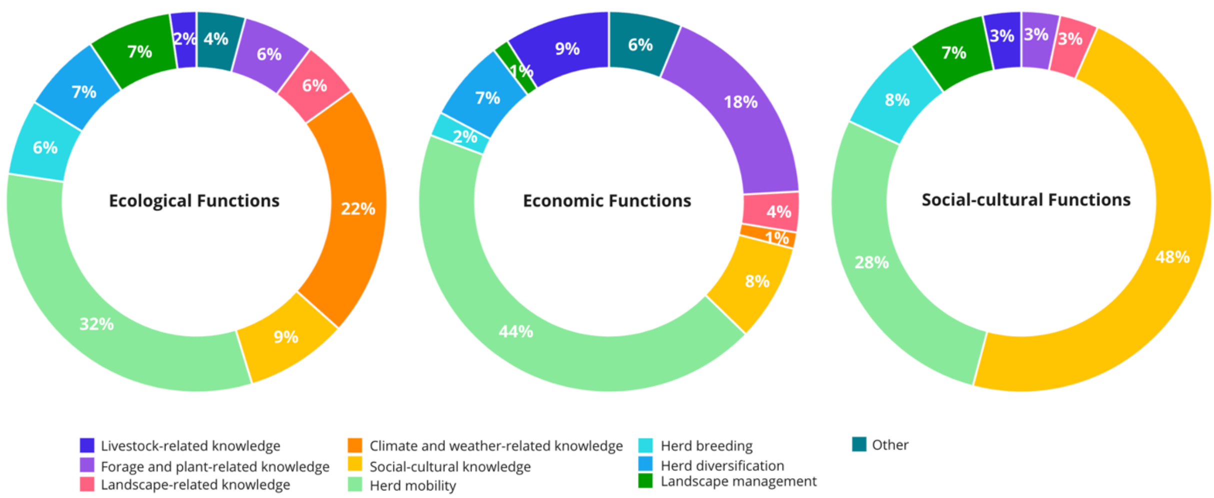

Fig. 3 Pie charts presenting the share of quotes (n = 393) of different PTK domains associated with ecological, economic, and socio-cultural functions

We further analyzed the data to better understand the weight of different subfunctions within the three main functions (Fig. 4). We did so by categorizing the 252 citations that described ecological functions into different sub-ecological groups. It was important to note that while some pieces of knowledge were unique to a single function, others had multiple functions. Likewise, the 139 citations that described economic functions and the 59 citations that described social-cultural functions were also further classified into specific subfunctions. The ecological functions of PTK stood out as the most common, with over half (58%) of the recorded subfunctions addressing four ecological functions: ecosystem monitoring, sustainable resource use, climate adaptation and resilience, and biodiversity conservation. Within ecological functions, climate adaptation and resilience was the most often cited subfunction, comprising 35% of all recorded citations. The subfunction of sustainable resource management represented 17% of the citations. Within economic functions, enhancing livestock productivity (14%) and livelihood support (12%) were two subfunctions most often cited. Overall, the social-cultural functions of PTK were the least often cited. Within those, cultural preservation (7%) was emphasized to a larger extent than some ecological and economic functions, including ecosystem monitoring and risk management.

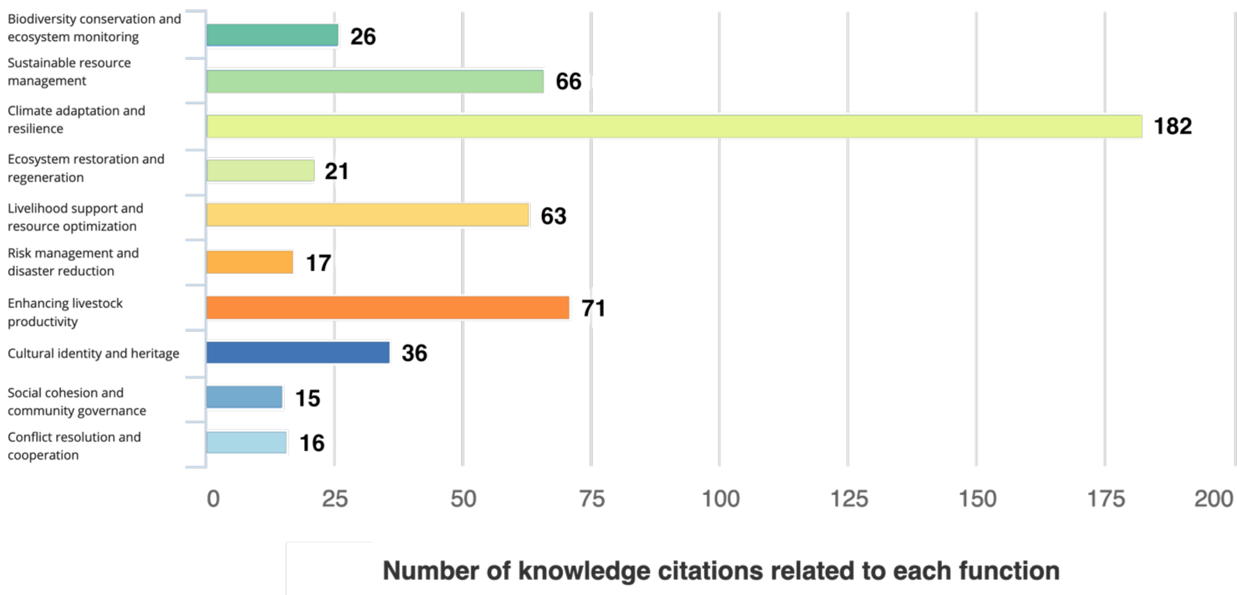

Figure. 4 Frequency of mention of different ecological, economic, and socio-cultural functions of PTK

3.4 Multifunctional Characteristics of PTK Domains

The visual representation of how different knowledge domains contributed to various functions revealed that most domains were connected to distinct functions (Fig. 5). For instance, social-cultural knowledge covered ten types of subfunctions, ranging from climate adaptation and resilience to social cohesion and community governance. Climate/weather-related knowledge (29%) contributed significantly to climate adaptation and resilience. Interestingly, livestock-related knowledge, which one might expect to predominantly impact areas directly related to herd management, such as productivity, in fact, showed a diverse range of functions. Indeed, while livestock-related knowledge contributed to herd productivity (11%), slightly more citations were observed in cultural identity preservation (17%), and sustainable resource management (12%). Another notable aspect was that social-cultural knowledge not only fulfilled important functions in cultural identity, social cohesion, and conflict resolution but also extended to ecological and economic subfunctions, such as contributing to climate adaptation and resilience (9%) and risk management (13%).

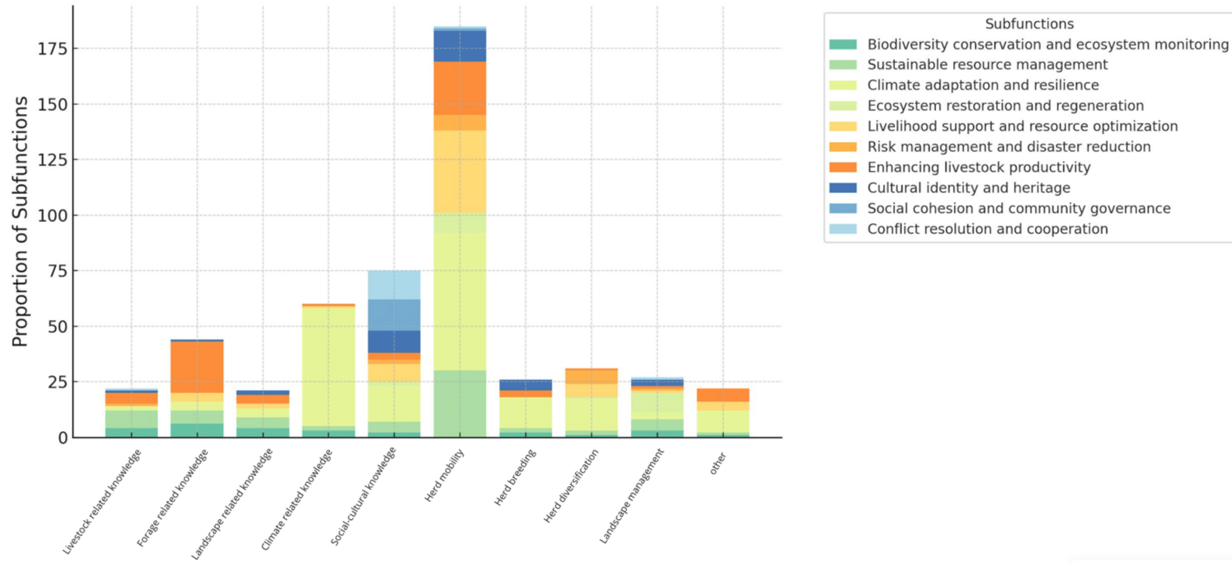

Figure 5 Distribution of different subfunctions across different knowledge domains

3.5 Functions Shared Across PTK Domains

In our comprehensive analysis of PTK, a pattern of common functions among various knowledge domains emerged. Fig. 5 suggested that all the knowledge domains examined collectively contributed to sustainable resource management and climate adaptation and resilience functions. Specifically, herd mobility practice, landscape-related knowledge, and livestock-related knowledge were the domains most frequently recorded as contributing to the sustainable management of resources. Climate/weather-related knowledge, social-cultural knowledge, and mobility practice were often cited as serving the climate adaptation and resilience subfunction, jointly addressing the challenges of environmental changes. For ecosystem monitoring, landscape-related knowledge emerged as the key contributor.

In terms of knowledge domains contributing to economic subfunctions, all the knowledge domains were found to have jointly contributed to improving livestock productivity. Furthermore, herd diversification and herd mobility practices were often intertwined in addressing risk management.

Culturally, almost all the knowledge domains contributed to the preservation of cultural identity and heritage. Although social-cultural knowledge played a dominant function in improving social cohesion and community governance, some case studies reported that herd mobility could serve the same purpose. For example, Fulani pastoralists effectively minimized competition for scarce resources such as water and grazing lands—common sources of conflict—by strategically relocating their herds to various locations (Bassett, 1986, as cited in Wario et al., 2016). Social-cultural-related knowledge, followed by livestock-related and landscape-related knowledge, contributed the most to avoiding or solving conflicts and enhancing cooperation.

4. Discussion

Our review is the first to use a functional lens to analyze traditional knowledge systematically. This approach offers a novel perspective to understand the functional characteristics of traditional knowledge. We focus on the analysis of different knowledge domains within traditional knowledge systems and the different functions and subfunctions each knowledge domain performs to support and nurture communities. Extensive literature suggests that the resilience of traditional communities is deeply rooted in their adaptive knowledge systems. These systems are responsive to environmental changes and play a significant role in sustainable ecosystem management (Berkes et al., 2000; Reyes-García et al., 2018). Our review delves into how traditional knowledge, particularly PTK, has historically and contemporarily contributed to the strength and adaptability of the community. We find that PTK serves diverse functions within pastoral communities, illustrating a complex interplay between various knowledge domains and their respective functions.

4.1 Domains of Pastoral Traditional Knowledge

Research has suggested that pastoral communities are remarkably adaptable worldwide, for which they rely on their rich and diverse knowledge (Hausner et al., 2020; Tugjamba et al., 2021). In accordance with previous reviews (e.g., Turner & Schlecht, 2019), our findings show that data about PTK in scientific publications is dominated by mobility practice and climate/weather-related knowledge. Mobility, a key practice, is widely practiced by pastoralists globally. It is mentioned in 124 of the 152 case studies we analyzed. Mobility takes diverse forms, from the seasonal migration of the Qashqai nomads in Iran, who move between summer and winter pastures (Saboohi et al., 2018), to the altitudinal transhumance of the Hutsul communities in Ukraine, who shift herds between mountain and lowland pastures (Fontana et al., 2022), or the otor movement of Mongolian herders, which involves flexible, opportunistic shifts based on forage availability and climatic conditions (Zhang et al., 2013).

The increasing research interest in how pastoral communities manage climate variability and change (Ayele et al., 2020) is mirrored in the identification of climate/weather-related knowledge as the second most frequently reported knowledge domain in our review, featured in 63 cases. Specific instances of climate/weather-related knowledge include knowledge of weather forecasting (Radeny et al., 2019) or observations of climate-related changes (Klein et al., 2014). In response to climate change, weather/climate knowledge empowers pastoralists to adapt to climate variability, a theme supported by many studies (Oteros-Rozas et al., 2013; Inman et al.,2020; Camacho-Villa et al., 2021).

However, our study also reveals significant imbalances in the focus of existing case studies regarding knowledge domains. The fundamental knowledge of pastoralism globally, such as livestock-related (10% of the cases), forage/plants, and landscape-related knowledge, are significantly underrepresented. It is difficult to believe that pastoral communities do not possess this knowledge, as it is central to their way of life and essential for managing their environments. Additionally, we found that more than half of the case studies (55%) investigated only one or two knowledge domains. This underrepresentation is problematic because it fails to capture the full complexity and interconnectedness of the pastoral knowledge system. Global research on traditional pastoral knowledge shows that pastoralists across diverse regions use a complex and common set of principles, including forage/plants, landscape, and livestock knowledge to manage resources efficiently and sustain their livelihoods (Sharifian et al., 2023). By focusing narrowly on certain aspects, research risks oversimplifying the holistic strategies that pastoralists employ. Pastoralists do not view these domains in isolation; rather, they integrate multiple domains to adapt to environmental uncertainties and ensure the sustainability of their resources. Thus, we argue that this narrow focus and fragmented approach risks presenting an incomplete or even distorted understanding of PTK. It fails to capture the holistic strategies pastoralists use to manage uncertainty and ensure the sustainability of their resources.

4.2 Functions of Pastoral Traditional Knowledge

Moving from the specific domains of PTK to its broader implications, PTK exhibits diverse functions, playing ecological, economic, and socio-cultural roles. In our database, the most common ecological subfunction of PTK is climate adaptation and resilience, which appears more frequently than the sum of the rest of the ecological subfunctions. This prominence likely stems from pastoralists' direct experience with climate variability, such as droughts, floods, and shifting seasonal patterns, underscoring their adeptness at navigating and mitigating the adverse effects of weather variability, and potentially of climate change (e.g., Ifejika Speranza, 2010; Ahmed et al., 2023). The review by Arjjumend (2018) further underscores how pastoralists' knowledge system enables them to cope with environmental unpredictability and variability through a variety of strategies, such as diversification and mobility.

Regarding the economic aspect, PTK is mainly mentioned for maintaining herd productivity, and livelihood support and resource optimization. The findings show that forage/plants-related knowledge and mobility practice are the core for maintaining herd health and productivity. This finding aligns with the findings of Launchbaugh (2020), who highlighted that livestock could benefit from mobile grazing behavior by taking a variety of forage with different nutritional qualities. Therefore, having knowledge about forage/plants identification and utilizing herd mobility are vital for maintaining herd health and productivity. Additionally, rangeland resources are often limited and can vary spatially and temporally due to factors like rainfall patterns, topography, and soil types (Godde et al., 2020). In such environments, the ability to optimize resource use becomes crucial for maintaining herd productivity. This consideration strongly reinforces the significance of our findings.

In terms of social-cultural functions, we found that livestock-related knowledge and landscape-related knowledge play significant roles in preserving the cultural identity and heritage of the pastoral communities. Similar findings are also presented in previous work (Russell & Ward, 2016; Ahozonlin & Dossa, 2020). For example, Gandini and Villa (2003) argue that local breeds should be regarded as cultural properties due to their contribution to the preservation of ancient local traditions. Furthermore, the landscapes that pastoralists inhabit and manage are imbued with cultural significance. Managing and preserving these landscapes, therefore, becomes an act of cultural heritage conservation. In certain communities, specific practices in landscape management, such as controlled burning, are important parts of their culture (Fernández-Giménez, 2015).

Building on the understanding of these varied subfunctions, our findings suggest that each domain of PTK serves multiple ecological, economic, and socio-cultural functions. For instance, in Peru, mobility helps mitigate overgrazing and facilitates natural regeneration; in Inner Mongolia, it preserves traditional nomadic culture; and among the Maasai herders in Kenya, it enhances herd productivity and aids adaptation to drought conditions (Huang et al., 2009; Sundstrom et al., 2012; López-i-Gelats et al., 2015). The significance of multifunctional characteristics within the knowledge system is profound. It enhances stability of communities by equipping them with a diverse set of strategies to deal with uncertainties and ensures that knowledge itself remains pertinent and flexible, capable of adjusting to evolving challenges. As some case studies show, even when a community is faced with constraints such as privatization, mobility adapts to fulfill other important functions, such as land preservation. For example, in response to land degradation and the fragmentation of pastures in Inner Mongolia, herders increasingly adopt the traditional mobility strategy, enabling rotational use of pastures to mitigate overgrazing and promote grassland ecosystem regeneration (Xie & Li, 2012). This gives reason to believe that the multifunctional characteristics of traditional knowledge systems contributes to their continued relevance and transmission. Therefore, future studies could examine this relation more directly. Additionally, there is a significant opportunity for future studies to explore how these functions evolve and adapt over time, particularly whether knowledge domains develop new functions in response to environmental and social changes.

Expanding on the finding of the multifunctional character of each domain, another finding that deserves attention is the substantial number of functions that are shared across knowledge domains. For example, all eight knowledge domains contribute to sustainable resource management and to climate adaptation and resilience, albeit with varying degrees of contributions. Similarly, all knowledge domains contribute to enhancing livestock productivity, an economic subfunction. Compared with these two functional groups, social-cultural functions present fewer overlaps across different knowledge domains, indicating that these functions may be more vulnerable to disruptions or change as they rely less on functional overlaps across multiple knowledge domains for their fulfillment. The idea that communities utilize alternative knowledge to achieve similar outcomes due to various challenges is discussed in the existing literature. For instance, Gauer et al. (2021) explore how indigenous communities adapt their knowledge in response to environmental changes, employing alternative strategies when certain knowledge becomes impractical or ineffective. Similarly, Berkes et al. (2000) highlight how environmental and social changes force communities to substitute or modify traditional practices, preserving the functionality of their knowledge systems despite new challenges. Drawing on these findings, we propose that future studies could interpret this interplay and synergy as a mechanism strengthening traditional knowledge systems. We hypothesize that the functions identified as common to different PTK domains allow pastoral communities to approach challenges such as climate change from various angles, thereby increasing the likelihood of finding a more effective solution.

Given the diverse range and complex interplay of ecological, economic, and socio-cultural functions within PTK, there is a need for adopting an interdisciplinary approach. As Berkes (2000) insightfully points out, researchers who lack expertise in ecology may not recognize the ecological significance of traditional knowledge. Conversely, ecologists may not fully capture the social and cultural significance of traditional knowledge. Therefore, by incorporating perspectives from various fields, future studies can achieve a more holistic understanding of traditional knowledge systems and their functions. Additionally, there is a need for future studies to involve and collaborate directly with local communities. In this way, researchers can ensure that their work captures the full depth and interconnectedness of PTK while respecting and valuing the perspectives and lived experiences of these communities.

Acknowledgements

The authors acknowledge financial support from the China Scholarship Council (CSC), which was crucial for the development and completion of this research. Research leading to this paper has received funding from the European Research Council under an ERC Consolidator Grant (FP7-771056-LICCI). This work contributes to the “María de Maeztu” Programme for Units of Excellence of the Spanish Ministry of Science and Innovation (CEX2019-000940-M).

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Chapter 3

Understanding Traditional Knowledge Systems Through a Resilience Lens -Case Study in East Ujimchin Banner, Inner Mongolia

Photo credit: Jesse Segura (2023)

This chapter corresponds to the article:

Chao, O., Reyes-García, V., Molnár Z., & Li, X. Understanding Traditional Knowledge Systems Through a Resilience Lens -Case Study in East Ujimchin Banner, Inner Mongolia. *Ecology and Society* (accepted, pending major revision).

Abstract

In the face of considerable socio-economic and environmental challenges, traditional ecological knowledge (TEK) systems around the world have demonstrated remarkable resilience. What features make a knowledge system resilient? With this question, this study explores the resilience of TEK by examining the continuity and adaptation of three traditional pastoral practices—mobile grazing, herd breeding, and herd sharing—in East Ujimchin Banner, Inner Mongolia, China. Through interviews, participatory mapping, and surveys, we delve into the adaptability of these practices, assessing their changes and enduring elements. Our findings show that while various elements of all three practices have changed, many others have persisted and remain active. For instance, in the context of mobile grazing, despite the changes in moving distance and frequency, herders still practice strategic seasonal movements within the limited pastures they have available. Another important finding is that each of the practices analyzed serves various functions, maintaining herd productivity, contributing to ecological balance, and adapting to changing climate. Additionally, the studied practices also share common functions, supporting each other in areas such as climate adaptation, where mobile grazing allows access to favorable pastures during severe weather, and herd sharing further provides a communal strategy for risk management.

Keywords: Herd breeding, Herd sharing, Mobile grazing, Resilience, Traditional Ecological Knowledge

1. Introduction

A large body of research demonstrates how traditional knowledge systems play a critical role in maintaining the resilience and sustainability of social-ecological systems (SES), including aspects such as environmental conservation, agriculture, health, and community governance (Berkes et al., 2000; Fernández-Giménez, 2000; Reyes-García et al. 2014; Biró et al. 2019). Simultaneously, important advances have been made in connecting these systems with Western scientific understanding (Huntington, 2000; Molnár et al., 2024; Reyes-García et al., 2024). Besides encouraging a deeper understanding of reality, these efforts advance a collaborative framework that integrates traditional and scientific knowledge, empowering local traditional communities, and leading to more comprehensive environmental research and more effective conservation outcomes (Reyes-García et al., 2019).

Despite these advances, a hierarchical divide between scientific and traditional ways of knowing persists. Consequently, policies regulating local people's practices are often designed disregarding traditional knowledge systems that are holistic and deeply rooted in community practices, beliefs, and oral traditions (Ihejirika, 2024). For example, conservation plans and policies, such as the creation of protected areas, aim to maintain a 'pure' wilderness ideal, which is based on and promotes a narrative that traditional practices were inimical to conservation efforts (Martinez, 2003). The case of the Banni grasslands in India exemplifies how conservation policies can overlook the ecological insights of traditional practices. Despite the Banni being historically managed sustainably by local Maldhari pastoralists through open and mobile grazing, state policies viewed these practices as 'inefficient' (Maru, 2021). In 2009, the state's Forest Department introduced a Working Plan aiming to enclose and fragment the grassland, which disrupted traditional grazing practices, reduced biodiversity, and adversely impacted the livelihoods and cultural practices of local pastoral communities (Maru, 2021). The same story is repeated around the world. In 2022, the Tanzanian government forcibly evicted Maasai communities from the Ngorongoro Conservation Area in the name of biodiversity conservation, ignoring the fact that their pastoral practices could coexist with local wildlife (Mantz, 2024). In Inner Mongolia, since the early 2000s until today, herders cannot graze their livestock on their pastures for 45 days at the beginning of spring, following the grazing ban policy, which aims to allow regeneration of degraded grasslands (East Ujimchin Banner Government Office, 2024). This echoes another grassland policy effort of the 1980s when land tenure reform was introduced as part of China's Household Responsibility System. Under this policy, formerly communal grasslands were divided and allocated to individual households, with fixed pasture boundaries and responsibility for managing and restoring the land. While this reform aimed to prevent overgrazing and improve rangeland management, it undermined the traditional pastoral production systems. As a result, restricted access to flexible grazing areas, loss of communal institutions, and fragmented land management structures contributed to the accelerated degradation of rangelands (Li et al., 2007; Li & Huntsinger, 2011). These examples show a recurring theme: while aiming to achieve ecological recovery, top-down conservation policies frequently fail to recognize the sustainable practices inherent to local cultures (Brockington, 2004; Berkes, 2012).

Rooted in colonial legacies, the forces of education systems, policies, market economy, urbanization, and globalization, compounded by environmental and other socio-ecological changes, make it increasingly challenging for traditional communities to perceive, function, and sustain themselves in the ways their ancestors taught them. These challenges are reflected in a large body of literature that reports on the status of traditional knowledge systems, often focusing on their loss or erosion (Fernández-Llamazares et al., 2023). For instance, Aswani et al. (2018) reviewed 92 studies, with 77% reporting a decline in TEK, particularly in ethnobotanical practices. Similarly, Sharifian et al. (2022), in a review of 152 publications on pastoral TEK, found 62 documented transitions, with 83% identifying knowledge erosion as the most prevalent change. Reporting loss and erosion can bring to light the vulnerabilities faced by traditional knowledge systems and mobilize support from global communities and policymakers to protect these traditional cultural legacies.

While some scholars acknowledge that TEK naturally adapts and evolves over time, continuously focusing on its loss or decline can be counterproductive. This negative-centered narrative may discourage traditional communities and hinder their efforts to preserve, revitalize, and develop their cultural practices (Gómez-Baggethun & Reyes-García, 2013; Fernández-Llamazares et al., 2021). Adding to this, the perspectives from which we view traditional knowledge systems shape our interactions with them (Benyei et al., 2019). Viewing traditional knowledge systems only as fading or disappearing may lead to their 'museumification,' taking away their agency and narrowing them to 'static' knowledge of the past, rather than recognizing them as inherently dynamic and adapting (Berkes et al., 2000; Reyes-García et al., 2014). Conversely, recognizing their resilience and adaptability opens opportunities to weave these living knowledge systems with other knowledge systems, such as science, potentially providing an enriched picture of the world (Tengö et al., 2014).

Furthermore, understanding how TEK systems persist, reorganize, and renew themselves, not only shifts the narrative from vulnerability to vitality, but also offers valuable insights into what features of these knowledge systems might help them sustain and evolve. This dynamic perspective aligns with the concept of ecosystems resilience, first introduced by Holling (1973) to refer to ecosystems' capacity to absorb disturbances while undergoing change and still retain their essential functions and identity. Later, the concept of resilience was used as a central feature for understanding complex system dynamics (Walker et al., 2004). In SES, resilience is about learning from and developing with change, rather than managing against change. It is about having the capacities to live with complexity, uncertainty, and change, abrupt or incremental, and continue to develop with ever-changing environments (Folke, 2006). This concept captures not only the idea of a system's persistence, but also its ability to react, reorganize, and renew itself.

However, while resilience is often framed positively, researchers have drawn attention to its potential downsides. Concepts like undesirable resilience or social-ecological traps refer to systems that are stable but maladaptive, inequitable, or unsustainable (Kerner & Thomas, 2014; Tidball et al., 2016). Lambert-Pech et al. (2024) further argue that resilience is not value-neutral. It can normalize loss, obscure vulnerability, or reinforce dominant interests. As Dornelles et al., (2020) stated we should consider resilience of what, to what and for whom. In pastoral contexts, pastoralists' resilience typically arises from embedded, self-organized practices such as mobility, herd sharing, and selective breeding. Yet policy-driven efforts to "build resilience," through sedentarization programs or grazing restrictions, often sideline or overwrite these internal strategies. What appears adaptive in the short term can, over time, limit pastoralists' options and lead to entrapment. This highlights the need to distinguish between externally imposed forms of resilience and those that emerge from within traditional knowledge systems themselves.

There is considerable research on how TEK systems can nurture the resilience of SES through biodiversity conservation, climate change adaptation, nature stewardship, and more (Ruiz-Mallén & Corbera, 2013; Reyes-García, 2023). However, far fewer studies investigate the resilience of TEK systems themselves. Illustrating this, Reyes-García and her colleagues (2014) have found that TEK of home gardeners in Spain show resilience through incorporating modern knowledge while, at the same time, maintaining the bulk of the accumulated body of knowledge. Similarly, in another study in coastal communities in Brazil, TEK shows resilience through the effective intergenerational transmission of knowledge (Zank et al., 2019).

Building on this foundation, this study examines the resilience of the TEK system among pastoral herders in East Ujimchin Banner, Inner Mongolia, China, focusing specifically on the intrinsic resilience mechanisms within TEK. Focusing on three traditional herding practices: *nuudel* (mobile grazing), *uriin mal songoh* (herd breeding), and *surug tabih/abah* (herd sharing), this study analyzes how these practices have historically enabled herders to adapt to past environmental changes and how they may continue to support adaptation to contemporary socio-environmental challenges. Our specific research questions are: 1) How were these three traditional practices implemented prior to the land tenure reform in 1984 (referred to as Q1)? 2) Which elements of these practices have persisted, and which have changed in response to contemporary socio-environmental changes (Q2)? and 3) What features enhance the resilience of TEK related to these three practices (Q3)?

By examining traditional mobile grazing, herd breeding, and herd sharing practices through the lens of resilience, rather than focusing on the 'end of nomadism,' the 'disappearance of local breeds,' and the 'breakdown of reciprocal relationships,' we aim to create an alternative narrative to approach current crises.

2. Methodology

2.1 Positionality Statement

As an ethnic Mongolian from China, the first author's cultural connection to the study community fundamentally informed the research approach and data interpretation. This cultural positionality offered the team privileged access to knowledge holders and enabled a nuanced understanding of the local cultural context. However, this insider status also requires careful reflexivity regarding potential biases arising from such close cultural proximity. The research team's composition, including scholars from Catalonia, Hungary, and China, brought diverse theoretical and methodological perspectives derived from their extensive work with local traditional communities globally. To enhance methodological rigor and minimize potential biases, we employed multiple methods and conducted collective reviews during the research design and implementation. We acknowledge that despite these measures and our diverse perspectives, our interpretation may not fully capture the complexity and nuances of the community's knowledge systems.

2.2 Data Collection

This study is based on nine months of fieldwork, from November 2022 to August 2023. Three *gacha*s - *Honger*, *Hargant*, and *Mantuhbolog* - were selected as study sites. The selection of these specific *gacha*s was influenced by the first author's previous engagements and familiarity with the local communities. Prior to data collection, ethical authorizations were obtained from the Ethics Committee of the Universitat Autònoma de Barcelona (CEEAH—6170), and informed consent was collected from all participants (see Figure 1). While traditionally, the role of men in grazing is prominent within pastoral communities in the area, we acknowledge the indispensable contribution of women to herding life (Meurs et al., 2021). To ensure gender inclusivity, we intentionally involved both men and women in all data collection methods. We combined both qualitative (i.e., semi-structured interviews and participatory mapping workshops) and quantitative methods (i.e., survey) for data collection, as detailed below.

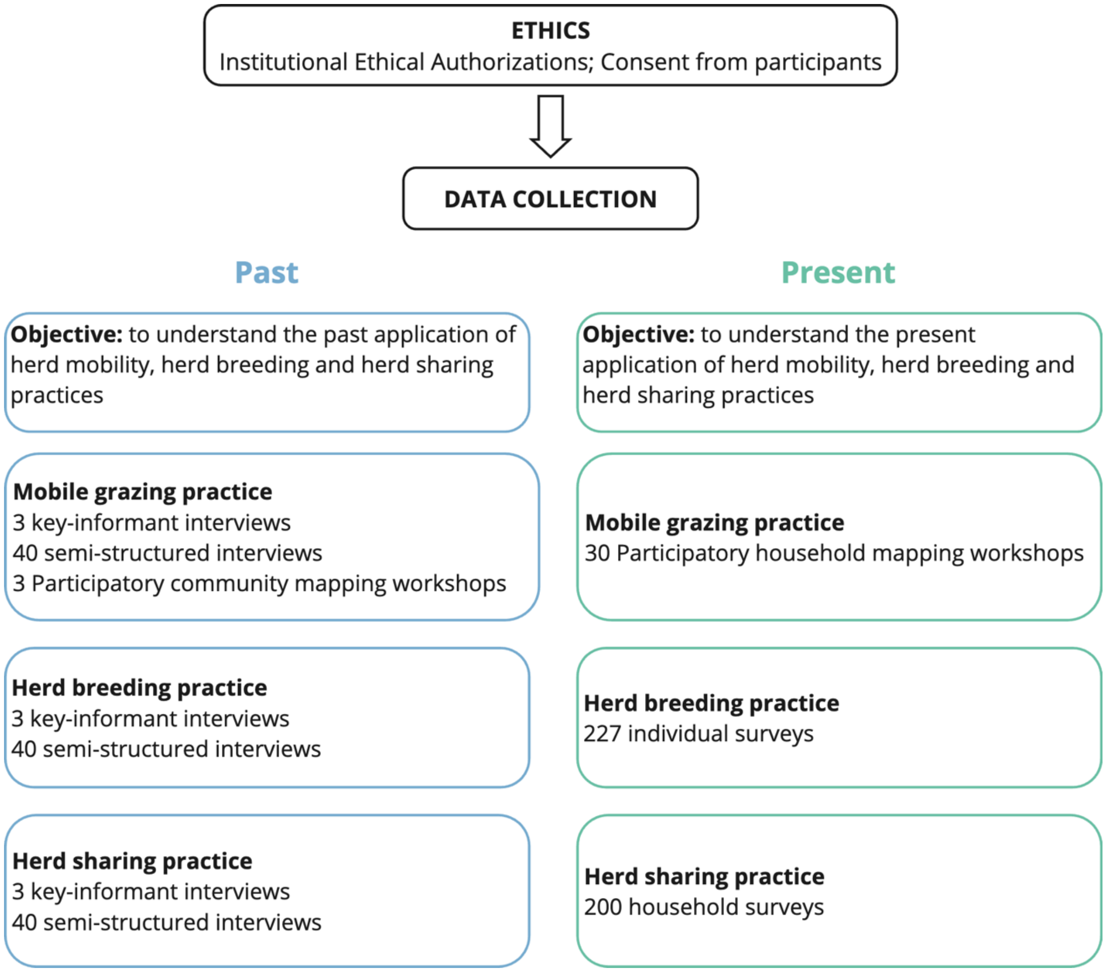

Figure 1. Flow chart showing the methodological approach used in this study from ethical procedures to data collection.

2.2.1 Past practices

To gain a comprehensive understanding of traditional practices in the study area, the study began with interviews with three key participants. Interviewees were selected through purposive sampling based on three criteria: (1) individuals aged 70 years or older, (2) recognition among East Ujimchin herders for their demonstrated success in managing livestock through harsh climatic events, and (3) formal acknowledgment as exemplary herders by their community. During these interviews, the main question posed was: "How did you, and other herders in your area, adapt to climate variability?" Through this question, we aimed to gather detailed insights into local traditional practices. We identified mobile grazing, herd breeding, and herd sharing as the practices that contributed the most to adapting to climate variability.

To delve deeper into the details of the past applications of these practices, semi-structured interviews were conducted with other elders (n = 40). Snowball sampling was employed to broaden the pool of participants, with the initially selected key participants recommending other knowledgeable elders. To better understand mobile grazing before the 1984 land tenure reform, we asked questions about the frequency and distance of movements, the selection of seasonal pastures, and the reasons for mobility. The 1984 land tenure reform was a major turning point for pastoral systems in Inner Mongolia, introduced as part of China's broader Household Responsibility System. Initially developed for agriculture, this policy was later extended to grasslands. In East Ujimchin, the reform transitioned grassland use from collective to household responsibility. Grasslands that were previously managed communally under *gacha*-level administration were allocated to individual households, each with defined parcels and management responsibilities. This shift was intended to increase land-use efficiency and accountability. However, its implementation was gradual, evolving over several years, with many local herders unsure of how to manage fragmented parcels under changing rules.

To complement this, we conducted three participatory mapping workshops in each *gacha* with 12 local elders to document historical mobile grazing practices (Ilboudo Nébié et al., 2021). Elders, selected for their prior *gacha* management roles through purposive sampling, used color markers to identify the pre-1984 seasonal pastures and key landscape features. In addition, to obtain further insights into the traditional knowledge associated with this practice and the reasons behind the choices of specific pastures, we also engaged in discussions with the elders during workshops. To better understand herd breeding before 1984, we asked elders about the specific traits used for selecting each of the five livestock types and the reasoning behind selection of these traits. Finally, to better understand past herd sharing practice, we explored the rules governing the sharing process, past experiences, and the purpose of the practice. One past herd sharing contract was collected from a herder.

2.2.2 Current practices

The dynamic and spatial nature of mobile grazing was difficult to capture in a survey, for which we used more visual and interactive methods to capture information accurately. Specifically, we organized household participatory mapping workshops with 30 randomly selected households to understand current mobile grazing practices. We asked households to draw their pastures and mark the pastures where they currently move their livestock during each season, detailing the characteristics of each seasonal pasture, the distances between them, and the frequency of movements. These mapping activities were complemented by discussions that provided further insights into whether households have engaged in long-distance mobility practices outside the mapped areas since 1984 and the reasons behind their mobility practices.

We used data from semi-structured interviews to design a survey aimed at gathering information on the current application of two of the practices examined: herd breeding and herd sharing. We conducted 227 individual surveys to collect data on whether the herder knew about the traditional breeding traits for five livestock types, and whether they still use these specific traits now. Additionally, we collected data on herders' perceptions of the different functions of this practice.

Since herd sharing practice is implemented at the family unit level and decisions are typically made collectively by the household, we conducted 200 household-level surveys on herd sharing. During these surveys, we collected data on whether households were aware of this practice, whether they have engaged in herd sharing practice, who they practice it with (i.e., relatives or strangers), and why they engage in it. To understand the current rules and formats, we also collected the herd-sharing contracts of households that reported that they have engaged in this practice. Individual and household background information, including details on demographic data, household size, herd types, and rangeland dimensions, was also collected.

2.3 Data Analysis

To understand how the three traditional practices were implemented before the land tenure reform in 1984 (Q1), we employed thematic analysis identifying themes within interview data. For mobile grazing, themes emerged related to the characteristics of seasonal pastures, and the timing, frequency, and reasons for moving. For breeding practices, we documented the detailed breeding traits, the timing of these selections, and the number of males chosen, alongside the purposes of this practice. Similarly, for herd-sharing practices, we explored with whom and how it was practiced, the specific rules, and the reasons for engaging in herd-sharing.

To explore the continuity and changes in three practices following the implementation of land tenure reform (Q2), we employed a combination of both qualitative and quantitative analysis techniques. For mobile grazing, we evaluated the number of seasonal pastures marked on historical *gacha* maps gathered from three participatory mapping workshops. Then, we compared them with those on current maps from 30 household participatory mapping workshops. We also performed thematic analysis on the characteristics of seasonal pastures, as well as the distances and frequencies of movements, using data from interviews and household mapping workshops. For herd breeding practices, we assessed the awareness and application of traditional breeding traits for five types of livestock. This involved calculating descriptive statistics to evaluate community knowledge and implementation of these traits, and tracking changes based on survey responses. Afterward, we conducted follow-up interviews with three knowledgeable local herders regarding the findings from the surveys on herd breeding. During the interviews, we asked their opinions on why certain traits are being used more now and incorporated their insights into our discussion section. In the case of herd-sharing practices, we compared the rules and formats of sharing, analyzing both historical (n = 1) and current written contracts (n = 2) along with data from interviews and household surveys.

To explore the features that contribute to the resilience of pastoral traditional knowledge (Q3), we used descriptive statistics. For mobile grazing, we quantified the responses from interviews and participatory mapping workshops to identify the functions attributed to this practice. Similarly, for both herd breeding and herd sharing, we analyzed the frequency of different reasons provided by herders for practicing these traditions in the past and now.

In the presentation of the findings in the results section, descriptions of the past application of these practices are articulated in the past tense to denote historical context. Conversely, findings about the current application of these practices are written in the present tense, reflecting their ongoing relevance and implementation.

3. Results

3.1 Mobile Grazing Practice

3.1.1 Motivations for mobile grazing

According to interview responses, mobile grazing was core to maintaining livestock health and productivity, ecological balance, and climate adaptation. The primary motivation for mobile grazing, as mentioned by 41 of 43 participants during key informant and semi-structured interviews, is the maintenance of livestock health and productivity.

> *"There are a lot of reasons* [to move the livestock]. *The first one is to feed our herd with different kinds of plants and change the taste for the herd. Like humans, if we keep eating the same meal every day, we will be sick of it one day"* (Sasereng, personal communication, 2023).

Moreover, 26 participants stressed *nutag sergeh* (ancestral land regeneration) as a motivation for mobile herding. In Mongolian, *nutag* refers not simply to "land," but to a deeply rooted sense of place that includes the historical, spiritual, familial, and ecological ties between herders and their homeland. *Sergeh* means "to awaken" or "to bring back to life," implying an active process of care and restoration. Adapting to climatic events, such as drought, is another critical function of mobile grazing, pointed out by 23 of 43 participants. Several participants shared an old proverb, *huraazh barhaar, nuuzh bar*, which can be translated as 'It is better to move and risk than to stay and risk.' Informants reported that, in the past, during severe climatic events, herders even moved beyond *gacha* boundaries to find suitable pastures.

Comments made during 30 household mappings of current movement show that nowadays herders continue practicing mobile grazing primarily to rest and regenerate pastures, as emphasized by 28 out of 30 participants. Seven participants cited the improvement of livestock health through varied pastures as their motivation, while two participants noted the importance of maintaining tradition.

3.1.2 The past practice of mobile grazing

During the interviews, elders emphasized that, before the 1984 land tenure reform, mobile grazing in the area was characterized by frequent movement, careful selection of seasonal pasture locations, strategic timing of movements, and long-distance mobility during extreme weather events. Traditional mobile grazing followed a dual-scale pattern, involving seasonal migration between different pastures and shorter-distance rotation movements, within each seasonal pasture. Decisions were typically guided by a knowledgeable elder. Families cycled through four seasonal pastures over the course of the year, and, within each pasture, they usually did not stay in the same spot for more than 15 days, moving around 11-17 km at a time.

Mobile grazing was not spontaneous but followed a clear process. There were criteria for where and when to move, specifically regarding the selection of the four seasonal pastures. Early forage growth during spring is crucial for livestock recovery after winter, making *gobi* pastures with salty vegetation such as *hers* (*Suaeda glauca* (Bunge) Bunge) and *bodargan* (*Atraphaxis manshurica* Kitag.) highly suitable during this season (see Figure 2a). These spring pastures were typically located in warm, sheltered areas, where snow tends to melt first, providing optimal conditions for early grazing. Summer pastures were strategically placed at higher altitudes in flat, open areas, ideally near water sources such as lakes or rivers, which is beneficial for the livestock to obtain *oson tarag*, or water fat (see Figure 2b). However, certain pastures are less favorable for summer pastures than others. Gobi pastures, while suitable in spring, are too salty during the summer, potentially harming the livestock. Mountain pastures pose a risk of flooding, which can be hazardous for both livestock and herders. Densely grown pastures are generally avoided for summer pastures, due to the high number of mosquitoes, which pose a risk to both livestock's and herder's health and comfort.

Figure 2. Mobile grazing practices before 1984 in East Ujimchin. a. Spring pasture: newborn lambs and calves rest in the sheltered *gobi* pastures; b. summer pasture: horses and cattle graze by the river; c. autumn pasture: cattle graze on nutrient-rich forage such as *mangir* and *agi*; d. winter pasture: livestock are sheltered by the mountains. Drawn in 2024 by local herder Borjigin Otgenbayar from *Mantuhbolog*, this artwork is based on data collected from interviews.

For autumn, participants prefer pastures with *mangir* (e.g. *Allium senescens* L.), *agi* (*Artemisia frigida* Willd.) and *zheergen* (*Ephedra sinica* Stapf), which provide *toson tarag*, or oil fat (see Figure 2c). To fatten the livestock in autumn, participants mentioned that the practice was to restrict water intake to once a month because frequent drinking prevents livestock from gaining oil fat, making them less resilient in cold weather and prone to weight loss in winter. Instead, herders let the livestock graze on the species mentioned above, which are considered watery plants, to minimize livestock's frequent need for water. participants noted that, during winter, the standard practice was to choose areas with less snow and with dense and rich forage and place herds there (see Figure 2d). Land with mountains was considered ideal for sheltering and grazing the livestock during heavy snow. Some participants noted that they observe wild animals to decide on winter pasture locations. Specifically, they mentioned that the presence of deer with reddish fur is an indicator of good pasture quality.

Regarding when to move, participants mentioned that changes in temperature, pasture quality, or the productivity of grazing areas determined the timing of seasonal movements. When snow cover melts and the forage availability decreases, it signals the time to leave *ubuljee*, the winter pasture, for *habarjaa,* the spring pasture, typically from late March to early April. When temperatures rise, mosquitoes appear, and rainfall is reduced, herders would transition to *zuslang*, the summer pasture, around late June to early July. As the air cools, early frosts set in, and rainfall increases, conditions that appear coupled with worsening pasture conditions and that would occur from mid to late August, herders moved to *namarjaa*, the autumn pasture. Finally, the appearance of cold winds and early snow in early November is a sign of the return to the winter pasture, completing the full cycle of their seasonal migration.

Participants reported that, in the past, East Ujimchin herders also employed long-distance mobility to cope with severe weather events, such as *dzud*, a period characterized by heavy snow and extreme cold, that severely restricted access to pastures. Participants explained that since 1967, six *dzud* events have occurred, five of which were before the year 2000 (see Figure 3). In the severe *tumer dzud* of 1977, thick ice made it nearly impossible for livestock to dig for grass. During those times, families moved their livestock up to 100 km to areas with vegetation that allowed their livestock to survive. Participants also noted an increase in the frequency of droughts in recent years, with more frequent occurrences since 2000 (see Figure 3).

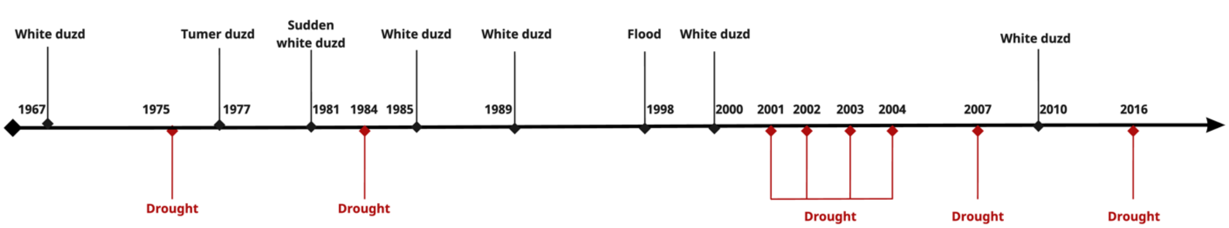

Figure 3. Timeline of significant climatic events since 1960s in East Ujimchin Banner, created based on data gathered from interviews.

3.1.3 Current practice of mobile grazing

Since 1984, mobile grazing practice has experienced significant changes, characterized by reduced movement frequency, fewer seasonal pastures, and diminished long-distance grazing. Participatory mapping workshops revealed that 90% of participating households (n = 27) attributed these changes primarily to restricted land access, a consequence of land tenure reform and the proliferation of boundary fencing. For instance, in *Mantuhbolog gacha*, movements from summer to autumn pastures have reduced from 27 – 40 km to just ca. 10 km. A similar reduction is seen in *Hargant gacha*, where spring-to-summer movements have dropped from 30 km to less than 5 km. Previously, households carried out four major seasonal movements and relocated every 15 days within a pasture to preserve pasture health. Today, no household can sustain such frequent movements. Additionally, no households reported practicing long-distance migration since the reform, marking an obvious contrast to the past.

Despite these changes, a key element of mobile grazing has persisted: seasonal utilization of pastures. Data from 30 participatory household mapping sessions shows that one-third of the interviewed households (n = 8) individually manage pasture areas over 1,333 hectares. These households typically have three seasonal pastures—primarily for winter, spring, and summer (see Figure 4a & b). One household also rents additional pasture from another herder as *hadleng*, or reserve pasture.

Another third of the households participating in the mapping exercise (n = 11) manage pasture areas ranging between 667 - 1,333 hectares. These households typically have two seasonal pastures: either winter and spring, or summer and autumn pastures (see Figure 4c & d). One family, lacking suitable summer grazing land, has rented a pasture adjacent to a river specifically for their summer use. Among participants with less than 667 hectares, micro-mobility is the predominant strategy (see Figure 4e & f). The term micro-mobility refers to more spontaneous rotation between pasture types within the grazing areas (Adriansen, 2008). During winter months, most of these households rely on purchased fodder, with only two households maintaining dedicated reserve pastures for winter grazing.

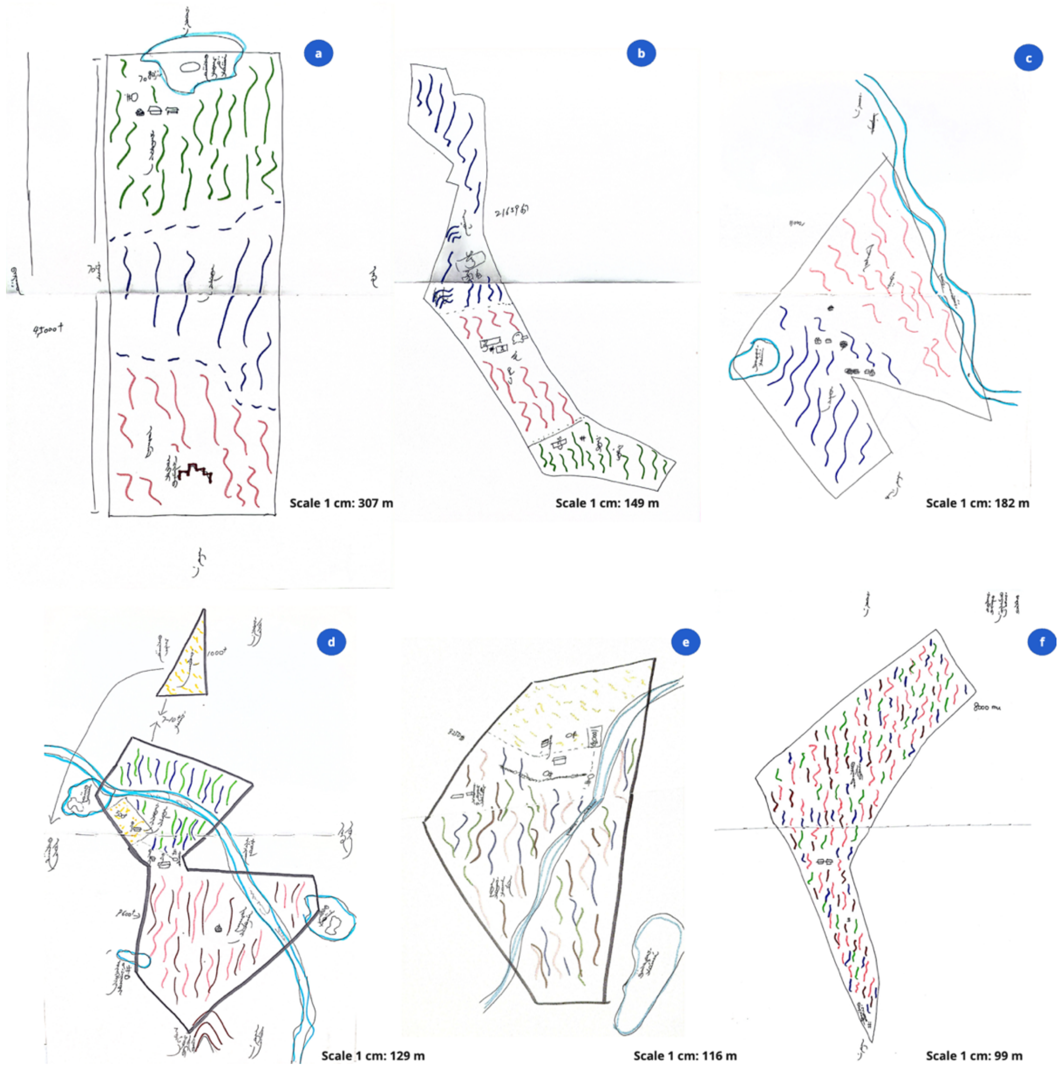

Figure 4. Current household mobile grazing maps. Green representing spring pasture, blue representing winter pasture, brown representing autumn pasture, pink representing summer pasture, and yellow representing pasture reserves. (a) and (b) are current mobile grazing practices of two households with more than 20,000 mu[1] pastures. (c) and (d) are current mobile grazing practices of two households with pasture sizes ranging from 10,000 to just under 20,000 mu. (e) and (f) are current mobile grazing practices of two households with less than 10,000 mu pastures.

As in the past, the type and number of seasonal pastures continue to be influenced by the available pasture area and landscape characteristics. Closeness to water sources and landscape features, such as mountains, play crucial roles in this process. However, due to limited land availability and environmental changes, it is increasingly challenging to find suitable areas for autumn pastures.

[1] 1 mu = approximately 0.067 hectares.

Participants of household mapping workshops noted that these constraints have led families to either purchase forage, rent additional pastures, or reserve nutrient-rich parts of their own pastures as reserve pasture to meet the high forage and specific plant needs of autumn grazing.

3.2 Herd Breeding Practice

3.2.1 Motivations for herd breeding practice

Herd breeding is a fundamental practice among herders in East Ujimchin. According to participants, traditional breeding traits for selecting male livestock helped ensure that the livestock are productive, well-suited to the local climate, and reflective of cultural values. The primary function, productivity, is particularly emphasized, with 12 traits identified across five types of livestock that maintain productivity. Climate resistance is the second most emphasized function, supported by 11 traits. Cultural significance is also a key aspect of breeding practice, with seven traits in total.

> *"You can easily tell how good a herder is by the Uriin Mal* [male breeding stock] *they choose"* (Dabxilta, personal communication, 2023).

Data from 227 individual surveys reaffirms the enduring relevance of herd breeding practice. A large majority of participants, 94% (n = 213), believe that in general herd breeding practice significantly contributes to restoring herd productivity. Moreover, 78% (n = 178) of participants view herd breeding as crucial for enhancing their livestock's resistance to winter disasters (see Figure S1). Similarly, most participants agree on the ability of breeding practice to enhance livestock resistance to drought (76%, n = 173). When considering the importance of herd breeding in increasing resilience to pasture shortages, levels of agreement were more varied, but still most informants agreed (62%, n = 141).

3.2.2 Past practice of herd breeding

Through interviews, we identified 19 traits across the five types of livestock, each serving different functions, including enhancing productivity, improving climate resistance, and preserving cultural values. Only some of the traits, such as lineage, were common across all livestock species. Participants provided the most detailed traits for rams and stallions, emphasizing characteristics such as coat color, tail structure, back alignment, and hip shape. Bucks and bulls share similar traits, referring to fur or skin thickness and horn structure. Differently, bull camels were selected based on unique characteristics such as the evenness of their humps, and distinct facial features such as a wide forehead and big eyes.

Regarding the functions of identified breeding traits, high productivity is particularly emphasized, with six key traits across different livestock types specifically valued to maintain productivity. For example, the *udom*, lineage, is crucial for all livestock types. When herders say, "This ram's *udom* is good", the ram's ancestors have consistently produced offspring with desirable traits, such as high fertility rates and strong health. Rams, stallions, and bulls are selected for their long and straight backs, indicative of physical strength essential for effective breeding. Balanced and wide hips signify higher reproductive success. Stallions are also picked for their same-sized and large testicles, which show they are fertile and likely to produce healthy offspring.

Table 1. Traditional breeding traits signaling/contributing to climate resistance, productivity, and cultural significance, for five livestock in East Ujimchin Banner

Herd type	Productivity	Climate resistance	Cultural significance
Ram (*guchi*)	*Udom* (lineage) Wide hip Long and straight back	Black eyes, ears, and snout Big and even tail Born in the middle of the lambing season Curly fur	Down-pointed snout
Buck (*ohon*)	*Udom* (lineage) Balanced and wide hip	Heavy fur	Even and big horn
Stallions (*uriye ajireg*)	Udom (lineage) Square hip Long back Same-sized and large testicles Long and balanced back	Heavy tail fur Heavy neck hair	Single color (particularly white)
Bull (*boh*)	*Udom* (lineage)	Thick body skin The end of the tail is furry	Balanced and even horns Single color
Bull camel[2] (*boor*)	*Udom* (lineage)	Standing even humps Thick fur	Wide forehead Big eyes

[2] The Bactrian camel (Camelus bactrianus), a two-humped species adapted to cold arid climates, is the traditional camel breed grazed by herders in East Ujimchin. This contrasts with the single-humped dromedary camels more common in hotter desert regions.

Climate resistance is crucial to ensure that livestock can withstand harsh weather conditions. Participants mentioned that, for rams, pure white color should be avoided, while black eyes, ears, and snout are preferred. Several participants shared an old proverb: *chadla gezh chagaan hoch bu taib, hanla gezh hara hoch bu taib*, which translates to 'Don't breed pure white rams, even if you have many livestock; don't breed pure black rams, even if you are satisfied with your livestock.' Participants explained that pure white and black rams are less desirable because white rams easily lose weight in cold winters and have poor vision in snowy conditions. Nevertheless, black sheep are not preferred either, in this case as the color represents bad luck and bad omen in Mongolian culture. Another trait to help selection is birth season. In the past, rams born in the middle of the lambing season were considered stronger than the ones born at the onset or at the end. Additionally, big and even tail, along with curly wool, are preferred, as these features indicate resistance to cold. Similarly, bucks, stallions, and bull camels are selected for their heavy fur. Moreover, the thickness of the skin determines a bull's resistance to cold. Bull camels with evenly standing humps are also highly valued for their ability to endure both cold winters and hot summers.

Table 2. Current awareness and application of traditional herd breeding practice in East Ujimchin banner (n = 227).

Herd type	Characteristics	Awareness		Application		
		I have heard about it	I never heard of it	I use it now	I don't use it now	It has changed
		%	%	%	%	%
Ram	Big and even tail	96	4	84	16	1
	Long and straight back	95	5	84	16	1
	Wide hip	96	4	84	16	1
	Udom (lineage)	96	4	82	18	1
	With curly fur	88	12	73	27	2
	With black ears, snouts, eyes, and neck	90	10	68	32	1
	Down-pointed snout	90	10	68	32	1
	Born in the middle of the lambing season	42	58	21	79	1
Buck	*Udom* (lineage)	90	10	48	52	1
	Balanced and wide hip	86	14	47	53	1
	Heavy fur	84	16	43	57	1
	Even and big horns	88	12	39	61	7

Stallions	*Udom* (lineage)	99	1	86	14	-
	Square hip	93	7	71	29	1
	Long back	91	9	70	30	1
	The balanced and wide balls	91	9	69	31	1
	Heavy tail fur	93	7	69	31	4
	Heavy neck hair	92	8	68	32	5
	Balanced and clean hooves	87	13	68	32	1
	Single color	79	21	56	44	1
	Long and balanced back	95	5	76	24	1
Bull	*Udom* (lineage)	96	4	72	28	3
	Thick body skin	93	7	69	31	1
	Balanced and even horns	90	10	48	52	25
	The end of the tail is furry	76	24	45	55	8
	Single color	89	11	41	59	24
Bull camel	Standing even humps	57	43	8	92	1
	Udom (lineage)	58	42	8	92	1
	Thick fur	55	45	7	93	1
	Wide forehead	53	47	7	93	-
	Big eyes	49	51	6	94	-

Beyond their practical functions, the physical traits of livestock also embody unique cultural identities and beliefs. For example, Ujimchin is known for its white horses. Participants noted that white color represents purity and nobility. Additionally, they believe this is a part of Ujimchin identity, as historical accounts describe Ujimchin herders wearing white and riding white horses. Bucks and bulls with even and big horns are preferred, as participants believe these horns symbolize *maliin sur*, the spiritual pride and power in male livestock. Some traits that primarily indicate climate resilience or high productivity also have cultural significance, particularly within the community's identity. For instance, the fat-tailed sheep, valued for their ability to store energy and thrive in harsh climates, are representative of Ujimchin identity.

Traditionally, the selection process for rams and bucks commenced by mid-April according to the agricultural calendar, strategically timed before castration. The number of males selected for breeding was not fixed but varied depending on the size of the herd. For example, in a herd of

1,000 sheep or goats, about 10-20 males would be chosen to ensure effective breeding. For cattle, bulls were evaluated and selected for breeding at two years of age. The typical selection ratio is at one bull for every 30 cows and two bulls for every 50 cows. Stallions were chosen at four years old, and each was paired with a group of approximately 20 mares.

One notable past practice among East Ujimchin herders was the rotational use of male livestock. Every three years, herders would engage in the exchange of male livestock, specifically selecting male livestock from families renowned for maintaining authentic herd traits. This practice is locally called *qus solih*, meaning changing the blood. The strategic exchange is particularly important when certain valued traits begin to weaken or disappear within herds. By introducing livestock from families where these traits are kept and strong, herders can effectively recover these characteristics in their livestock. Additionally, introducing bloodlines from geographically distant herds is believed to prevent inbreeding (locally called *qus oirtoh*, which literally means "blood becoming close") and to maintain the overall quality of the livestock.

3.2.3 Current practice of herd breeding

Parallel to changes observed in mobile grazing, herd breeding practices in East Ujimchin have also undergone significant transformations since 1984. Certain selection traits, such as 'single-color selection' of stallions and bulls and 'born in the middle of lambing season' of rams have a noticeable shift in awareness and use (see Table 2). According to participants, the main reason behind the color choice change is the shift to foreign breeds of stallion and bull. The decline in selection of 'heavy tail fur' and 'heavy neck hair' of stallions is also due to breed change. Moreover, bucks and bulls are now preferred without horns. Participants reported that the reason behind the change in preference is that now they keep livestock in shelters during winter and horns make it easy for them to harm each other. Some participants also reported that livestock with horns are not resistant to the cold and are more likely to lose weight. Among all five types of livestock, bull camel traits have experienced the most considerable reduction (see Table 2). Less than 60% of the survey participants know about the four selection traits and only 6-8% of participants use these traits now. Buck selection using traditional traits is also largely under-practiced now. A significant factor contributing to this shift is that many participants don't own any of these types of livestock.

Despite these changes, 30 traditional traits continue to be practiced, although their use varies. For the selection of rams, most participants follow four traditional breeding traits (i.e., selecting males with big and even tails (84% of survey participants), long and straight backs (84%), and wide hips (84%), the lineage (82%)). Stallion selection continues to value traits such as 'lineage' (86%), 'square hip' (71%), and 'long back' (70%). In the case of bulls, traits such as lineage (72%), thick body skin (69%), and balanced and even horns (48%) remain important. Although bull camel selection has significantly declined, participants who still herd camels continue to value traits such as lineage (8%), thick fur (7%), and wide foreheads (7%) (see Table 2).

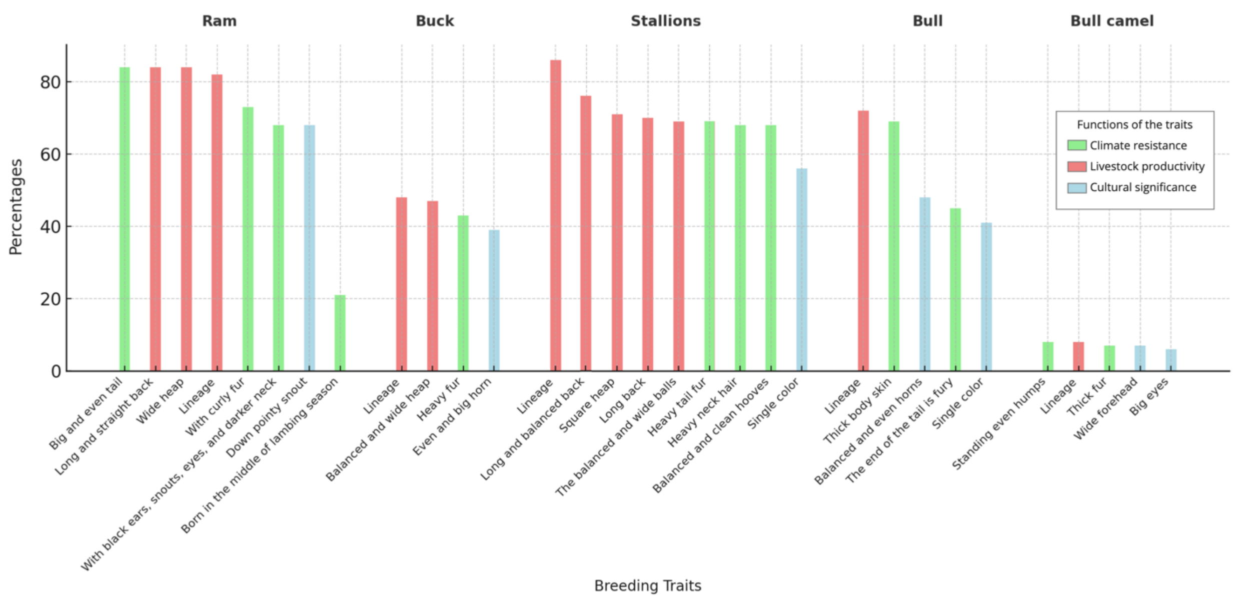

Figure 5. Bar chart showing the current use of each traditional trait for five livestock types, based on data from individual surveys (n = 227). The colors represent the functions of these traits.

Moreover, survey data also shows that traits contributing to maintaining herd productivity are the most widely used across all livestock types. For example, lineage stands out as the most consistently valued trait across all livestock types (see Figure 5). It is used by 84% of participants for rams, 86% for stallions, and 72% for bulls. Traits related to hip structure are widely used for ram, buck and stallion selection. Traits that ensure livestock adaptation to harsh environmental conditions are the second most frequently applied. Notable examples include big and even tails for rams, thick body skin for bulls, and heavy fur for bucks, stallions, and bull camels. Compared to herd productivity and climate resistance traits, cultural traits are less frequently used. While less frequently applied, many of the cultural traits, such as down-pointed snout of rams, single-color selection, and big even horns, are still used by around 40%-70% of participants, depending on the trait.

3.3 Herd Sharing Practice

3.3.1 Motivations for herd sharing practice

Herd sharing, locally known as *surug tabih/abah*, is a long-standing practice among herders in East Ujimchin. As participants reported, traditionally, this practice contributed to fostering societal equality. During the collective era (1950s-1970s), it was also practiced to maintain herd-pasture balance, address labor shortages, minimize climatic risks, sustain herd growth, and help herders with few or no animals to increase their herd size. Prior to the fencing of pastures in 2000, herders continued to employ traditional herd sharing to cope with climatic events, even after the implementation of land tenure reform in 1984. This practice was engaged at the community level, enabling herders to recover from severe climatic events by hosting livestock from other communities.

Household survey results show that the primary reason for engaging in herd sharing now is to mitigate land shortages, cited by 38% of households (see Figure S2b). Other significant reasons include helping families in need and addressing labor shortages (18% each). Additionally, 15% of households use herd sharing to increase their herd numbers, and 7% of participants utilize it as a strategy to adapt to severe climatic events. A smaller portion, 3%, view herd sharing as an important tradition that should be preserved.

3.3.2 Past practice of herd sharing

In the past, families with larger herds would share part of their livestock with families with fewer or no livestock. This system allowed host families to improve their economic stability and living conditions. In return, the sharing families paid the labor of caring for the livestock by offering some of their livestock, along with meat and dairy products, to the host families. Thus, the system was considered mutually beneficial. The selection of host families varied and could include relatives, herders from the same *gacha*, or even those they had never met, with agreements made orally and based primarily on trust.

During the 1950s, before the collective era, this practice was encouraged and formalized by the local government. At that time, Inner Mongolia operated under a decentralized system of animal husbandry. According to interview participants, when a giving family (a family with a larger herd) lent part of their livestock to another household, the receiving family (with few or no animals) would receive animals under the condition that 60% to 70% of the herd be female. After one year, 30% to 40% of the newborn offspring would belong to the receiving family. For instance, a herd-sharing contract from 1953 (see Figure 6) stated that the receiving family would retain 40% of the newborn animals, while 60% would be returned to the giving family each year. Additional details indicate that in the case of twin births, one offspring would stay with the mother, while the other would be returned to the giving family. If unexpected livestock deaths occurred, the receiving family bore one-third of the loss, and the giving family assumed the remainder. In the event of disease-related losses, such as from brain infections, the burden was shared equally. The herd was returned after shearing, allowing the receiving family to keep the wool as part of their benefit.

Participants noted that, during the collective era (1950s-1970s), the main use of this practice was to assist herders in need. Although all livestock and pastures were owned by the community, households still retained small amounts of livestock to sustain themselves, with the local government acting as the sharing entity to ensure every household had enough.

> *"In the 1970s, they* [the government] *gave us 100 sheep to herd, and by the end of the year, they took back the original ones with 70% of their offspring, leaving us with the rest…not just us, many families increased their herd number."* (Altengerel, personal communication, 2023).

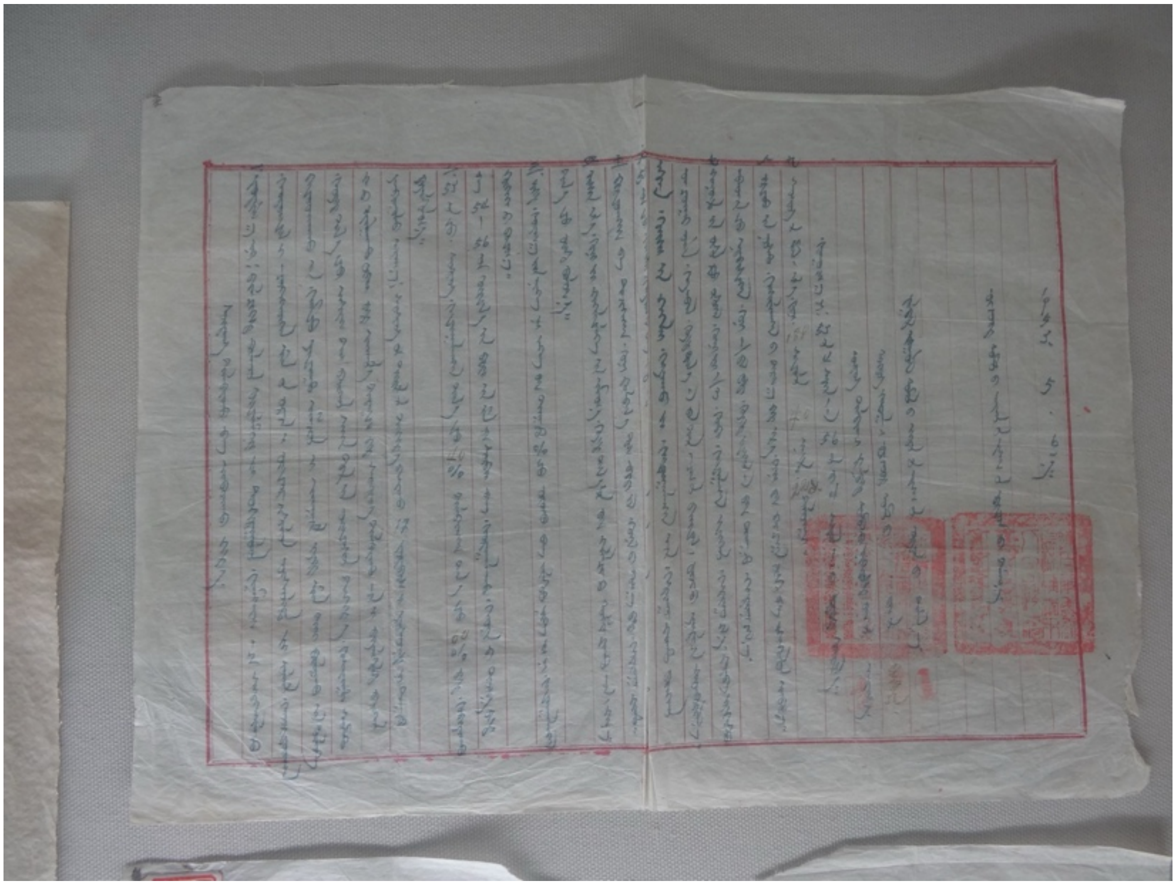

Figure 6. A herd sharing contract between two herder families from 1953. Picture provided by a local herder.

As recently as the early 2000s, herd sharing was employed as a collective strategy to help herders mitigate and recover from severe climatic events. For example, in the winter of 2000, the *Honger gacha* suffered a devastating white *dzud*, losing almost 75% of its livestock. The following year, the neighboring banner of *Sunid* experienced a severe drought, leaving no grazing available until early July 2001. In response, leaders from the two communities collaborated to implement herd sharing. Herders from *Hongor gacha* took charge of 20,000 ewes from Sunid, agreeing to return the same number of mother ewes (without returning the offspring) the following year. This initiative was pivotal not only in helping *Honger* herders rebuild their livestock base, but also in helping *Sunid* herders to cope with the drought.

3.3.3 Current practice of herd sharing

Survey data shows that 81% (n = 162) of the households know about the herd sharing practice, and 25% (n = 49) of the households either have shared their livestock with other families or got livestock from others. Compared with the past, among the households who practice herd sharing now, most (43%, n = 21) prefer to share their livestock to relatives, neighbors constituting the second most popular option (28%) (see Figure S2a). Only 18% of households choose to share their livestock with strangers, and 7% share with families they know, but who are not necessarily neighbors or relatives.

Compared to past practice, now it is more common to receive/pay money rather than take/give back offspring. In East Ujimchin, the original livestock that have been shared are called *monghk mal,* literally meaning 'everlasting herd'. Herders assume that each base livestock will give birth to one offspring. According to one of the recent contracts provided by a herder (see Figure 7a), 'On the basis of ensuring the base number of livestock that have been shared, the receiving family should pay around 55 USD per sheep, around 11,000 USD annually to the giving family. Participants noted that this payment is equivalent to giving back 50% of the offspring, as the market price of a lamb is 110 USD. If the herd gets sick, the host families must fully absorb the losses resulting from the illness. Previously, the administrative unit served as the guarantor of the contract, but now an individual household takes on that role, as agreed upon by both parties.

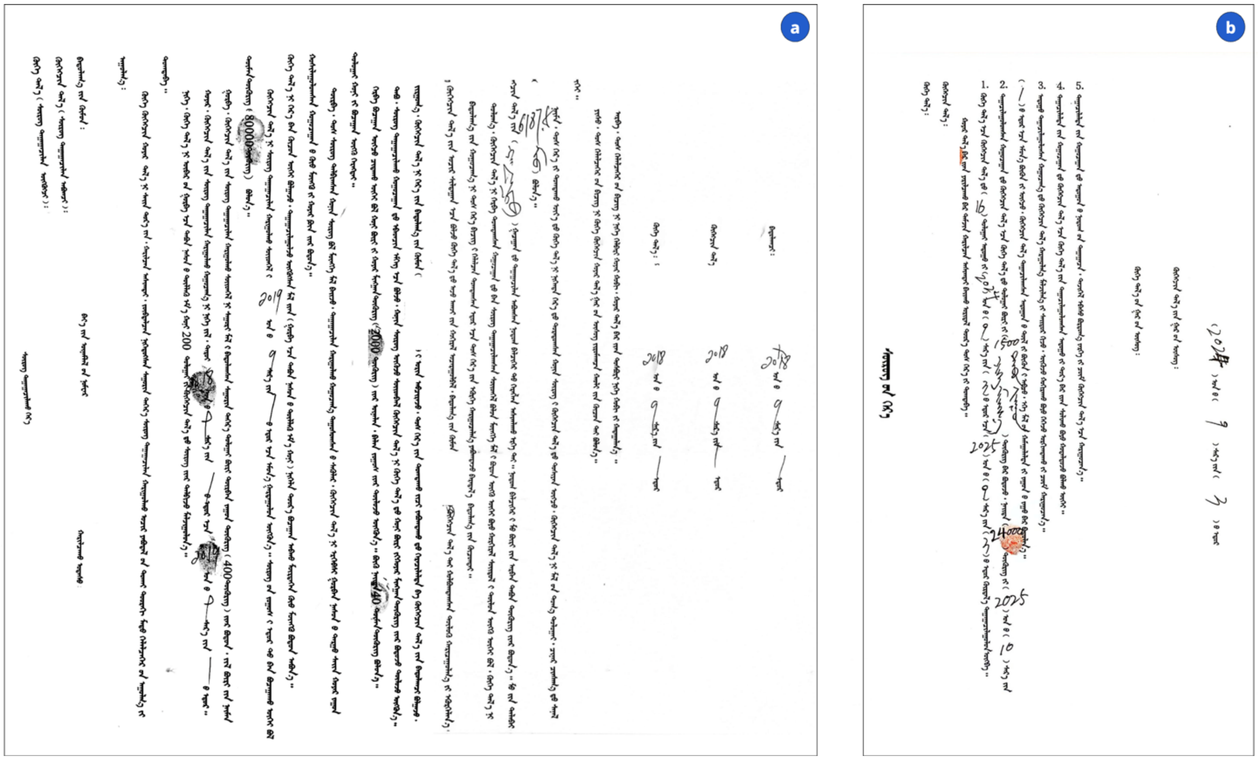

Figure 7. Current herd sharing contracts between herder families. The contract provided by local herders; (a) is a sheep sharing contract from 2018, and (b) is a horse sharing contact from 2024.

Besides sheep sharing, horse sharing is also common in East Ujimchin. Compared with sheep sharing, horse sharing requires slightly lower payback rate of the offspring. For instance, one horse sharing contract (see Figure 7b) shows that the receiving family must pay approximately 200 USD for each young horse, equating to one third of the market value. This arrangement means the receiving family pays back 30% of the offspring's value.

Overall, based on survey data, herd sharing is perceived positively for its ability to address several critical challenges faced by herders (see Figure S3). A significant portion of households (82%, n = 162), believe that herd sharing can help herders manage land shortages. 73% of the households also recognize its role in dealing with current labor shortages. Additionally, 70% of households perceive herd sharing as an effective strategy to combat land degradation, and more than half of them (52%) reported it helpful in mitigating severe climatic events.

4. Discussion

4.1 Continuity within Changes

One of the main findings from our work is that while various elements of all three practices have changed, many others have persisted and remain active. In the context of mobile grazing in East Ujimchin, despite the changes in moving distance and frequency, herders still practice strategic seasonal movements within the limited pastures they have available. They do so by careful observation of the subtle signs in the pastures, the landscape, and changes in vegetation. For families with insufficient pasture area to support distinct seasonal grazing, micro-mobility is adopted. Aligning with these findings, despite the sedentary or semi-sedentary reality of many pastoralists globally, it is crucial to remember that mobility remains an integral component of the herding life (Na et al., 2018; Varga et al., 2020). The change towards micro-mobility is not unique to Inner Mongolia but mirrors challenges and diverse adaptations observed in other parts of the world. From the adjustment of mobility routes by Kenyan Maasai pastoralists and the Fulani communities in northwestern Ghana, to the delay of migration timings by nomadic groups in Semirom, Iran, pastoralists globally continue to adapt their mobile grazing strategies to meet the shifting conditions they face (Napogbong et al., 2021; Saboohi et al., 2022). Therefore, while acknowledging that traditional communities globally increasingly face pressures that threaten their knowledge (Fernández-Llamazares et al., 2021), it is essential to recognize that knowledge changes do not always signify an absolute loss, but rather prove the non-static nature of knowledge (Gómez-Baggethun & Reyes-García, 2013).

Similarly, many traditional traits that help herders to cope with various challenges-whether they are related to productivity, climate resistance or cultural values- have also persisted. To better understand the rationale behind the documented persistent use of specific traits among the herders of East Ujimchin, we engaged in discussions with three local herders. They explained that a good lineage is highly valued by herders because it correlates with key productivity indicators: increased offspring numbers and greater body weight, and higher milk production. Similarly, livestock with wider hips and long back are preferred because they have fewer complications when giving birth and higher meat production. The preference for sheep with big and even tails is explained because tails supply stored nutrients that sheep need to get through harsh springs and winters. These insights from herders show that current breeding trait selection is a deliberate strategy rooted in the traditional knowledge, thoughtfully applied to fulfill their needs.

In the practice of herd sharing, while the format of agreements has transitioned predominantly to written contracts and financial compensation has largely replaced the return of offspring, various families still share and take herds from each other based on reciprocity relations. The literature suggests that the traditional practice of herd sharing was practiced in several other places of the world, adapting to local contexts. One example is the *mafisa* system (lending cattle to the poor) in southern Africa, particularly in Botswana. This livestock loan system involves distributing livestock among a few people in different locations, effectively reducing the risks associated with livestock mortality during droughts. An estimated 11–12% of families in Botswana were engaged in this practice as of 2002 (Mokomane, 2018), though the regional scope of this estimate is not clearly defined in the source.

4.2 Multifunctionality

Another important finding from our study is that each of the practices analyzed serves various functions. Historically, these practices have been multifunctional. Currently, as environmental, and socio-economic conditions evolve, new functions are also emerging, allowing these practices to adapt and respond effectively to contemporary challenges.

In East Ujimchin, the practice of mobile grazing was mainly used as a mechanism to restore herd health and productivity, but nowadays it also plays roles in maintaining ecological balance and adapting to climate change. Furthermore, herders also emphasized their commitment to mobile grazing as a way to preserve their ancestral Mongolian culture. This multifunctional nature of knowledge was also observed by Robinson and colleagues (2021) in Kazakhstan, where mobile grazing, used to optimize forage intake through spatial and temporal variability, collapsed in the 1990s after the dissolution of the Soviet Union, but has been revived in recent years to improve pasture conditions, animal weight gain, and farm profitability (Robinson et al., 2021). This example of the revival of mobile grazing in Kazakhstan also shows that when TEK becomes ineffective, the loss of relevance can potentially lead to its decline or loss. However, this does not always mean an absolute end. Rather, it could mark a phase of ongoing adaptation where knowledge is refined through cycles of observation, experience, and trial, allowing itself to evolve in response to new challenges and opportunities.

The practice of herd breeding also traditionally plays diverse functions, including maintaining herd health and productivity, contributing to ecological balance, and adapting to changing climate. Our data indicates that, following the 1984 land tenure reform, in addition to original functions, East Ujimchin herders now also increasingly recognize the new evolving functions of herd breeding practice in enhancing the herd's resistance to drought and pasture shortages. Similarly, in Gambia, herd breeding addresses not only direct economic benefits, such as milk and meat production and adaptation to environmental stresses, but also the preservation of cultural heritage (Ejlertsen et al., 2012). In Hungary, the Hungarian Grey cattle, known for their strength in draught and tillage, faced near extinction in the mid-20th century due to the mechanization of agriculture (Bartosiewicz, 1997). However, because of Hungarians' deep cultural attachment to the breed and its historical identity, this traditional breed and its breeding practices have survived to the present day (Bartosiewicz, 2017).

In addition to mobile grazing and herd breeding, herd sharing also has a multifunctional nature in East Ujimchin. Historically, herd sharing played a crucial role in supporting herders in need, but over time, its functions expanded to include maintaining herd-pasture balance, addressing labor shortages, sustaining herd growth, and minimizing climatic risks. With the implementation of land tenure reform and the fencing of pastures, herd sharing has shifted to address new challenges, such as land shortages and climate adaptation. Some families also view herd sharing as an important tradition that should be preserved.

If we imagine East Ujimchin pastoral knowledge as an ecosystem, then different types of knowledge can be understood as populations within this ecosystem. Just as species populations in an ecosystem perform diverse roles—from nutrient cycling to climate regulation—so too different elements of traditional knowledge perform diverse and multiple functions. Research suggests that ecosystems with greater functional diversity are more resilient to disturbances and changes, as this diversity enables multiple adaptive responses to environmental fluctuations, thereby maintaining ecosystem stability and facilitating recovery after disturbances (Díaz & Cabido, 2001). Similarly, we argue that the diverse functions of TEK may contribute to the resilience of the knowledge system itself, ensuring that it remains dynamic and capable of withstanding socio-environmental shifts.

4.3 Functional Complementarity

Another finding of this work is that the studied practices perform shared functions together. TEK systems are inherently holistic and complex; within them, diverse knowledge and practices work synergistically to adapt to and manage the natural environment effectively (Iaccarino, 2003). For example, in adapting to climate variability, herders do not simply rely on weather forecasts (Alemayehu & Hizkeal, 2022), but also emphasize strategic herd breeding to select traits that improve livestock's drought tolerance and productivity (Ghorbani et al., 2013). To sustainably manage the pastures, herders often use not only their understanding of forage/plants growth cycles, but they also consider grazing preferences and habits (Sharifian et al., 2023). This way they can better adapt to changing pasture conditions.

In East Ujimchin, mobile grazing and herd breeding practices are both employed to maintain herd health and productivity. Herders in East Ujimchin make sure the livestock access to seasonally optimal pastures with diverse forage, and this mobility helps livestock build strength throughout the year, as different pastures provide specific benefits (Behnke et al., 2011). However, after 1984, the accelerated grassland degradation, driven by both climatic and anthropogenic factors, significantly reduced the productivity benefits previously achieved through mobile grazing (Liu et al., 2015; Liu et al., 2020). With this, herd breeding has taken on a heightened importance in maintaining herd health and productivity by focusing on selecting traits that increase offspring numbers and improve meat production.

The three practices also complement each other in terms of climate adaptation. Mobile grazing is particularly essential during severe weather events such as *dzud*, when herders move their livestock over long distances to access pastures that are more favorable for survival. Herd breeding has also been integral to climate adaptation, as herders continue to select livestock with traits that enhance their ability to withstand extreme weather. Herd sharing further provided a community-based mechanism for managing climatic risks. However, since the land tenure reform, long-distance mobile grazing has become nearly impossible to practice in the area (Xie & Li, 2008; Tugjamba et al., 2021). Thus, herders now cope with increasing droughts through stressing selection on certain breeding traits and through herd sharing practice. This functional complementarity of knowledge allows pastoral communities to approach challenges from various angles. But more importantly, we argue that the interplay and synergy among functions may contribute to the resilience of the knowledge systems through maintaining the essential ecological, economic, and socio-cultural functions of these systems.

Conclusion

Understanding the non-static nature of TEK through analyzing its local functions can empower communities to address various challenges with a broader range of local solutions, rather than relying solely on unified scientific solutions. For instance, in East Ujimchin, local herders use mobile grazing to rest and regenerate pastures. In contrast, the top-down solutions have often been to restrict mobility, disconnecting herders from their pastures and pushing them toward market integration (Han, 2011). On a global scale, while TEK systems are locally developed and tailored to specific environments, the challenges faced by local traditional communities often share commonalities, such as land enclosure. By systematically understanding the functions of TEK systems worldwide, we can create a shared knowledge and functional database. This could enable the development of innovative solutions, not just through the bridging of TEK with scientific knowledge, but also by connecting different TEK systems with each other.

Acknowledgements

The authors extend their sincere gratitude to the community members of East Ujimchin banner for their invaluable participation and knowledge contributions to this research. We particularly thank Borjigin Otgenbayar for providing the original illustrations that enhance this manuscript. This research was made possible through financial support from the China Scholarship Council (CSC). Additional funding was provided by the European Research Council under the ERC Consolidator Grant (FP7-771056-LICCI). This work contributes to the "María de Maeztu" Units of Excellence Program (CEX2019-000940-M) funded by the Spanish Ministry of Science and Innovation. This work has been also supported by the Laboratory for the Analysis of Social-Ecological Systems in a Globalized world (LASEG), Universitat Autònoma de Barcelona and Generalitat de Catalunya (2021-SGR-00182).

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Chapter 4

'Everything is Talking to Us': Understanding Traditional Weather Forecasting Knowledge through Proverbs in East Ujimchin Banner

This chapter corresponds to the article:

Chao, O., Li, X., & Reyes-García, V. *'Everything is Talking to Us'*: Understanding Traditional Weather Forecasting Knowledge through Proverbs in East Ujimchin Banner. *Weather, Climate, and Society* (under review).

Abstract

Oral traditions serve as a means for local communities to encode and transmit environmental knowledge through concise and memorable phrases, guiding daily decision-making. This study examines whether traditional proverbs carry traditional forecasting knowledge and whether local communities still recognize, use, and perceive them as reliable today. This study is based on nine months of field research in East Ujimchin Banner, Inner Mongolia, China, using online interviews (n = 4), semi-structured interviews (n = 43), and individual surveys (n = 227). After analyzing 28 locally recognized proverbs, we found that they predict six different types of weather and climatic events over both short- and long-term periods, relying on four main categories of indicators: natural phenomena, animal ecology, plant growth, and calendar-based observations. Survey results show that herders primarily recognize, trust, and use proverbs for short-term weather predictions, particularly those based on natural phenomena and animal ecology, with wind and cold weather being the most commonly predicted events. Older herders know and use more proverbs than younger ones, while those with higher formal education tend to be less familiar with them and rely on them less. These findings suggest that oral traditions not only encode generational weather knowledge but are also deeply rooted in a traditional worldview that emphasizes the interconnectedness of nature. Recognizing traditional knowledge as a legitimate and complementary source of weather and climate wisdom would not only enhance community autonomy in the face of increasing uncertainties but also preserve a sustainable way of understanding and living in balance with nature.

Keywords: climate adaptation, oral tradition, proverb, traditional ecological knowledge, weather forecast

1. Introduction

People around the world throughout human history have observed the living and non-living components of their surroundings to understand and prepare for the immediate and future weather (Uriyaanhan, 2018). Whether among pastoralists, hunter-gatherers, farmers, or fishers, this practice of observation has given rise to rich bodies of traditional ecological knowledge, often transmitted orally through stories, signs, and especially weather-related sayings and proverbs. Such weather lore represents one of the most widespread and enduring forms of environmental knowledge across cultures (Harrison et al., 2024; Garteizgogeascoa et al., 2020).

Current literature on traditional weather forecasting knowledge (TWFK) has documented and explored diverse ecological indicators used by different communities, and their practical usages in predicting weather and preparing for climatic variability. For example, Borena herders in Ethiopia observe that cattle becoming unusually calm and huddling close together in the pen signals an approaching drought (Ayal et al., 2015). Mossi people in Burkina Faso interpret the abundant fruiting of taanga trees as a sign of a good rainy season ahead (Roncoli et al., 2002). Similarly, Mongolian herders monitor the alignments of the moon and stars to anticipate severe spring and winter weather events (Uriyaanhan, 2018). In the Philippines, farmers and fishers rely on the behaviors of animals and insects to forecast incoming rain and storms (Galacgac & Balisacan, 2009). Along the Tamil Nadu coast of India, traditional fisherfolk interpret changes in wind direction (*kaatru*) and ocean currents (*neerottam*) to determine suitable fishing grounds and predict hazardous sea conditions (Salim, 2019). Among the Tsimane' people in Bolivia, seasonal flowering of plants and bird calls are used to signal transitions in the rainy season and guide subsistence strategies (Reyes-García et al., 2018).

These examples show how nature-dependent communities have developed sophisticated systems for reading environmental cues. Such knowledge systems not only guide immediate livelihood decisions but also help anticipate climatic risks and sustain community resilience over time (Berkes et al., 2000; Reyes-García et al., 2015; Hosen et al., 2020). In recent years, there has been growing recognition of the contributions of traditional weather forecasting knowledge (TWFK) to broader climate adaptation strategies (Iticha & Husen, 2019; Balehegn et al., 2019; Camacho-Villa et al., 2021; Chao et al., 2025). For communities whose daily activities are intricately tied to the natural environment, TWFK gives these communities autonomy to gain more localized, culturally relevant, and accessible insights to tackle ongoing challenges (Zuma-Netshiukhwi et al., 2013; Zvobgo et al., 2023). However, despite the continuous significance of TWFK, some researchers report that increasing weather variability and changing climatic patterns have reduced the reliability of many TWFK systems, as some indicators no longer behave predictably (Kalanda-Joshua et al., 2011; Kagunyu et al., 2016). As a result, many traditional communities are gradually abandoning these knowledge systems (Roncoli et al., 2011; Balehegn et al., 2019). However, whether TWFK systems are being abandoned because of their perceived lack of accuracy is an open question.

This study addresses this question by analyzing the characteristics and the relevance to local climate variability of traditional weather-related proverbs from East Ujimchin Banner, Inner Mongolia. While the role of TWFK in community resilience and climate adaptation has been covered by many studies (Tanyanyiwa, 2018; Camacho-Villa et al., 2021; Alemayehu et al., 2023), less attention has been given to the role of oral traditions, particularly proverbs, as carriers of weather knowledge. Proverbs, like other forms of oral tradition, condense generations of environmental observations into simple, memorable phrases, making it easier for communities to recall and apply them in daily decision-making. Across different regions, weather-related proverbs continue to reflect localized climate wisdom. In Spain, proverbs like 'When birds flock together, men go on spree' reflect knowledge about predicting upcoming rainfall based on changes in birds' behavior (Garteizgogeascoa et al., 2020). In Hungary, there is a widely known weather proverb, 'A rain in May is golden', though they do not constitute forecasting in the predictive sense (Paczolay, 2007)[3].

However, despite their widespread use in many cultures, proverbs are often referenced only anecdotally, with little systematic effort to collect, analyze, or interpret them as significant carriers of TWFK. This raises the central research question of this study: *What role do weather-related proverbs play in preserving ecological memory and guiding local adaptation across different cultural and climatic contexts, especially in an era of increasing environmental uncertainty?* To address this gap, this study aims to: 1) analyze the characteristics and themes of weather-related

[3] This proverb means that rainfall in May is highly beneficial.

proverbs in East Ujimchin; 2) examine how these proverbs are recognized, used, and perceived as reliable based on different characteristics and themes; and 3) investigate how the recognition, usage, and perceived reliability of traditional weather-related proverbs vary across key sociodemographic factors, including gender, age, education level, livestock ownership (both number and diversity), and land area.

2. Methodology

2.1 Study Area

This study was conducted in East Ujimchin Banner, located in the eastern part of the Inner Mongolia Plateau and on the western slopes of the Bogd Uul Mountains, China (Figure 1). With 46,419 people — 74.70% of the total population—the banner hosts a significant number of Mongolians (Statistic Bureau of East Ujimchin, 2020). The banner's 4,611,300 hectares overall rangeland area is nearly equivalent to the area of the Netherlands (Local Government of East Ujimchin, n.d.). The Ujimchin grasslands experience four distinct seasons. Spring is unpredictable, characterized by fluctuating conditions that include snow, rain, and frequent windy days. Summer generally has high temperatures with regular rainfall. In contrast, autumn is relatively cool with minimal rainfall and stable weather, while winter is intensely cold, often marked by significant snowfall. Temperature extremes in the region range from highs of 39.3°C in summer to lows of -40.5°C in winter (Uriyaanhan, 2018). The annual precipitation is 300 mm, concentrated around June through August (Uriyaanhan, 2018).

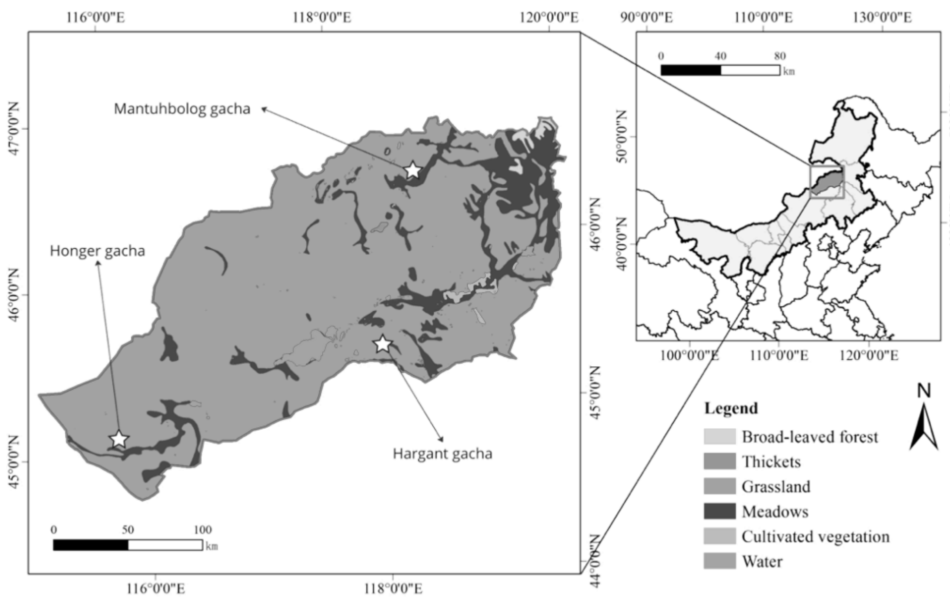

Figure 1. Map of the study area showing the locations of the selected sites - *Honger, Hargant, and Mantuhbolog gacha.*

2.2 Data Collection and Sampling

This study is based on nine months of fieldwork from November 2022 to August 2023. We employed a variety of methods, starting with proverb collection from elders through online interviews, then semi-structured interviews (SSIs), face-to-face individual surveys, and follow-up interviews. Prior to data collection, necessary ethical authorizations were obtained from the Ethics Committee of the Universitat Autònoma de Barcelona (CEEAH—6170). Consent was collected from all herders, ensuring it was free, informed, and before the participation.

For data collection, three *gacha* (the smallest administrative units in Inner Mongolia) were selected: *Honger*, *Hargant*, and *Mantuhbolog* (Figure 1). *Honger* has an area of around 60,533 hectares and consists of 127 households. *Hargant* covers 45,100 hectares and has 142 households. *Mantuhbolog* includes an extensive area of over 100,000 hectares and has 132 households. The total area of rangeland per household ranges from 300 to 800 hectares. In addition to their size, these *gacha* share comparable socio-ecological characteristics. The choice of these *gachas* was influenced by the first author's previous engagements and well-established connection with both the area and the herders there.

To gain preliminary insights into how the herders traditionally predicted weather in the study area, firstly, we conducted informal online interviews with four knowledgeable elders before traveling to the sites (Figure 2). These herders, who are recognized as local experts in Ujimchin culture[4], were selected through purposive sampling. During the interviews, they emphasized that Mongolians have a rich *cheej soyol*—a 'memory culture' where wisdom is preserved and transmitted orally rather than through written records. A key component of this oral tradition is the use of proverbs, which serve as a means to encode and pass down environmental knowledge, including weather prediction. They shared numerous traditional weather-related proverbs, and we retained those recognized by at least three of the elders during the initial interviews.

[4] We consider that a local expert in Ujimchin culture is someone who has been a herder and published book(s) about Ujimchin culture.

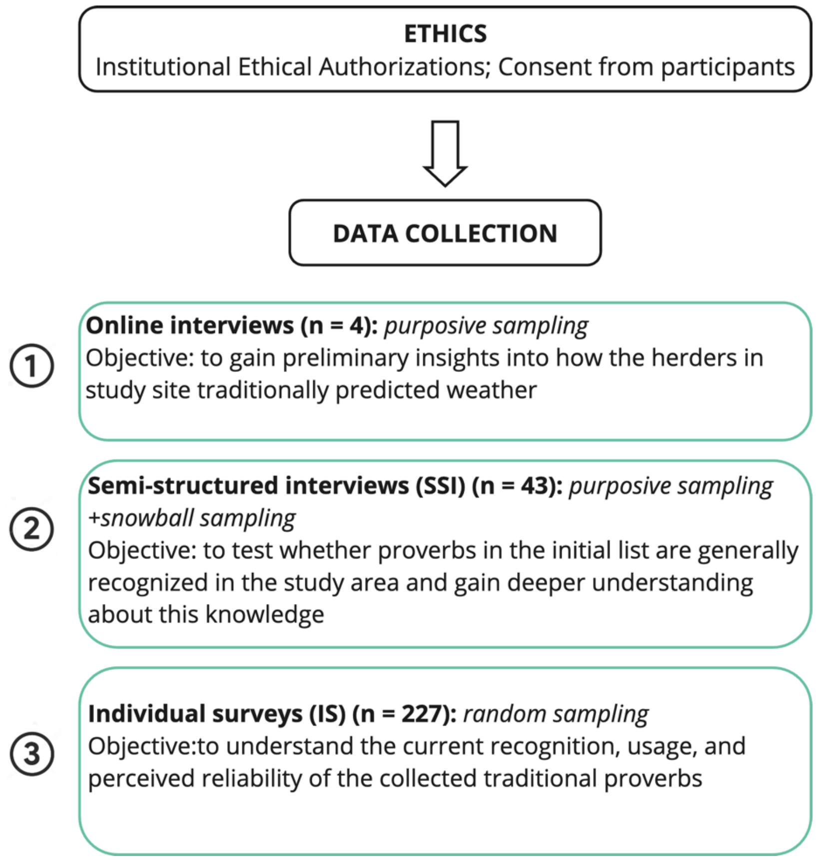

Figure 2. Summary of the data collection methods. Main steps include: 1) online interviews; 2) semi-structured interviews; 3) individual surveys; and 4) follow-up interviews.

To test whether proverbs in the initial list are generally recognized in the study area, and the role of these proverbs in predicting climate variability in the past, we conducted 43 SSIs with knowledgeable elders. Unlike the four expert herders interviewed online at the start of the study, these elders were not formally recognized as experts but were respected for their long-term experience with pastoral practices. We first used purposive sampling to select three elders with rich traditional knowledge, all over the age of 60 and honored locally as leading herders. Then, to broaden the pool of herders, a snowball sampling technique was then used, wherein the initially selected elders recommended additional elders. To confirm whether proverbs in the initial list are locally recognized, we asked all herders whether they knew each of the proverbs on our list and their past experiences. We also added proverbs mentioned by more than three elders that were not in our initial lists. Our final list includes 28 proverbs.

To understand the current recognition, usage, and perceived reliability of the collected traditional proverbs in East Ujimchin, we conducted 227 individual surveys using a random sampling method. For the individual selection process, we first numbered the households based on a list provided by the *gacha* leader. We then used a random number generator to select households for participation. Within each selected household, we surveyed the household head. In some families, we surveyed both male and female household heads. While the vast majority of households were male-headed, only two households were headed solely by females. To ensure gender balance, when possible, we prioritized selecting female household heads over the male in some families. In the end, we surveyed 71 female and 156 male herders. We also collected other demographic data, including the age, education level, livestock ownership (both the number and types of livestock), and the size of their land. At the beginning of the survey, respondents were first asked about the methods they use to predict weather. Following this, the survey included 28 proverbs finalized through SSI. For each proverb, respondents were asked whether they recognize it, whether they still use it, and whether they consider it reliable.

To better understand the findings, we then conducted follow-up interviews with three additional knowledgeable herders. During these interviews, we showed and explained them the survey results and asked, ‘Why do herders who question the reliability of certain proverbs continue to rely on them?’ and incorporated their insights into our discussion section.

2.3 Data Analysis

In this study, we used a mixed-methods approach, combining qualitative content analysis with quantitative descriptive and inferential statistical analyses. To analyze the characteristics of the weather-related proverbs in East Ujimchin (Objective 1), we first employed content analysis to identify common emerging themes within the collected proverbs (Braun & Clarke, 2006). Through this process, three main characteristic categories emerged: (1) prediction periods (the timeframe for which the proverb predicts weather), (2) prediction indicators (the signs referenced in the proverb), and (3) predictions (the specific weather events being forecasted). Then we quantified and calculated the frequency of each category to explore the most and least commonly used prediction periods, indicators, and the predictions. To further explore the interconnectedness of the prediction indicators with prediction periods and the predictions, we made an alluvial diagram.

To examine proverb recognition and usage according to different proverb characteristics (Objective 2), we calculated the average percentage of survey respondents (out of 227) who recognized and used proverbs across the proverb characteristics. To further analyze the differences between proverb recognition and usage, we calculated the recognition-usage gap for each proverb by subtracting the percentage of respondents who reported using it from the percentage who recognized it. We then ranked the proverbs based on the size of these gaps and examined which prediction periods, indicators, and predictions were associated with the largest and smallest gaps. Perceived reliability was analyzed separately, considering only respondents who reported actively using a given proverb. For each proverb characteristic, we calculated the average perceived reliability rate by summing the number of respondents who considered the proverbs in that category reliable and dividing it by the total number of responses in that category.

To examine how these proverbs are recognized, used, and perceived as reliable based on sociodemographic factors (Objective 3), including gender, age group, education level, livestock ownership (both the number and types of livestock), and the size of their land, we employed an inferential statistical analysis to the survey data. We used independent t-tests to compare differences in recognition and usage between male and female respondents, while a weighted t-test was applied for perceived reliability to account for variations in the number of proverbs each respondent reported using. One-way ANOVA was used to assess differences across age groups. For continuous factors such as education level, livestock number, livestock type diversity, and land size, we performed correlation analysis to determine their relationships with recognition, usage, and perceived reliability.

2.4 Positionality Statement

As an ethnic Mongolian from China, the first author's cultural connection to the study community fundamentally informed the research approach and data interpretation. This cultural positionality offered the team privileged access to knowledge holders and enabled a nuanced understanding of the local cultural context. However, this insider status also requires careful reflexivity regarding potential biases arising from such close cultural proximity. The research team's composition, including scholars from Catalonia and China, brought diverse theoretical and methodological perspectives derived from their extensive work with local traditional communities globally. To enhance methodological rigor and minimize potential biases, we employed multiple methods and conducted collective reviews during the research design and implementation. We acknowledge that despite these measures and our diverse perspectives, our interpretation may not fully capture the complexity and nuances of the community's knowledge systems.

3. Results

3.1 Descriptive Characteristics

3.1.1. Characteristics of traditional weather-related proverbs

The examination of the 28 collected proverbs showed that there were clear patterns in terms of the prediction periods, indicators, and the kinds of climatic events foreseen (Table 1). Daily predictions emerged as the most frequently observed category, including a variety of natural phenomena and animal ecology that indicated imminent weather changes (Table 2). For instance, herders interpreted the snorting of goats or camels stretching their necks and lying down as signs of approaching cold weather. Additionally, a cloudy sunset was often followed by windy conditions. Yearly and seasonal predictions were equally frequent, each accounting for seven proverbs (Table 2). As an example, the appearance of dark-blue clouds during the first day of Tsagaan Sar (Mongolian New Year) was believed to indicate a year that would see abundant rainfall. Seasonal predictions included watching the height at which migrant birds flew during the autumn season, which offered insight into the potential for severe winter events. Though less frequent with six proverbs, monthly predictions included some very commonly known proverbs, such as the one noting that *Boljimor* (Asian Short-Toed Lark) flying closely together indicated the approach of colder and snowy weather.

Table 1. The collection of 28 weather-related proverbs and their prediction period, prediction indicator, and prediction

ID	*Traditional proverbs*	*Prediction period*	*Prediction indicator*	*Prediction*
1	On the first day of *Tsagaan Sar* (Mongolian New Year), if the bull lies with the wind, the year will be disastrous; if it lies against the wind, the year will be good.	Yearly	Animal ecology	Both drought and severe winter event
2	If there is an abundance of *Hamhool* (*Salsola collina* Pall.) on the grassland, the year will experience severe winter events.	Yearly	Plant growth	Severe winter event

3	If *Chahildeg* (*Iris Lactea* Pall.) blooms early on the grassland, drought will occur during the year.	Yearly	Plant growth	Drought
4	During the '*Meqid Sariin Hargaa'* event (when a particular star and the moon align), if the group of stars is above the moon, the year will experience drought or severe winter events.	Yearly	Natural phenomena	Both drought and severe winter event
5	If dark-blue clouds appear on the first day of *Tsagaan Sar*, the year will have abundant rain.	Yearly	Natural phenomena	Precipitation
6	If the first day of Tsagaan Sar is marked in blue on the Mongolian traditional calendar, the year will be rainy and prosperous; if it is marked in red, the year will experience drought.	Yearly	Calendar-based observations	Precipitation and drought
7	If Oodegen (Mongolian gerbil, *Meriones unguiculatus*) collect their food early and in larger quantities than usual, the year would experience severe winter events.	Yearly	Animal ecology	Severe winter event
8	If the Nuudeliin Xubuud (migrant birds) fly low and leave late in autumn, the winter will be favorable; if they fly high and leave early, there will be cold and severe winter events.	Seasonal	Animal ecology	Both cold and severe winter event
9	If there are many *Nogteruu* (Pallas's Sandgrouse), the winter will not be cold.	Seasonal	Animal ecology	Cold
10	If there is an abundance of *Hilgan* (*Stipa grandis* P. Smirn.) on the grassland, the winter will experience severe snow events.	Seasonal	Plant growth	Severe winter event
11	If *Taan* (*Allium polyrhizum* Tirzc. ex. Rege) flowers early, the winter will have heavy snow.	Seasonal	Plant growth	Precipitation
12	Frequent light snow in winter signals severe snow events.	Seasonal	Natural phenomena	Severe winter event

13	If it is windy on the 4th of April, the following 45 days will be windy.	Seasonal	Calendar-based observations	Wind
14	The weather from September 1st to the 6th on the Agricultural calendar can predict the upcoming three months of spring and the three months of winter.	Seasonal	Calendar-based observations	Other
15	In winter, if *Boljimor* (Asian Short-Toed Lark, *Alaudala cheleensis*) fly in groups, the month will be cold or snowy.	Monthly	Animal ecology	Both cold and precipitation
16	If a horse sneezes continually, it indicates a rainy month.	Monthly	Animal ecology	Precipitation
17	If *Agi* (*Artemisia frigida* Willd.) grows tall and flowers, the month will be cold.	Monthly	Plant growth	Cold
18	At the beginning of summer, if there are many *chagan huar* (*Hibiscus trionum* L.), the month will be rainy.	Monthly	Plant growth	Precipitation
19	If the 22nd and 25th of each month are pleasant, the following month will be nice; if the 22nd has bad weather, the next month will be harsh.	Monthly	Calendar-based observations	Other
20	Every second day of the month, if the moon's mouth is on the side, the following month will be good; if it is upward, the next month will experience bad weather.	Monthly	Natural phenomena	Other
21	If a goat snorts, the weather will be cool.	Daily	Animal ecology	Cold
22	If sheep ram each other, expect snowy cold weather.	Daily	Animal ecology	Cold and precipitation
23	If camels stretch their necks and lie on the ground, it will be cold or snowy.	Daily	Animal ecology	cold
24	In summer, if cows start to smell the air, rain is imminent.	Daily	Animal ecology	Precipitation

25	In winter, if there are three suns during sunrise, the weather will be cold; if there are three suns during sunset, the next day will have nice weather. [5]	Daily	Natural phenomena	Cold
26	If the sunset is cloudy, the next day will be windy.	Daily	Natural phenomena	Wind
27	In summer, if the sun rises with a white halo, rain is coming; in winter, it indicates cold snowy weather.	Daily	Natural phenomena	Precipitation and cold
28	If there is a halo around the sun, the day will be windy and cold.	Daily	Natural phenomena	Wind and cold

The collected proverbs analyzed revealed a diverse range of indicators used for predictions, categorized into animal ecology, natural phenomena, plant growth, and calendar-based observations. This variety showed a rich understanding of the natural world, where every element provided clues about upcoming weather changes. As one of the interview participants described, "Everything is talking to us: the birds, the herd, the sunrise and the sunset, and even the wind" (Saasereng, personal communication, 2023). Out of all the indicators, animal ecology was the most frequently observed indicator, appearing in 10 of the proverbs (Table 2). These observations focused on various species, from the herder's own livestock to wild animals such as Asian Short-Toed Larks (Alaudala cheleensis) and Mongolian gerbils (Meriones unguiculatus). For instance, the behavior of *Oodegen* (Mongolian gerbils), gathering food early and in larger quantities, was a traditional sign signaling severe winter conditions. Following animal ecology, natural phenomena were cited in eight proverbs. These included atmospheric signs such as the alignment of the moon and stars during the "Meqid Sariin Hargaa" event, predicting drought or severe winter events. Plants were another important indicator and were noted in six of the proverbs. Various species such as *Chahildeg* (*Iris lactea* Pall.), *Hamhool* (*Salsola collina* Pall.), and *Taan* (*Allium polyrhizum* Tircz. ex Regel) appeared in these proverbs. These plants were monitored for specific changes such as early blooming or an abundance of growth. Calendar-based observations, although less

[5] This refers to a natural atmospheric phenomenon known as a *sundog* (or *parhelion*), where bright spots appear on either side of the sun due to the refraction of sunlight through ice crystals. Sundogs are commonly observed in cold climates such as Mongolia and Inner Mongolia (CGTN, 2020).

frequent, were featured in four proverbs. These observations often involved precise dates or particular phenomena, such as the phase of the moon on a certain day. Moreover, they also included the interpretation of the colors associated with specific calendar years. Herders believed that a year associated with the color blue was viewed as a sign of abundant rainfall, whereas a year linked to the color red might suggest drier conditions[6].

Table 2. Characteristics of Traditional Weather-Related Proverbs

		No. of proverbs
Prediction period	Daily	8
	Yearly	7
	Seasonal	7
	Monthly	6
Prediction indicator	Animal ecology	10
	Natural phenomena	8
	Plant growth	6
	Calendar-based observations	4
Prediction	Cold	10
	Precipitation	9
	Severe winter event	7
	drought	4
	wind	3
	Other	3

The analysis of the collected proverbs also highlighted various climatic events that herders predicted. Out of all predictions, cold weather was the most frequently mentioned, appearing in 10 proverbs. For example, when herders observed goats snorting (proverb 21) or sheep ramming each other (proverb 22), they took measures to set up insulation around the sheep corral to keep livestock warm during the night. Precipitation was the central theme in 9 of the proverbs. A common example was when herders noted horses sneezing (proverb 16) or observed cows smelling

[6] In the traditional Mongolian calendar, each year is defined by a combination of a zodiac animal and one of five elements: wood, fire, earth, metal, or water. Each element is associated with a specific color — green/blue (wood), red (fire), yellow (earth), white (metal), and black (water). These color-element pairings are more than symbolic; they are believed to influence the character of the year. For example, blue (associated with water) is traditionally linked to rainfall and favorable agricultural conditions, while red (fire) is often associated with dryness and potential drought. As such, herders interpret the "color" of the year as an early signal of expected climate patterns, agricultural productivity, and even general fortune or hardship.

the air (proverb 24), which herders interpreted as a sign of rain. Another event that particularly bothered herders during winter was dzud, severe winter events, predicted in 7 proverbs. A severe winter event was defined by frigid temperatures and substantial snowfall, resulting in a significant loss of herds due to lack of feed and exposure. Therefore, typically around the start of the new year, herders were especially careful in the early morning to observe the bull's orientation in relation to the wind—whether it was facing or opposing it (proverb 1). One of the interview participants recounted a memory from his youth, stating, "When I was young, I visited a neighbor on New Year's Day. At their house, they were discussing the upcoming weather. The old man sitting at the back of the yurt spoke in a low voice, citing a proverb: 'This winter is going to be good; you should've seen my bull this morning.' True to his prediction, we had a great year" (Dabxilt, personal communication, 2023). Additionally, drought and wind were noted in 4 and 3 proverbs, respectively. Drought predictions were all associated with yearly observations such as the early blooming of *Chahildeg* (*Iris lactea* Pall.) (proverb 3). In contrast, predictions of windy conditions typically related to daily indicators. For example, a cloudy sunset often preceded windy conditions the following day (proverb 26).

To further explore the connections among the prediction periods, indicators, and predictions detailed in these proverbs, an alluvial diagram was developed (Figure 3). This diagram showed that daily predictions predominantly utilized animal ecology and natural phenomena. In contrast, predictions on a yearly, seasonal, and monthly basis drew from a broader range of indicators, including all four types. The diagram also showed the connection between different indicators and the types of weather events predicted. Cold weather and severe winter events, for instance, were primarily predicted through a combination of animal ecology, natural phenomena, and plant growth. Meanwhile, precipitation and drought were predicted through an integration of all four indicators. Additionally, wind conditions and other weather phenomena, such as general good or bad weather, were typically forecasted by natural phenomena and calendar date observations.

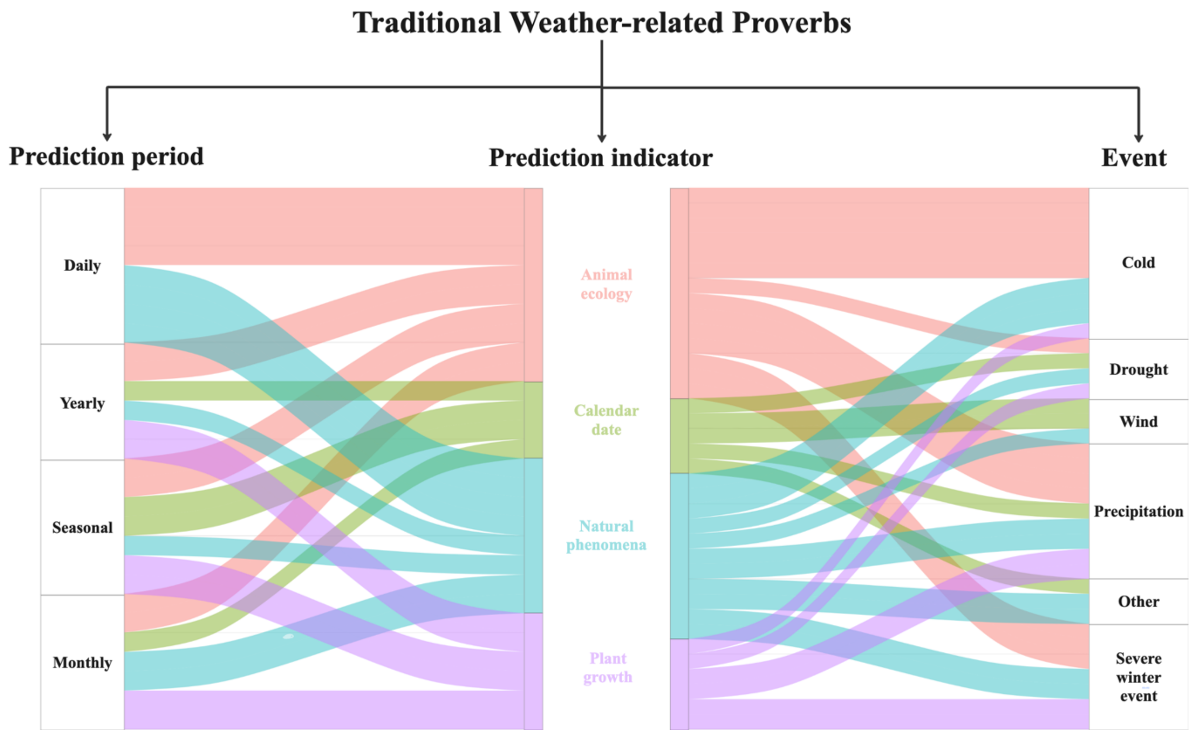

Figure 3. Alluvial diagram of the proverbs and the relationships between prediction indicators, prediction periods, and predictions.

3.1.2. Descriptive characteristics of the survey sample

In this study, the majority of our survey respondents were male, with a total of 156 males and 71 females participating (Figure 4). The age distribution of respondents showed a relatively even spread across the middle age groups, with 68 respondents from the 40–49 age group, 66 from 30–39, and 46 from 50–59. Notably, fewer respondents were either very young or very old, with only 10 respondents from 20–29 and two respondents over 70. In terms of educational background, the majority had completed middle school or primary school. A smaller number of respondents had either no formal education or had reached college and high school levels.

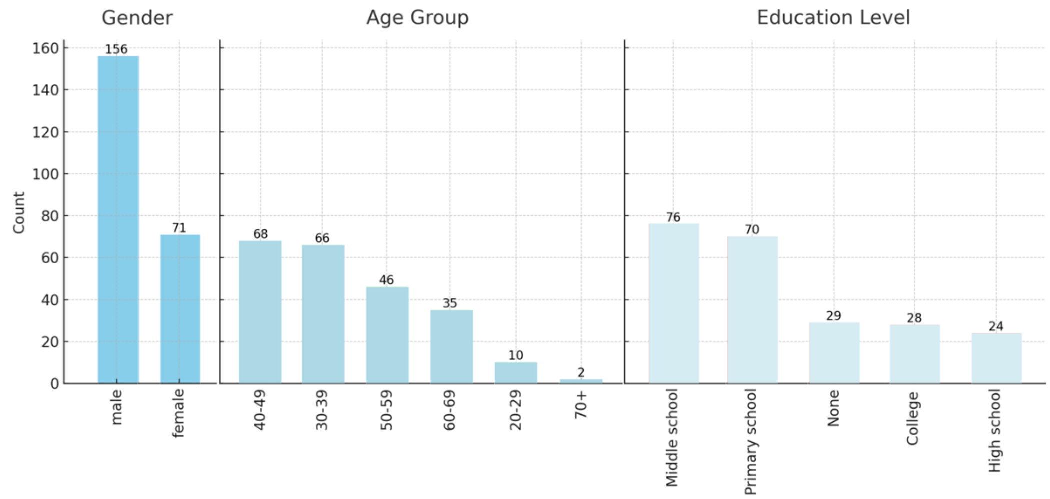

Figure 4. Demographic distribution of survey respondents by gender, age group, and education level.

On average, respondents owned approximately 643 livestock, with herd sizes ranging from 25 to 3,675. Additionally, households owned an average of three different types of livestock, with the number of livestock types per household ranging from one to five. In terms of land ownership, the average household land size was 471 hectares, with a minimum of 87 hectares and a maximum of 2,979 hectares.

3.2 Main Variables' Distribution Across Proverbs Characteristics

3.2.1. Distribution of main variables according to the characteristics of proverbs

The survey data showed that the recognition level of proverbs differed depending on prediction periods, indicators, and predictions. Specifically, recognition levels decreased with the length of the prediction period. Proverbs predicting daily weather events were recognized by a high percentage of respondents, with an average recognition rate of 75.2% (172 respondents) for this category (Table 3). For instance, daily prediction proverbs, like proverb 25, were recognized by a large majority of respondents (211, 93%). This was in contrast to longer-term predictions, where both seasonal and monthly predictions showed an average recognition of around 65%, and yearly forecasts dropped further to 57%. For instance, proverbs 11 and 3 showed a noticeably low recognition level (83, 4%; 70, 3%).

When it came to prediction indicators, proverbs related to natural phenomena were the most recognized, with an average of 79.4% (180 respondents) recognizing each of these proverbs. As an example, proverbs 25 and 28 were both known by over 200 respondents. The proverbs based on animal ecology and calendar-based observations also were recognized by, on average, around 67% of the respondents, although their overall usage was slightly lower. The least recognized prediction indicator was plant growth, with not even half of the respondents (43%) familiar with proverbs related to it. For instance, proverb 11 was recognized by not even one-third of the respondents (70).

Moreover, the survey data also showed differences in recognition based on the specific climatic events predicted by the proverbs. Proverbs predicting wind were notably frequently recognized compared to others, with the average recognition rate at 89%. All three wind-related proverbs were recognized by around 200 respondents. Proverbs related to cold and severe winter event predictions were also recognized by a considerable number of respondents; around 70% of respondents on average knew these proverbs. Other weather conditions (e.g., general good/bad weather) and precipitation were also common predicted events, recognized by around 65% of respondents on average. The lowest recognition was observed with drought predictions, which only 52.6% of respondents on average were aware of.

Table 3. Average recognition and usage of traditional weather-related proverbs based on prediction periods, indicators, and predictors.

Prediction Periods	**Average recognition (%)**	**Average usage (%)**
Daily	75.2	49
Seasonal	64.6	32.4
Monthly	62.6	39
Yearly	57.1	26.1
Prediction Indicators		
Natural phenomena	79.4	51.6
Animal ecology	67.6	37.1
Calendar-based observations	67	38.7
Plant growth	43	16
Predictors		
Wind	88.8	61.9
Cold	71	43.4
Severe winter event	69.4	34.4
Other	64.2	40.5

Precipitation	61.5	33.9
Drought	52.6	19.3

3.2.2 Distribution of usage across prediction periods, indicators, and predictions

The analysis of survey data also showed variations in the usage of proverbs based on prediction periods, indicators, and predictions. The data demonstrated that proverbs predicting daily weather events were the most actively used, with on average nearly half of the respondents regularly using them (Table 3). In contrast, the average usage rates for proverbs that predicted weather over longer periods showed a decline, with only an average of 39% of the respondents regularly using monthly predictions, 32.4% using seasonal forecasts, and just 26.1% relying on yearly predictions.

Regarding prediction indicators, proverbs associated with natural phenomena showed the highest usage, with an average of 51.6% of the respondents. In particular, respondents continued to actively observe the appearance of the sun, especially at sunrise and sunset, as key indicators of weather changes. For example, proverb 25, the three suns phenomenon, remained relevant, with 64% of respondents still applying it in their daily decision-making. Conversely, calendar-based observations and animal ecology predictions were used less frequently, with usage rates of 38.7% and 37.1%, respectively. Proverbs based on plant growth demonstrated significantly lower usage, with a usage rate of only 16.0%. In terms of predictions, wind-related proverbs were the most frequently used, with an average usage rate of 61.8%. Cold weather predictions were also commonly used (43.4%). However, average usage rates dropped for proverbs predicting severe winter events and general weather conditions, noted at 34.4% and 40.5%, respectively. Precipitation-related predictions were utilized at a rate of 33.9%, while drought-related proverbs saw the lowest usage at only 19.3%.

Upon closer examination of the differences between recognition and usage of these proverbs, we observed several significant gaps (Figure 5). The largest gaps between recognition and usage were particularly notable among seasonal and yearly prediction proverbs. For example, proverb 8, about the flying height of migrant birds, was known by 197 respondents, but only 98 reported using it in their decision-making. This pattern of large gaps between recognition and usage was similarly reflected in results for proverbs 1, 2, and 6. In contrast, the smallest gaps were found in proverbs predicting daily and monthly weather changes, such as proverb 22. When considering the indicators of these proverbs, the largest gaps were predominantly among those relying on animal ecology and plant growth. However, it was also noteworthy that some of the smallest gaps were found within these same categories. Furthermore, regarding prediction types, proverbs forecasting severe winter events showed the most substantial gap between recognition and usage. Conversely, proverbs predicting precipitation and cold weather conditions had the smallest gaps between recognition and usage.

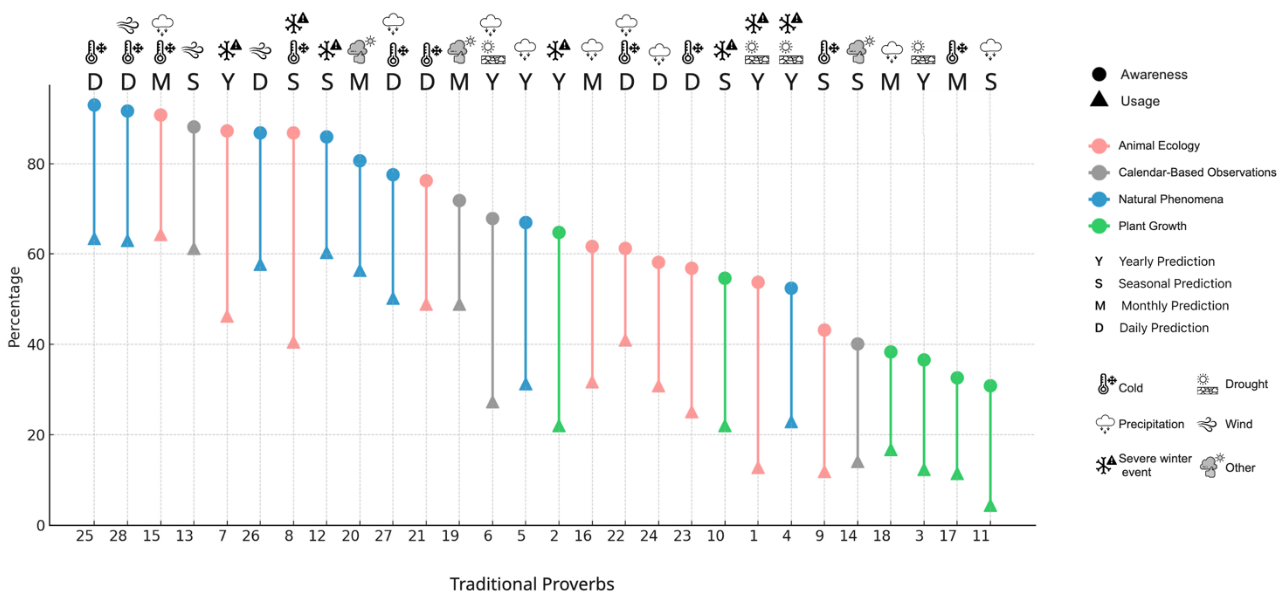

Figure 5. Line graph illustrating the gaps between recognition and usage of traditional proverbs, with prediction period, indicator, and prediction type shown (ranked by recognition rate).

3.2.3 Distribution of perceived reliability across prediction period, indicator, prediction

After analyzing survey data on the perceived reliability gathered from respondents who still used these proverbs, the results showed that 15 out of 28 proverbs were viewed as reliable by over 90% of respondents (Table S1). In terms of prediction periods, short-term prediction proverbs were generally believed to be the most reliable. 95.6% of the respondents who used these daily proverbs considered proverbs predicting daily weather to be reliable. For example, 110 out of 113 respondents (97.4%) believed proverb 21 was still reliable. Monthly proverbs also maintained relatively high reliability rates (94.5%). Seasonal proverbs showed somewhat mixed results. Although all seasonal proverbs remained widely recognized as a whole (88.3%), proverb 11 (related to the flowering time of *Taan*) was only considered reliable by around two-thirds of the respondents (66.7%). The yearly proverbs category, meanwhile, had the lowest perceived reliability (84.6%). While some proverbs, such as proverb 4, were considered reliable by 94.6% of respondents who used them, others had lower perceived reliability, with less than 85% of the respondents considering them reliable.

Compared to the other three indicators, respondents frequently cited natural phenomena-based observations as the most reliable, with 92.6% of the respondents believing that they were reliable. For example, proverbs related to the observation of the sun (such as proverbs 25, 27, and 28) were considered reliable by over 95% of respondents. Similarly, calendar-based observations and animal ecology were trusted by the majority, with perceived reliability rates of 92.5% and 92.3%, respectively. Notably, over 97% of respondents continued to observe and benefit from animal ecology indicators, such as birds (proverb 15), horses (proverb 16), sheep (proverb 22), and goats (proverb 21). However, not all indicators maintained the same level of reliability. For instance, proverb 7, "If *Oodegen* (Mongolian gerbil) collect their food early and in larger quantities than usual, the winter will experience severe winter events," was reported as unreliable by 18.3% of respondents (22 responses). These respondents noted that while *Oodegen* still collected food, they sometimes stored it inside their burrows rather than outside. Among all the proverbs, those based on plant indicators showed the lowest perceived reliability rate (83.3%). Nine out of 56 respondents questioned the reliability of proverb 2 because they noted that the abundance of *Hamhool* (*Salsola collina* Pall.) had increased on pastures due to its high tolerance to environmental stress.

In terms of the climatic events predicted by these proverbs, those forecasting wind and cold weather were regarded as the most reliable by respondents who applied them, with perceived reliability rates exceeding 95%. Specifically, around 140 respondents continued to use each of the three proverbs predicting wind, and fewer than 10 reported them as unreliable. Similarly, proverb 15, which predicted cold weather based on the flight patterns of birds, was used by 149 respondents, with only one reporting it as unreliable. Proverbs predicting precipitation and general weather conditions were also highly trusted, with reliability rates at 93.7% and 92.1%, respectively. For example, proverb 17 and proverb 25 were both used by over 120 respondents, and fewer than five questioned their accuracy. Conversely, although predictions related to extreme weather events such as drought and severe winter events were still perceived as reliable, their perceived reliability was somewhat lower than other types, at 86.8% and 85.4%, respectively.

3.3 Distribution of Main Variables Across Sample Characteristics

The analysis of survey data showed that only 69 out of 227 respondents (30.4%) relied solely on modern weather forecasting methods. In contrast, the majority (147 respondents, 64.8%) combined modern tools with traditional knowledge. Notably, a small but notable proportion of respondents (11, 4.9%) continued to rely exclusively on traditional knowledge.

We also explored the recognition, usage, and perceived reliability of the collected proverbs across different sociodemographic factors, including gender, age groups, education level, livestock ownership, and the size of their holding. Firstly, we found that gender was not associated in a statistically significant way with proverb recognition ($t = 0.683$, $p = 0.497$). However, with regard to age group, we found that older respondents recognized more proverbs in total ($F = 3.223$, $p = 0.008$). Especially, respondents aged between 50–59 recognized the greatest number of proverbs. Beyond gender and age, the relationships between educational level, livestock, and land area factors with total recognition were also analyzed using correlation analysis. We found that respondents who had received higher education recognized slightly fewer proverbs than people who had lower levels of education or had never been to school ($r = -0.18$). In addition, respondents with more livestock and larger land area knew slightly more proverbs than those with fewer livestock ($r = 0.203$) and land area ($r = 0.179$), while the number of different types of livestock did not affect how many proverbs they recognized ($r = 0.030$).

In addition to recognition, we examined how sociodemographic factors influenced the actual usage of traditional proverbs. Our analysis revealed that there were no significant differences in the total number of proverbs used between male and female respondents ($t = -1.048$, $p = 0.297$). However, age appeared to play a crucial role ($F = 13.270$, $p < 0.001$). Specifically, those aged 60–69 used the greatest number of proverbs. Regarding education, respondents with higher educational levels tended to use slightly fewer proverbs ($r = -0.36$). Meanwhile, a slight positive correlation was noted between proverb usage and both the number of livestock owned ($r = 0.124$) and the size of land ($r = 0.071$). Respondents with more livestock and larger land area used slightly more proverbs.

Similar to recognition, the diversity of livestock owned also showed no significant impact on the usage of proverbs ($r = -0.034$).

Next, we analyzed the perceived reliability of proverbs among respondents who actively used them. The results showed that there was no difference in male and female respondents' perceived reliability of these proverbs ($t = -1.644$, $p = 0.100$). We found there were statistically significant differences in the perceived reliability of proverbs among the age groups ($F = 11.183$, $p < 0.001$). Respondents from the age group 60–69 reported a greater number of proverbs they used as reliable. In terms of education level, respondents with higher educational levels reported slightly lower reliability of the proverbs they used ($r = -0.36$). The results also indicated that respondents who owned more livestock and larger land areas reported slightly higher perceived reliability of proverbs, with trends to positive correlations ($r = 0.124$ and $r = 0.071$, respectively). The variety of livestock managed by respondents did not significantly affect the perceived reliability of the proverbs they used ($r = -0.034$).

4. Discussion

Traditional weather-related proverbs in East Ujimchin remain valuable tools for climate adaptation, despite their declining usage, particularly among younger and more formally educated herders. However, they continue to be widely recognized and highly trusted by those who still rely on them. Beyond their forecasting role, these proverbs also reinforce local autonomy, allowing herders to make informed decisions based on their own observations. Additionally, they carry ancestral old knowledge and embody important cultural elements.

4.1 The Roles of Traditional Weather-Related Proverbs

A key role of the weather-related proverbs is their ability to enhance both short-term responses and long-term planning, enabling herders to prepare for immediate weather shifts while also predicting broader climatic patterns. Unlike modern forecasting providing mainly immediate and short-term prediction (Orlove et al., 2010), these proverbs offer insights across multiple timescales—daily, seasonal, and even yearly. This extended forecasting capacity is particularly valuable for pastoralists, whose livelihood strategies require both immediate adaptability and long-term preparation. Short-term predictions allow herders to take immediate protective measures, like sheltering livestock or adjusting grazing routes. Meanwhile, long-term ones, such as plant blooming patterns signaling drought, help them plan months or even a year in advance, ensuring that they use resources effectively and store enough fodder. This method of long-term prediction is also reported among other communities. For example, in the Okavango Delta, the Batawana people utilize the timing of fruit-bearing by specific trees to indicate rainfall patterns for the season (Kolawole et al., 2014). While the accuracy of such long-term predictions may be debated, their value extends beyond weather forecasting—they serve as early warning systems that allow communities to proactively organize livelihood activities and mitigate the impacts of extreme weather events. For instance, in Rwanda, local communities have expressed a preference for their traditional seasonal prediction knowledge over scientific meteorological forecasts, which often are not disseminated in a timely enough fashion to be of practical use (Irumva et al., 2021).

Beyond their practical function in weather forecasting, these proverbs can provide autonomy to local communities, especially in the context of an increasingly uncertain socio-ecological environment. The diverse indicators encoded in proverbs, from animal ecology and plant growth to cloud color and solar phenomena, can further strengthen this autonomy by ensuring that predictions are drawn from multiple environmental signals rather than a single source. For instance, if a proverb states that an early bloom of a particular grass species signals a dry year, herders can compare this observation with animal ecology or cloud patterns to cross check the prediction. Moreover, even if certain proverbs become less applicable due to the loss of specific plant or animal species, herders can still rely on other available indicators, ensuring the adaptability of their knowledge system (Chao et al., 2025). Communities that become overly reliant on a single forecasting system, especially one that is highly centralized or technologically dependent, might become more vulnerable to disruptions when that system fails or is compromised. The recent political targeting of the National Oceanic and Atmospheric Administration (NOAA) in the United States highlights the risks of over-reliance on any one system (Flavelle et al., 2025). If a government chooses to manipulate or defund the core forecasting agency, or if technological infrastructure is damaged due to some factors, communities that have lost their traditional knowledge systems may find themselves without alternative means of predicting and preparing for extreme weather events. This could then come with potentially catastrophic consequences.

Another important role of these proverbs is that they can encourage continuous environmental observation and preserve cultural elements. One of our findings shows that some herders who question the reliability of certain proverbs continue to use them. To understand this contradiction, we conducted three follow-up interviews with knowledgeable herders. When asked why this was the case, two of the herders also pointed out that, even if certain proverbs no longer function as consistently accurate forecasting tools, they remain an integral part of East Ujimchin culture and should be preserved. One herder explained that observing the environment is a natural and habitual part of daily herding. He believes that even if a proverb's reliability is questioned, the act of monitoring nature will always continue. Similarly, another herder emphasized that when a proverb fails to predict the weather correctly, they do not blame the natural signs themselves but rather their own lack of observation. This perspective aligns with the argument that traditional ecological knowledge is not static but continuously evolving, adapting to environmental and societal changes (Berkes et al., 2000; Reyes-García et al., 2014). Rather than being set aside when its reliability declines, this knowledge system should be recognized for its adaptive nature and its ability to complement 'modern' modes of weather prediction.

4.1.1 Ways forward

As climate variability intensifies, preserving and revitalizing TWFK become even more important. While our findings show that many weather-related proverbs remain widely recognized and trusted, their actual usage is declining, particularly among younger and more formally educated herders. This trend raises concerns about the long-term survival of traditional weather forecasting knowledge as a valuable climate adaptation tool. To ensure its preservation, we believe that more targeted and localized efforts are needed to document proverbs systematically and promote intergenerational knowledge transfer. An example model for knowledge preservation and transmission already exists within East Ujimchin in the form of *Ubligqi*, or cultural transmitters. This practice titles elders as guardians of cultural knowledge, who are responsible for mentoring younger generations and ensuring that core elements of Mongolian heritage, including oral traditions, or traditional games, are passed down. We believe expanding and formalizing this approach, such as by incorporating TWFK into existing *Ubligqi* mentorship programs or creating structured training for younger herders, could be an effective way to strengthen intergenerational transmission. However, for TWFK to remain a relevant and respected knowledge system in the face of modernization and climate change, it must be actively valued, supported, and integrated into broader decision-making frameworks. Recognizing TWFK as a legitimate and complementary source of climate wisdom, rather than an ‘old’ practice, will not only help preserve an essential aspect of cultural heritage but also enrich climate adaptation strategies with locally grounded insights.

Acknowledgements

The authors extend their sincere gratitude to the community members of East Ujimchin banner for their invaluable participation and knowledge contributions to this research. This research was made possible through financial support from the China Scholarship Council (CSC). Additional funding was provided by the European Research Council under the ERC Consolidator Grant (FP7-771056-LICCI). This work contributes to the “María de Maeztu” Units of Excellence Program (CEX2019-000940-M) funded by the Spanish Ministry of Science and Innovation.

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Chapter 5 Conclusions

Photo credit: Jesse Segura (2023)

In this Ph.D. thesis, I have examined the diverse functions, adaptability, and contemporary relevance of pastoral TEK, particularly how it continues to support livelihoods, ecological resilience, and cultural identity. To gain a broad perspective on how pastoral TEK systems function across different contexts, I conducted a systematic literature review on a global scale. I then complemented this global overview with an in-depth understanding of a specific community's traditional pastoral knowledge system. For that, I undertook nine months of ethnographic fieldwork in three gachas of the East Ujimchin community in Inner Mongolia, China.

5.1 Theoretical Contributions

The major theoretical contribution of this thesis is the demonstration that pastoral TEK, while often recognized for its ecological value, also plays diverse and significant economic and socio-cultural functions. This challenges a narrow framing of TEK as primarily an environmental tool and instead positions it as a multifunctional system embedded in the everyday lives, livelihoods, and identities of pastoral communities. Building on this, the thesis further develops the concept of 'functional complementarity' to explain how different domains of TEK—such as knowledge of grazing, herd management, and climate forecasting—interact and support each other. Rather than functioning in isolation, these domains reinforce one another, allowing pastoralists to flexibly respond to uncertainty and change. This interdependence helps maintain the internal coherence and resilience of TEK systems, especially under pressure from land reforms, climate variability, and shifting policy environments. Finally, the thesis contributes empirical evidence to the understanding of TEK as a highly adaptive and dynamic system. Drawing on ethnographic data from East Ujimchin, it shows that even as external pressures reshape herders' practices, the underlying logic and values of TEK remain active and relevant. Traditional practices are not static relics of the past but are being intentionally modified, repurposed, or combined in new ways to meet emerging challenges.

5.1.1 TEK as a multifunctional system

The first theoretical contribution of this thesis is the recognition and further development of the concept that pastoral TEK is inherently multifunctional (Chapter 2, Chapter 3, and Chapter 4). Scholars have long acknowledged the ecological value of TEK, particularly its contributions to biodiversity conservation and sustainable natural resource management; however, its broader economic and socio-cultural functions have received comparatively less attention (Gadgil et al., 1993; Berkes et al., 2000; Fernandez-Llamazares et al., 2015; Garnett et al., 2018; Reyes-Garcia & Benyei, 2019). Drawing from both global and local perspectives, this thesis demonstrates that although the ecological function of pastoral TEK is predominant in the literature, this body of knowledge also fulfills important economic and social-cultural functions. From an ecological perspective, pastoral TEK contributes to monitoring ecosystem health, preventing unsustainable use of nature, and maintaining biological diversity in the ecosystem (Ifejika Speranza, 2010; Ahmed et al., 2023). From an economic perspective, it contributes to the optimization of limited resources, mitigating the impacts of natural disasters, and maintaining livestock productivity and health (Fernández-Giménez, 2000; Molnár, 2017; Sharifian et al., 2023). Finally, from a socio-cultural perspective, TEK systems play an important role not only in preserving traditional culture but also in enhancing the social bond of the community and promoting cooperation (Fernández-Giménez, 2015; Wangdi & Norbu, 2018).

Additionally, findings from this work show that a single domain of knowledge or practice is rarely used for just one purpose, but rather, it often serves multiple functions (Chapter 2, Chapter 3, and Chapter 4). This theoretical insight is exemplified in the analysis of knowledge from pastoralists from East Ujimchin. Information collected from this thesis shows that knowledge of pastoralists in East Ujimchin regarding mobile grazing, herd breeding, herd sharing, and weather forecasting has historically addressed multiple needs, from maintaining herd productivity to improving social cohesion. This knowledge has continued to evolve to meet new challenges that occur. These diverse functions highlight that TEK is not static, but inherently adaptive and responsive to socio-ecological changes. Just as functional diversity enhances the resilience of ecosystems (Hérault & Piponiot, 2018; Hiltner et al., 2018), the multifunctionality of TEK may also enhance the resilience of the knowledge system itself, ensuring its ongoing relevance and capacity to respond to disturbance and transformation.

5.1.2 Functional complementarity across knowledge domains

The second theoretical contribution of this thesis is the development of the concept of ‘functional complementarity’ within pastoral TEK (Chapter 2 and Chapter 3). By highlighting the relational and systemic qualities of TEK systems, this work contributes to a more nuanced understanding of how knowledge systems function as integrated and interdependent wholes. Findings from both the global review and the East Ujimchin case study show that pastoralists do not treat different domains of knowledge in an isolated or compartmentalized manner. Instead, knowledge and practices from various domains are actively combined and reconfigured to achieve shared goals. This finding aligns with earlier studies that characterize TEK as inherently holistic, where knowledge, practices, and values are interwoven in ways that sustain both livelihoods and ecosystems (Fernández-Giménez, 2000; Iaccarino, 2003; Berkes, 2012).

Moreover, TEK is not only multifunctional, but its different domains are closely connected and often share similar functions. When one knowledge or practice becomes less viable, for example due to environmental stress, policy shifts, or land degradation, other components can fulfill similar roles. Such flexibility and internal overlap provide pastoralists with multiple options when navigating uncertainties and help maintain the overall coherence and resilience of the knowledge system. These dynamics are particularly visible in East Ujimchin. Following land reforms and ecological degradation, the feasibility of long-distance mobility has become increasingly constrained (Li & Huntsinger, 2011). In response, herders have repurposed long-standing practices such as herd breeding and herd sharing, adapting them to new challenges like restricted mobility and climate risks. When selecting breeding stock, they now place greater emphasis on drought-tolerant traits, while herd sharing is used strategically to manage climate risks and address land constraints. Although the emphasis may differ between households, these practices work together to support key goals such as sustainable resource use and climate adaptation.

5.1.3 Adaptability and continuity through change

The third theoretical contribution of this thesis relates to the adaptability of pastoral TEK (Chapter 2, Chapter 3, and Chapter 4). By comparing the past and present characteristics of pastoral knowledge and practices, as well as current levels of recognition, application, and perceived reliability, this thesis provides empirical evidence that TEK is not static but a dynamic and evolving system (see Berkes et al., 2000; Reyes-García et al., 2014 for a similar argument). According to the findings from my work, even if the practices of pastoralists in East Ujimchin have changed over time, their core functions and values remain active and relevant today. Changes are not necessarily indicators of erosion, they can also be signs of continuity through adaptation.

Importantly, findings from this work also show that new functions for pastoral knowledge have emerged in response to shifting conditions. For instance, herd breeding is now increasingly oriented toward enhancing herd drought resistance and improving forage efficiency, while herd sharing has taken on expanded roles in addressing land constraints and maintaining herd-pasture balance. These shifts are not random, they are intentional and informed by observation and experience, confirming that herders are active agents in shaping how TEK is applied today. Therefore, this thesis contributes to a broader understanding of TEK as a co-adaptive and resilient knowledge system shaped by lived experience, local priorities, and an ongoing negotiation with change.

5.2 Methodological Contributions

Methodologically, this thesis makes two notable contributions. First, it develops a structured typology for categorizing the functions of TEK. Second, it suggests the value of integrating oral traditions as a means of uncovering embedded TEK that may not be easily accessed.

5.2.1 Categorizing the functions of pastoral TEK

One of the methodological contributions of this work is the development of a framework for categorizing the diverse functions of pastoral TEK (Chapter 2). Through analyzing 152 case studies from 62 countries, the thesis systematically organizes pastoral TEK into three primary functional domains: ecological, economic, and socio-cultural, each further broken down into ten different subfunctions. This categorization not only clarifies the multiple roles TEK plays but also allows for the identification of cross-cutting patterns across different knowledge domains. Although previous studies have recognized the diverse functions of TEK (Oba & Kotile, 2001; Adger et al., 2005; Knight et al., 2022), to the best of our knowledge, none have attempted to synthesize and systematize these functions in a globally comparative way.

The proposed categorization provides a foundation for future research that seeks to evaluate the contributions of TEK systems across varied pastoral contexts. Rather than treating TEK as a general body of knowledge, identifying specific functional roles allows researchers to trace how pastoral knowledge systems respond to complex challenges, and to assess how particular practices evolve, adapt, or persist over time. Moreover, the categorization captures the overlap and synergy among different knowledge domains, providing a basis for analyzing multifunctionality and complementarity. This framework may also be of interest for researchers mapping and understanding TEK in not only in pastoral systems but also other subsistence-based livelihood settings worldwide.

5.2.2 Oral traditions as a method to reveal embedded TEK

The second methodological contribution of this thesis is the use of oral traditions, specifically proverbs, as a lens to examine and contextualize TEK (Chapter 4). It is well established that oral forms such as stories, songs, and proverbs serve as key vehicles for the transmission of TEK across generations (e.g., Kim et al., 2017; Berkes, 2018; Garteizgogeascoa et al., 2020). However, despite this recognition, oral traditions have often been underutilized in TEK research in terms of both data collection and analytical depth. For instance, they are often cited merely as descriptive narratives rather than systematically examined for their epistemological content or practical application (Wehi et al., 2009). By systematically examining weather-forecasting related local proverbs in East Ujimchin, we identified three core components of these proverbs: the time frame of the weather forecast (ranging from daily to yearly predictions), the types of indicators used (e.g., plant growth, animal ecology, atmospheric signs), and the specific climatic conditions they aim to predict. Our approach shows not only that oral proverbs encapsulate the depth of ecological observation, but also that they have a value for climate adaptation. By positioning oral traditions as legitimate and insightful sources of environmental knowledge, this thesis may offer a replicable method for uncovering subtle and often-overlooked dimensions of TEK. Thus, future research could further explore oral traditions not only as cultural expressions but also as methodologically rich tools for understanding human-environment relations.

5.3 Limitation and Caveats

Like all research, this thesis represents a step in an ongoing learning journey. Although it offers important insights into TEK systems, it also has limitations that deserve acknowledgment. In this section, I reflect on these limitations, not only as a way to strengthen the integrity of this work but also to suggest directions for future research.

Firstly, the way TEK functions were categorized in this thesis presents a limitation. This thesis classifies knowledge functions into ecological, economic, and socio-cultural domains, and further analyzes them through their specific subfunctions. While this structure helps organize and compare data across diverse cases, it is based on an external and analytical logic. In practice, pastoralists may not perceive their knowledge in such clearly segmented terms. As shown in this thesis through the concept of functional complementarity, pastoralists often combine practices from multiple domains to meet overlapping needs. Therefore, the framework used here is a useful analytical tool but may not fully capture the holistic and lived reality of TEK as experienced by herders themselves.

Moreover, this thesis does not capture the full breadth of pastoral TEK present in the community. For example, local naming systems for hills, mountains, and pasture types—forms of ecological folk taxonomy—carry embedded ecological and cultural meanings that were beyond the scope of this study. Similarly, herders' knowledge of sustainable resource use, such as manure burning as a way to produce clean energy, remains underexplored. Although this thesis discusses the holistic and interconnected nature of TEK, the selection of practices and domains analyzed is necessarily limited. As such, this thesis should be understood as a partial representation of the rich and complex TEK system of East Ujimchin, rather than a comprehensive account.

Another limitation of this thesis relates to the timeframe of the fieldwork. TEK adaptation is a gradual and often subtle process that unfolds over long periods of time. Knowledge transformation rarely occurs within the period of a year or two, it is shaped through sustained environmental interaction, cumulative experience, and social learning. For instance, some herders observed that the Mongolian gerbil, previously known to store hay outside its burrow, has now begun storing it inside. Such behavioral changes might eventually become new ecological indicators and lead to reinterpretations of existing proverbs or the creation of new ones, emphasizing that local knowledge systems adapt through time. Without extended engagement, it is difficult to assess whether and how these kinds of observations develop into accepted forms of TEK. Long-term ethnographic interaction with one community would allow researchers to trace how knowledge is evaluated and transformed through repeated cycles of use and reflection. A more longitudinal approach would be especially valuable for understanding adaptation in response to slow-onset changes.

Finally, a key limitation that became evident post-fieldwork concerns the method used to assess recognition of traditional knowledge, particularly livestock breeding traits and weather-related proverbs. Participants were presented with the full content of a proverb or trait and asked if they knew or used it. While this provided a general overview, I came to recognize that this method may have overestimated familiarity. Some herders may have affirmed recognition due to partial familiarity, or the desire to appear knowledgeable, even if their understanding was incomplete. In hindsight, more interactive and cognitively engaging methods, such as offering only part of a proverb and asking participants to complete it, or using simple matching and multiple-choice formats, could have allowed for more accurate and meaningful data collection. These techniques not only make the process more engaging but also help distinguish between passive recognition and active, accurate knowledge. However, applying such methods effectively would also require more time during the data collection process.

5.4 Future Research Directions

While this research offers insights into key issues related to pastoral TEK, it also highlights several questions that require further investigation. This section outlines several directions for future research that could build upon the findings of this thesis, address its limitations, and contribute to a more nuanced and grounded understanding of TEK in pastoral and other nature-dependent communities.

5.4.1 Linking functional characteristics of TEK to system resilience

A first possible research direction is in assessing whether and how the functional characteristics of TEK, such as multifunctionality and functional complementarity between knowledge domains, contribute to the resilience of knowledge systems themselves. In ecology, it is widely argued that functional diversity and redundancy enhance ecosystem resilience by providing multiple pathways for response and recovery (Chillo et al., 2011; Mori et al., 2013). A similar hypothesis could be explored for TEK systems. Do more functionally diverse or internally complementary knowledge systems show greater adaptive capacity in the face of environmental or socio-political uncertainties? To meaningfully investigate this question, future studies would need to shift from broad aggregated reviews to localized system-specific analyses. For example, comparing TEK systems among pastoral communities that share similar climatic conditions and livelihood strategies would offer a more controlled context for examining how functional characteristics of knowledge support resilience. Such an approach could provide valuable insights not only for the understanding of knowledge systems but also for designing local policy and adaptation strategies.

5.4.2 Exploring oral traditions as pathways to hidden knowledge and worldviews

A second possible direction for future research is the further exploration of different oral traditions as a means of uncovering ecological knowledge, as these traditions are often overlooked in more conventional research methods. This thesis shows the potential of weather-related proverbs to unwrap hidden understandings of environmental cues and forecasting systems. Future studies could expand this by systematically investigating oral forms such as poems, songs, and stories in other small-scale subsistence communities. These traditions may illuminate unexpected ecological insights that are not immediately visible through interviews or observations alone. While this dimension has been explored in many contexts, future work could continue deepening our understanding of how oral traditions reflect evolving cosmological views in response to environmental change (Segura & Sekulova, 2024).

5.5 Policy Implications

5.5.1 Rethinking top-down rangeland policy models

Rangelands, by nature, are shaped by spatial variability, climatic variability, and seasonal dynamics (Manzano et al., 2021; Scoones, 2024). However, many local policies, such as those implemented in East Ujimchin, have often been modeled on sedentary agricultural frameworks. These policies tend to emphasize fixed land use, fencing, and privatization, often encouraging herders to intensify market integration at the expense of traditional mobility. As shown throughout this thesis, such approaches can undermine the ecological and social functions of TEK-based pastoralism. Instead of relying on top-down, one-size-fits-all approaches, future policy must take seriously the adaptive and decentralized logic of pastoral knowledge systems.

i) Supporting community-led management of shared rangelands

One relevant area to apply this thinking is the management of the remaining shared-use rangelands. Under current realities, it may be unrealistic or impractical to fully return to the collective pasture management systems of the socialist era. But many *gacha*s in East Ujimchin still retain substantial areas of shared-use rangeland. For example, *Mantuhbolo sumu* has over 40,000 hectares and *Hargant gacha* around 1,300 hectares of pasture that were deliberately left out of full privatization, in part because both local officials and herders recognized the continued need for flexible, shared access. Although this thesis did not explore in depth how these pastures are currently governed or shared, their existence points to important opportunities for locally adapted approaches. Moving forward, policies that do not impose rigid management models but instead support community-led efforts to coordinate seasonal access allow for maintaining flexibility and upholding the ecological and social functions of these remaining common lands.

ii) Strengthening local herders' cooperatives and collaborative institutions

Another relevant policy area involves supporting the local cooperatives and collaborative arrangements that herders themselves are initiating. In East Ujimchin, the *Harigaobi gacha* Herders' Cooperative is one such example, where herders have come together to collectively purchase hay, share tools, and coordinate labor, strategies that reduce individual costs and strengthen collective bargaining power. The cooperative was established primarily through herders' own investments and informal agreements, without significant government involvement. At the time this research was conducted, some families contributed financially, while others joined through sharing land or livestock instead of capital. However, without a mature legal system, these diverse forms of contribution are not equally protected, creating uncertainty and limiting broader participation. Many herders remain hesitant to formally join due to unclear regulations, weak institutional safeguards, and concerns about benefit distribution or conflict resolution. To foster such grassroots efforts, local policy can play a more active role. This includes formally recognizing herders' cooperatives, offering legal and institutional support, ensuring the rights of all contributors, and facilitating access to technical advice or subsidies. Rather than promoting externally imposed organizational models, policies could strengthen these locally meaningful institutions in ways that build on pastoralists' own adaptive strategies and social cooperation.

5.5.2 Supporting the intergenerational transmission of TEK through education policy

Another policy implication of this thesis is the need not only to support the intergenerational transmission of TEK, but also to promote its meaningful integration into modern education and policy frameworks. Aligning education systems more closely with the rhythms, needs, and values of pastoral life can play a vital role in sustaining the relevance of TEK. At the same time, developing institutional pathways to incorporate TEK into scientific and policy decision-making would help recognize it as a legitimate and complementary form of knowledge.

i) Adapting education schedules to pastoral rhythms

One entry point is considering the herding calendar when planning the school calendar. In many pastoral regions, including East Ujimchin, school breaks follow the national model, occurring in winter and summer. However, these are not the seasons when children are most engaged in pastoral activities, i.e., the time they are learning practical herding knowledge. Spring and autumn are the busiest and most instructive periods in the herding calendar, involving tasks like calving, shearing, migration, and pasture management. Numerous herders who I have spoken with expressed frustration that current school schedules prevent children from participating meaningfully in these key seasonal activities. While adjusting school calendars may seem like a romantic or radical proposal, it reflects a culturally grounded logic and could significantly enhance intergenerational knowledge transmission.

ii) Incorporating TEK and pastoral worldviews into formal education

A second recommendation is to incorporate herding-related knowledge, values, and worldviews into formal school curricula. This could take the form of elective courses or community-based modules that engage local elders and experienced herders as instructors. These classes would not only transmit practical skills but also affirm the cultural legitimacy of pastoralism, fostering pride and continuity among younger generations. In East Ujimchin, there are already small-scale examples of such collaborations. For instance, some *Ubligqi* have been invited to local primary schools to teach traditional games and skills such as wool processing. However, these initiatives remain informal and lack institutional support. More systematic partnerships between schools and local knowledge holders could greatly contribute to TEK transmission.

5.5.3 Recognizing the significance of local livestock breeds in pastoral resilience and landscape stewardship

Local livestock breeds have evolved alongside local climate and landscape. They are not only biologically adapted to withstand harsh winters and drought-prone summers, but they also carry significant cultural meaning and embody locally valued traits selected over generations. Despite this, policies and market forces often encourage the replacement of local breeds with external ones due to their perceived higher economic value. These shifts not only erode genetic diversity but also increase herders' dependence on external inputs, including feed, veterinary care, and infrastructure. As herders adjust to managing less resilient commercial livestock, much of the embedded knowledge and low-input practices historically linked to local breeds is also lost or devalued.

i) Expanding support for local breeds

In East Ujimchin, the Ujimchin fat-tailed sheep and the Ujimchin white horses have received some support from local governments, including limited subsidies and recognition of their cultural value. However, other traditional livestock, especially local breeds of cattle and goats, are being increasingly displaced. Market demands and policy incentives have favored the introduction of commercial meat cattle and dairy cows, leading to a steady replacement of locally adapted cattle. At the same time, goats have been widely stigmatized as contributors to rangeland degradation, which has resulted in discouragement of goat herding. Thus, future policies should recognize the ecological and cultural contributions of local breeds. This includes extending targeted subsidies, breeding programs, and conservation efforts to a broader set of species and supporting local breeding strategies.

5.5.4 Facilitating shared learning through collaborative knowledge platforms

A final policy recommendation is to support shared learning across TEK systems by creating collaborative and open-access platforms. While TEK is deeply localized, shaped by specific ecological characteristics, histories, and worldviews, many of the challenges faced by subsistence-based communities today, such as land tenure shifts, climate uncertainty, and policy constraints, are shared across pastoral, fishing, farming, and foraging societies. A global database of TEK case studies, organized by functional characteristics and regional context, could be a valuable resource for mutual learning, policy innovation, and dialogue across diverse livelihood systems.

But it is important to note here that this platform should not seek to standardize or generalize TEK systems. Instead, it should support respectful comparison by showing both similarities and differences in how communities adapt, persist, and innovate. In doing so, it would help foster TEK-to-TEK exchange, enabling communities to learn from one another's knowledge, practices, and values, not just through integration with science, but also through solidarity across local knowledge systems worldwide.

Overall, these recommendations call for a shift in how pastoralism is understood and supported, moving away from narrow economic metrics toward more holistic frameworks. By valuing the local knowledge system, community-led governance, culturally grounded education, and local breeds, policies can more meaningfully support herders' lives. Supporting pastoral TEK is not just about preserving tradition, but about fostering adaptability and resilience rooted in local knowledge systems.

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Appendices

Appendix 1 – List of Publications

Published peer-reviewed article:

Chao, O., Li, X., & Reyes-García, V. (2025). Exploring the dynamic functions of pastoral traditional knowledge. *Ambio*, 1-15. https://doi.org/10.1007/s13280-025-02131-x

Reyes-García, V., García-Del-Amo, D., Porcuna-Ferrer, A., Schlingmann, A., Abazeri, M., Attoh, E. M. N. A. N., Vieira da Cunha Ávila, J., Ayanlade, A., Babai, D., Benyei, P., Calvet-Mir, L., Carmona, R., Caviedes, J., Chah, J., Chakauya, R., Cuní-Sanchez, A., Fernández-Llamazares, Á., Galappaththi, E. K., Gerkey, D., Graham, S., Guillerminet, T., Huanca, T., Ibarra, J. T., Junqueira, A. B., Li, X., López-Maldonado, Y., Mattalia, G., Samakov, A., Schunko, C., Seidler, R., Sharakhmatova, V., Singh, P., Tofighi-Niaki, A., Torrents-Ticó, M., Álvarez-Fernández, S., Bulamah, R. C., Chambon, M., **Chao, O.,** Chen, Z., Chengula, F., Cruz-Gispert, A., Demichelis, C., Dudina, E., Gallois, S., Glauser, M., Guillerminet, T., Hirsch, E., Izquierdo, A. E., Junsberg, L., Mariel, J., Miara, M. D., Miñarro, S., Porcher, V., Shrestha, U. B., Sharma, A., Ulambayar, T., Wu, R., Zakari, I. S., & Zant, M. (2024). Local studies provide a global perspective of the impacts of climate change on Indigenous Peoples and local communities. *Sustainability Earth Review*, 7:1. https://doi.org/10.4324/9781003356837-1

Articles under review

Chao, O., Reyes-García, V., Molnár Z., & Li, X. Understanding the Traditional Knowledge Systems Through a Resilience Lens -Case Study in East Ujimchin Banner, Inner Mongolia. *Ecology and Society* (accepted, pending major revisions).

Chao, O., Li, X., & Reyes-García, V. ‘Everything is Talking to Us’: Understanding Traditional Weather Forecasting Knowledge through Proverbs in East Ujimchin Banner. *Weather, Climate, and Society* (under review).

Published book chapter:

Chao, O., Li, X., & Reyes-García, V. (2023). Faith, reciprocity, and balance: Inner Mongolian Ovoo offering ritual and its contribution to climate change adaptation. In Routledge Handbook of Climate Change Impacts on Indigenous Peoples and Local Communities (pp. 348-357). Routledge. https://doi.org/10.4324/9781003356837-26

Published conference papers:

Chao, O., Li, X., & Reyes-García, V. (2025, June 2-6). A Comprehensive Analysis of Pastoral Traditional Knowledge Functions [Conference presentation]. XII International Rangeland Congress, Adelaide, Australia.

Chao, O., Reyes-García, V., Molnár Z., & Li, X. (2025, June 2-6). Pastoral Traditional Knowledge in East Ujimchin Banner, Inner Mongolia [Conference presentation]. XII International Rangeland Congress, Adelaide, Australia.

Appendix 2 – Chapter 2

Table S1. List of publications included in the systematic literature review

Paper ID No.	References
11	Ghai, R. (2021). Understanding 'culture' of pastoralism and 'modern development' in Thar: Muslim pastoralists of north-west Rajasthan, India. *Pastoralism, 11*(1). https://doi.org/10.1186/s13570-020-00190-1
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Table S2. Definition of variables used in the systematic literature review

Variable		Definition	Format
Metadata			
Study area	Location	Indicate name(-s) of regions where research took place	Coordinates
	Country(-ies)	Indicate country(-ies) where research took place	Name of the country(-ies)
	GPS	The Global Positioning System coordinates that precisely define the location of the study area	Latitude and Longitude
	Climate zones	Climate types as defined by Koeppen-Geiger climate classification (if not mentioned, it is extrapolated from location)	1 = Dry 2 = Continental 3 = Temperate 4 = Tropical 5 = Polar
Study group	Ethnic groups	Indicate which ethnic groups were respondents in this study	The name of the ethnic group. if not specified, write NA
	Indigenous Peoples	Whether the authors conceptualize the respondents as indigenous peoples	0 = No 1 = Yes
	Type of pastoralism	Nomadism: characterized by the regular movement of herds to new pastures. Transhumance: involving seasonal migration between fixed pastures. Agro-pastoralisim: combines crop farming with pastoralism. Sedentarism: indicating settled herding with limited livestock movement.	1 = Nomadism 2 = Transhumance 3 = Agro-pastoralisim 4 = Sedentarism
	Type of herd (can be multiple)	The type of herd the local communities manage.	1 = Cattle 2 = Sheep 3 = Goat 4 = Camel 5 = Horse 6 = Reindeer 7 =Yak 8 = Other

Methods	Research Methods	Method of data collection	1 = Community Mapping 2 = Focus Group Discussions 3 = Free list 4 = Interviews 5 = Participant Observation 6 = Surveys 7 =other
Pastoral Traditional Knowledge Domains			
PTK domains	Livestock-related knowledge	This knowledge includes understanding the nutritional needs, well-being, grazing preferences, and unique characteristics of the livestock.	0 = No 1 = Yes
	Forage and plant-related knowledge	This knowledge involves the identification of plants, a detailed understanding of their characteristics, and their utilization.	0 = No 1 = Yes
	Landscape-related knowledge	This knowledge is about the observation and understanding of the specific landscapes where pastoralists live.	0 = No 1 = Yes
	Climate and weather-related knowledge	This knowledge refers to information about the local climate, weather patterns, and seasonal variations that impact pastoral activities.	0 = No 1 = Yes
	Social-cultural knowledge	This knowledge is about the cultural traditions, social institutions, and community dynamics specific to pastoral societies.	0 = No 1 = Yes
	Herd mobility	This knowledge refers to the movement of livestock groups from one location to another for different purposes.	0 = No 1 = Yes
	Herd breeding	This knowledge is specific to the selective breeding and reproduction of livestock within a specific pastoral context.	0 = No 1 = Yes

	Herd diversification	This knowledge focuses on the trade-offs of diversifying the composition of the livestock.	0 = No 1 = Yes
	Landscape management	This knowledge includes the traditional insights and techniques developed for interacting with their environment.	0 = No 1 = Yes
	Other	This domain includes knowledge that does not fit in any of the domains, such as holistic knowledge.	0 = No 1 = Yes
Pastoral Traditional Knowledge Functions			
PTK functions	Main functions (can be multiple)	Ecological function includes various aspects such as managing ecosystem health, preventing weather and climate variations and contributing to ecosystem recovery. Economic function includes functions related to enhancing the efficiency and sustainability of pastoralists' livelihoods. Social-cultural function includes functions contribute to the maintenance of pastoral communities' cultural integrity and social structures.	1 = Ecological function 2 = Economic function 3 = Social-cultural function
	Subfunctions (can be multiple)	Biodiversity conservation and ecosystem monitoring emphasizes the role of knowledge in monitoring and maintaining ecosystem health, and in conserving local species, and the genetic diversity of livestock breeds. Sustainable resource management emphasizes the role of knowledge in maintaining sustainable use of the natural resources and ensuring long-term sustainability of rangelands.	1.1 = Biodiversity conservation and ecosystem monitoring 1.2 = Sustainable resource management 1.3 = Climate adaptation and resilience

		Climate adaptation and resilience emphasizes the role of knowledge in observing and predicting weather patterns and preparing for the varying climatic conditions and environmental stressors. Ecosystem restoration and regeneration emphasizes the role of knowledge in contributing to the recovery and regeneration of ecosystems. Livelihood support and resource optimization emphasizes the role of knowledge in optimizing the use of limited resources, including water and forage, to support livelihoods. Risk management and disaster reduction emphasizes the role of knowledge in mitigating the impacts of natural disasters and environmental fluctuations. Enhancing livestock productivity emphasizes the role of knowledge in improving livestock productivity. Cultural identity and heritage emphasizes the role of knowledge in preserving the cultural heritage and traditional practices that define community identity. Social cohesion and community governance emphasizes the role of knowledge in strengthening community bonds through shared decision-making,	1.4 = Ecosystem restoration and regeneration 2.1 = Livelihood support and resource optimization 2.2 = Risk management and disaster reduction 2.3 = Enhancing livestock productivity 3.1 = Cultural identity and heritage 3.2 = Social cohesion and community governance 3.3 = Conflict resolution and cooperation

		resource-sharing, and collective management of resources. Conflict resolution and cooperation emphasizes the role of knowledge in resolving disputes over resources and fostering cooperation in herding practices.	

Appendix 3 – Chapter 3

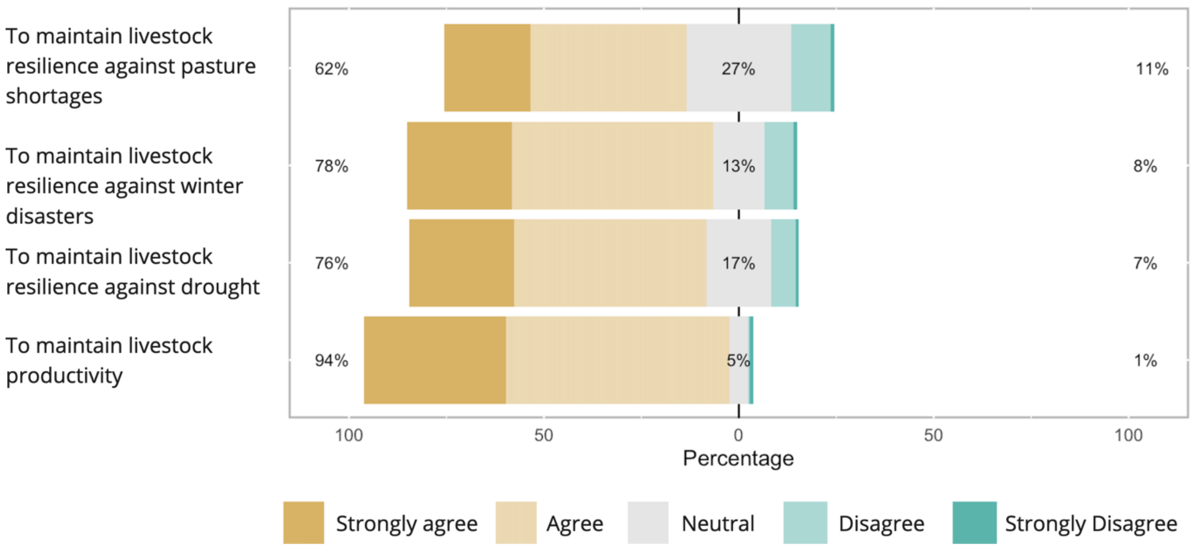

Figure S1. Herders' perceptions of the different functions of traditional breeding practice.

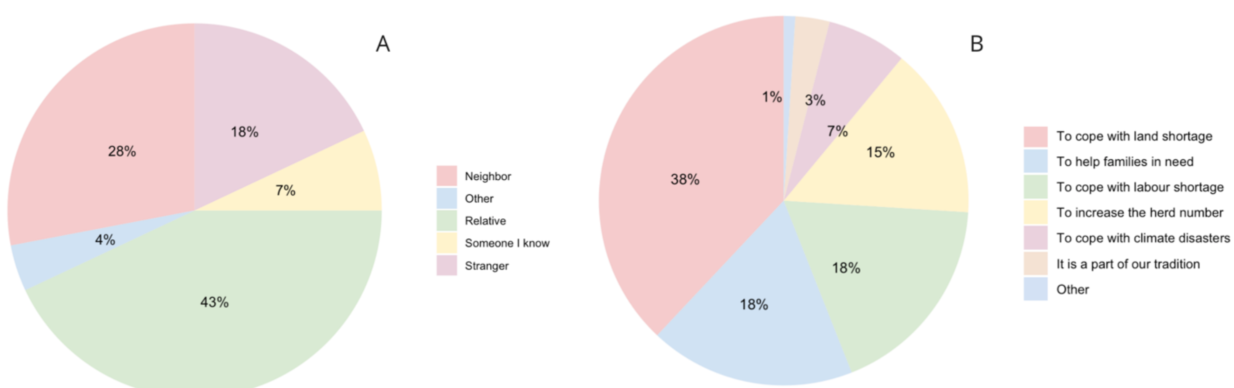

Figure S2. (A) Distribution of the receiving family types in herd sharing practices; (B) reasons for participating in herd sharing practice.

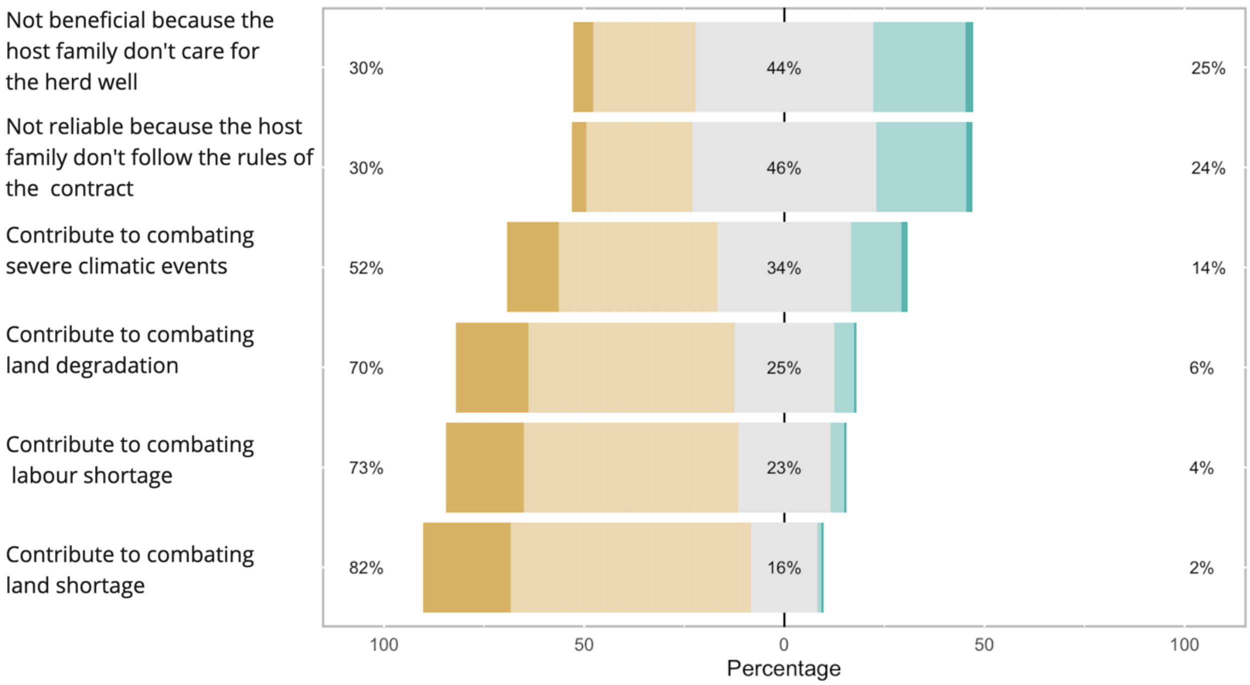

Figure S3. Herders' perceptions of the different functions of traditional herd sharing practice.

Appendix 4 – Chapter 4

Table S1 Perceived reliability and unreliability of traditional weather-related proverbs

ID	Frequency of perceived reliability	Percentage of perceived reliability	Frequency of perceived unreliability	Percentage of perceived unreliability	Total responses
1	34	85.0%	6	15.0%	40
2	47	84.0%	9	16.1%	56
3	23	79.3%	6	20.7%	29
4	52	94.6%	3	5.45%	55
5	63	84.0%	12	16.0%	75
6	55	84.6%	10	15.4%	65
7	98	81.7%	22	18.3%	120
8	90	88.2%	12	11.8%	102
9	28	84.9%	5	15.2%	33
10	49	83.1%	10	17.0%	59
11	10	66.7%	5	33.3%	15
12	122	84.7%	22	15.3%	144
13	139	96.5%	5	3.5%	144
14	31	91.2%	3	8.8%	34
15	148	99.3%	1	0.7%	149
16	77	97.5%	2	2.5%	79
17	26	92.9%	2	7.1%	28
18	35	85.4%	6	14.6%	41
19	106	92.2%	9	7.8%	115
20	121	92.4%	10	7.6%	131
21	110	97.4%	3	2.7%	113
22	93	99.0%	1	1.1%	94
23	58	84.1%	11	16.0%	69
24	71	94.7%	4	5.33%	75
25	140	95.9%	6	4.1%	146
26	131	94.9%	7	5.1%	138
27	115	96.6%	4	3.4%	119
28	143	97.3%	4	2.7%	147

Photo credit: Jesse Segura (2017)