Republic of Kazakhstan Assessment of the Resource Base in Akmola Region for the Development of a Meat Production Value Chain

Final Report

Prepared by Michigan State University for the Ministry of Agriculture of Kazakhstan

This consultant’s report does not necessarily reflect the views of ADB or the government concerned, ADB and the government of the Republic of Kazakhstan cannot be held liable for its contents. Not all the views expressed in this report need be incorporated into the proposed project design.
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Forward

The Asian Development Bank (ADB) approved the Assessment of the Resource Base in Akmola Region for the Development of a Meat Production Value Chain within the framework of the TA-9476: Joint Government of Kazakhstan and ADB Experience Exchange Program, Phase 3 on 1 July 2019. The project envisioned integrated assessment of soil, water, and vegetation conditions and specialized capacity building to support strategic objectives of the beef livestock sector in the Akmola Oblast (Region).

Implementation of this project began in July 2019 but was interrupted by the COVID-19 pandemic. However, the project team modified the plan by adopting alternative approaches, field protocols, virtual communication and training to accomplish the objectives, with excellent assistance and support from ADB staff, local partners and researchers at the Kazakhstan National Agrarian Research University, with active engagement of a new partner, Bel Ata Aksu LLP, and the staff at USDA-ARS-Great Basin Rangeland Research, Reno, Nevada and Michigan State University.

This report explains research activities, approaches, results and recommendations for sustainable rangeland management in Akmola Oblast, Kazakhstan. It is hoped that, although the project focused on Akmola Oblast, the findings, conclusions, and recommendations should provide a prototype, an operational approach, and an example that can be replicated across the vast rangeland areas in Kazakhstan for national economic development and planning.
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Abbreviations

AGWA  Automated Geospatial Watershed Assessment Tool
ANPP  Above-ground net primary production (kg/ha/year)
ANFP  Annual Non-forage standing biomass (kg/ha/year)
ARS   Agricultural Research Service (USDA Agency)
AUE   Animal Use Equivalent
CAFO  Confined Animal Feed Operation
DFI   Daily feed intake (kg/day)
EBRD  European Bank for Reconstruction and Development
GBRRU Great Basin Rangelands Research Unit, USDA-ARS
GDP   Gross Domestic Product
GE    Grazing efficiency (default value is 35%)
GEE   Generalized Estimating Equation
GWP   Global warming potential
GHGI  Greenhouse gas intensity
GLEAM Global Livestock Environmental Assessment Model (FAO Model)
HG    Heavy grazing intensity
IPCC  Intergovernmental Panel on Climate Change
KazNARU Kazakhstan National Agrarian Research University
KEEP  Knowledge and Experience Exchange Program
LANDSAT Land Remote Sensing Satellite (System)
MG    Moderate grazing intensity
MOA   Ministry of Agriculture of Kazakhstan
MODIS Moderate Resolution Imaging Spectroradiometer
MSU   Michigan State University
NASA  National Aeronautics and Space Administration
NPP   Net primary production
NRCS  Natural Resource Conservation Service (USDA Agency)
RHEM  Rainfall Hydrology Erosion Model
Sentinels Satellite operated by European Space Agency
USDA  United States Department of Agriculture
USGS  United States Geological Survey
I. Definitions

**Annual grass**: Grass that grows from seed to seed in one year, dying at the end of the year.

**Bunchgrass**: Grass that grows in tufts or clumps.

**Concentrated flow erosion**: Removal of surface soil, which often has the highest biological activity and the most soil organic matter.

**Continuous grazing**: When livestock are grazed for an extended amount of time with zero or infrequent rest to the plants from grazing.

**Carrying capacity**: The stocking rate sustainable over time per unit land area.

**Foliar cover**: Measure of a vertical projection of exposed leaf area.

**Ground cover**: Dense low herbaceous plants and shrubs that grow over the surface of the ground.

**Gully erosion**: Removal of soil along drainage lines by surface water runoff. Once started, gullies will continue to move by headward erosion or by sideward slumping unless steps are taken to stabilize the disturbance.

**Invasive plants**: Plant species that are non-native or alien to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to grazing animals.

**Peak standing crop**: Maximum amount of standing crop observed during a given year.

**Plant census**: The number of individuals of a species that occur within a sample unit or study area. Density is often used in vegetation surveys to describe a species status in a plant community, including invasive plants.

**Process-based model**: Mathematical (often computer-based) representation of one or several processes characterizing the functioning of well-delimited biological systems of fundamental or economic interest.

**Rangeland carrying capacity**: The number of grazing animals a management unit can support without depleting rangeland vegetation or soil resources.

**Sodgrass**: A section cut or torn from the surface of grassland containing the matted roots of grasses.

**Soil C**: Soil carbon levels.

**Soil pH**: A measure of soil acidity.

**Standing crop**: Total above-ground plant biomass on the site at a particular point in time.

**Stocking rate**: Number of animals on a given amount of land over a certain period. Stocking rates generally are expressed as units of animals per unit of land area.

**Transect**: A straight line or narrow section through an object or natural feature or across the earth's surface along which observations are made or measurements taken.
II. Executive Summary

Kazakhstan is the ninth-largest country in the world and has the world’s fifth-largest grazing land area. Native rangelands cover approximately 70% of the country’s total land area and are the primary source of forage for livestock production. Knowledge about rangeland health, condition and carrying capacity is critical for economic planning and development but is currently inconsistent. The TA 9476-KAZ KEEP project was designed to i) assess rangeland conditions and baseline of livestock carrying capacity, ii) build capacity around sustainable livestock management, and iii) assess animal health, productivity, and management practices.

Field-based measurements, household surveys, ecological and hydrological models and remote sensing techniques were integrated to address these objectives. A decision support system was developed to visualize and disseminate livestock carrying capacity information.

Analyses of data and information revealed the baseline information of livestock carrying capacity, challenges, potential and opportunities to expand, enhance and invest in livestock production in Akmola Oblast, including management practices, governance policies, animal health and climate change.

Major findings

The total rangeland area of the Akmola Oblast is 236,965 km$^2$. Approximately 40% is degraded to some extent. Efforts to restore and revegetate degraded rangelands and abandoned croplands are required to achieve optimal livestock production.

There is significant spatial and temporal variability in stocking rate across the oblast, with the mean stocking rate ranging from 0.099 to 0.17 animal unit equivalent per hectare during 2001–2019. The spatial and temporal variability is due to annual climate variations and rangeland management practices.

In the oblast, there were 860,940 animal unit equivalents or AUEs (cattle, horses, sheep and goats) reported on September 1, 2019. With a conservative stocking rate, about 80,292 km$^2$ is required to sustainably graze the current number of livestock, leaving the remaining 156,673 km$^2$ for future development.

There is potential to increase livestock production in the Akmola Oblast by three-fold if appropriate management is implemented, including maintaining range and pasture health, controlling weeds, pests, and shrubs, prescribing fire, and restoring and seeding degraded areas.

There is evidence of climate impacts on rangeland productivity, indicated by the annual variability in stocking rate. Drought reserves are advised when planning livestock operations to avoid rangeland degradation and economic disruptions in livestock markets. Up to 79% variation in rangeland productivity was observed between 2001 and 2019 due to weather variability at a single ranch. Average variation was near 40% across the oblast. Thus, a minimum reserve of 25% to 40% of grazing lands, hay lands and croplands is recommended. Drought, crop or herd insurance to reduce risks to small and medium livestock producers is also recommended.

There is a lack of professional veterinary services and animal tracking programs to facilitate documenting animal vaccinations and birth information across all sites visited. Enhancements in this area will facilitate herd management, reporting on animal performance in feedlots and the quality of meat produced.
Infrastructure development such as roads is required to efficiently move livestock and feed across the region to facilitate increases in production from ranches to meat processing facilities to meet national and international market demands. Water infrastructure information is lacking. Water source availability within 1.5 km in pastures is critical for sustainable grazing.

Summary of recommendations

Policy on grazing rights: Allocating grazing rights (i.e., land tenure and ownership) to ranchers could help incentivize ranchers to optimize forage resources for the desired herd size and mixtures of grazing animals. Appropriate grazing rights would avoid multiple livestock producers grazing the same ground, as there is minimal fencing across the Akmola Oblast. Otherwise, there is little incentive to invest in infrastructure and implement appropriate grazing systems to achieve sustainable grazing practices.

Programs to restore degraded rangelands: There is an opportunity to restore severely degraded lands and promote appropriate grazing practices. Some severely degraded lands should be protected from active grazing until assessments have been made regarding the feasibility and economics of restoration. Policies on how the land is rested and on restoration plans need to be developed. Effective rangeland restorations would enhance carbon sequestration, plant biodiversity, and livestock carrying capacity. Enhanced rangeland condition monitoring programs should be established to systematically assess restoration programs, which would help facilitate accurate livestock carrying capacity assessment.

Resources access enhancement: Enhancing access to capital, land and equipment can help small-scale livestock owners scale up their livestock operations. The ability to purchase livestock and farm equipment is recommended to increase herd size and anticipated forage demands.

Opportunity to invest: There are opportunities to invest in hay production as an increase in hay and grain production is necessary to meet the winter feed supplement requirements to maintain animals in good health. On many ranches, the above-ground annual net production was so low that onsite production of hay and grain was not feasible. In these cases, purchases of winter feedstocks become necessary.

Modern technologies: It is recommended to operationalize the rangeland decision support system to scale up livestock grazing expansions. Decision support systems can be further enhanced with Kazakhstan’s national remote sensing capabilities to provide monthly status, trends, and drought early warning to minimize disruptions in livestock production and avoid rangeland degradation.

Capacity-building programs: Training individuals in sustainable livestock management is essential and recommended. Programs may include developing instructional programs (i.e., degree programs in rangeland management and extension services) and summer courses to train future ranchers in sustainable rangeland science and management. It is recommended to explore the opportunity to create an information blog on the site https://www.qoldau.kz/, which farmers and agricultural representatives use, to provide training and capacity-building information.

Addressing climate change: There is an opportunity to increase carbon sequestration from on-ranch production, given minimal external inputs currently used in beef livestock grazing systems in the oblast, if ranchers can increase efficiency to produce more beef per unit of greenhouse gases emitted and enhance land-based carbon sequestration to offset cattle greenhouse emissions through the restoration of degraded lands. There is a need to avoid greenhouse gas emissions induced by confining animals during the harsh winters through
effective on-ranch manure and urine management practices.

**Future efforts:** It is recommended to initiate a new project to use FAO Gleams (2019) or USDA COMET-farm carbon models and the rangeland decision support system developed in this project. These models can be linked to estimate greenhouse gas emissions and carbon sequestration rates to determine a net-zero balance of greenhouse gases for on-ranch production of beef cattle at both the enterprise and the oblast scale.

**Conclusions**

The global demand for beef is rapidly increasing. The rangelands in the Kazakhstan Akmola Oblast have the potential to increase stocking rates as much as three-fold, contributing to national food security and an increase in gross domestic product. However, challenges to overcome include infrastructure improvements such as access to water and roads, management improvements such as winter feeds, revegetation, and social structures and policies to allow efficient livestock grazing related to land tenure and ownership.
III. Technical Descriptions

Introduction

Kazakhstan has the world’s fifth-largest pasture resources, and its rangelands cover 65–70% of the country’s total land area. There is potential to increase livestock grazing to meet the increasing demand for meat (Kamp et al. 2016; Daribaeva et al. 2021; Kerven et al. 2021). However, knowledge about carrying capacity is incomplete for sustainable livestock development.

Since the dissolution of the Soviet Union system in 1991, large-scale agricultural abandonment occurred across the entire country, significantly altering food production systems and socioeconomic structures (Dubovyk et al. 2016; Zou et al. 2019; Kerven et al. 2021). Kazakhstan’s beef production declined rapidly following the dissolution and the removal of large-scale government subsidies and the collapse of the government-owned farming system. The cattle population in 1992 was 9.5 million head and had fallen below 4 million by 1999 (Tzahibaev et al. 2014). There is now a lack of accurate information regarding grazing capacity in the country and insufficient knowledge about the spatial distribution of rangeland productivity (Klein et al. 2012; Dubovyk 2016).

Kazakhstan went through a gradual transition to a new nexus of food, energy, and water security by capitalizing on its natural gas resources in the western part of the country. Between 2008 and 2015, Kazakhstan’s economic growth rate was 7% and was substantially higher than the average world growth rate of 2.6% (Zou 2019). However, Kazakhstan has changed from a meat exporting country to a meat importing country along with importing breeding cattle (Zou 2019). The migration of people to the increasingly urbanized new capital, Nur Sultan and other major cities such as Almaty have depleted skilled individuals in animal husbandry and range management needed to support a livestock industry expansion.

The country’s dominant land cover is rangeland (Figure 1 and Photo 1), based on remote sensing estimates (Buchhorn et al. 2015). Grazing horses, cattle, sheep, goats, and camels dates to the bronze age (Ventresca et al. 2018; Kerven et al. 2021). Rapid globalization and increasing food demand, particularly on Kazakhstan’s north and east borders, have created promising economic opportunities for the meat industry as both Russia and China have increased meat imports. Kazakhstan has set a strategic target to boost its livestock production by repurposing abandoned agricultural lands to graze livestock.

The four major ecoregions in Kazakhstan are steppe (25% of land area), semi-desert (25%), desert (40%) and mountains (7%) (Ryabushkina et al. 2008). There is a vast temperate grassland of Kazakhstan steppe known as the Kirghiz Steppe with interspaced savannas and shrublands and is the dominant grass type in northern Kazakhstan. The Ministry of Agriculture selected Akmola Oblast to prototype assessments of livestock production potential due to its historic role in livestock production and representativeness of the Kazakhstan steppe region (Figure 1). The oblast includes 17 administrative districts and three cities of regional significance (Kokshetau, Stepnogorsk, and Kosshy). The capital of Kazakhstan, Nur Sultan, formerly known as Astana, is in the center but not administratively part of the oblast. There are also eight cities of regional subordination, 15 villages and 245 rural districts.
Figure 1: Kazakhstan National and Oblast Boundaries (A) and Vegetation Classification (B)

Source: Government of the Republic of Kazakhstan.
The Kazakhstan steppe is the dominant grass type, covering approximately 804,500 km², and has been historically grazed by nomadic herders. The Kazakhstan steppe is representative of grass types in a semi-arid, continental climate with precipitation ranging from 200 to 400 mm from south to north and temperatures ranging from 20°C to 26°C in July to 12°C to 18°C in January. The flora of Kazakhstan is diverse, with over 13,000 species, of which 5,754 are vascular plants (Ministry of Environmental Protection 2009). In the National Atlas of Kazakhstan (2010), 23 representative plant community associations for the temperate and dry steppes on chestnut soils dominate steppe landscapes. According to the United States system of soil nomenclature, the dominant soil classification is a mollisol with a silty clay loam surface texture.

The carrying capacity of Kazakhstan’s vast rangelands is largely unknown. Even the current stocking rate baseline is either missing or inaccurate due to the lack of systematic reporting and assessment systems. This makes it impossible to set a target for livestock production (Hankerson et al. 2019) and thus inhibits investment from the meat industry. Dara et al. (2020), using Landsat imagery, mapped grazing pressure across northwest Kazakhstan. They developed metrics to classify grazing intensity. However, they could not estimate sustainable stocking rates because they did not correctly allocate standing biomass between forage and non-forage species. They also did not address the winter feed requirements to sustain a herd for a year. There is limited work on stocking rate assessments in Kazakhstan but de Leeuw et al. (2019) used MODIS net primary production and a correction equation by Hui and Jackson (2005) to estimate above-ground biomass from the mean annual temperature in neighboring Azerbaijan. They determined that the current stocking rate or carrying capacity...
was exceeded and the area should be destocked. Their recommendation was destocking in areas with slopes above 10% to prevent overgrazing. This approach is simplistic because it assumes all vegetation is available forage. To avoid the over-allocation of above-ground biomass as a forage resource, they used a Proper Use Factor of 65%, higher than that used in the United States and Pakistan (USDA-NRCS 1997; George and Lyle 2009; Sardar, 2003).

Sustainable rangeland management mechanisms are the key to economic development in Kazakhstan but are often absent. Pasture leasing is not regulated in most countries in Central Asia. Organizational mechanisms and extension services to support technology transfer for sustainable management of rangelands are weak (CACILM, 2006 a, b, c, d, e). Therefore, exploring mechanisms for developing, protecting, and sustainably managing rangeland resources has important theoretical and practical significance for the sustainable development of animal husbandry and livestock production systems.

There are three general types of ranches where livestock are raised in Kazakhstan. The largest are agricultural enterprises, ranging from a few thousand to tens of thousands of animals. The second group is private ranches with animal numbers between 100 and a few thousand head of livestock. The third and smallest ranch type, household or backyard ranching, typically has only a few animals per household, where animals are grazed in a common herd unit on community lands. This group of ranchers is the largest in Kazakhstan (Petrick et al. 2013; Hankerson et al. 2019; Kerven et al. 2021). They produce 76.7% of cattle, 67% of sheep and goats, and 62.7% of the horses, with land holdings averaging 176 hectares. These ranches rarely produce adequate forage to meet livestock needs and have an inadequate water supply (Tazhibaev et al. 2014).

Many ranchers raise beef cattle, dairy cattle, horses, sheep and goats but it is common for a ranch or village to graze a single herd with mixed animal species on a single pasture. This increases the challenge to define appropriate stocking rates as these species have different preferences for forages, ability to access forage and susceptibility to poisonous plants. Livestock is usually housed overnight at the ranch headquarters as the area grazed generally has no fenced structures. A herder collects the animals in the morning and decides where the animals will graze each day, significantly limiting the distance the animals can be grazed and increasing risks of over grazing.

**Economic Development Needs**

The government of Kazakhstan has recently adopted a new comprehensive program promoting its livestock development focused on its beef cattle and sheep breeding industries and related value chain components. This ambitious program places family farms with 100–200 head of cattle and 500–600 sheep as the core element of the industry’s development. By 2027, the program aims to create 500,000 new jobs and generate $2.5 billion in beef and lamb export revenue, with $5 billion worth of livestock assets. The program also targets developing human capital in rural areas to raise labor productivity in livestock value chains.

However, progress is hampered by a lack of quality data on natural resources, rangeland conditions and capabilities to prepare an initial baseline of stocking rates. Appropriate methods adopted in other countries and relevant international experience are also lacking. Given Kazakhstan’s vast grazing land and its terrestrial diversity, combined with the relatively limited development of beef cattle breeding and other livestock value chains, the program needs to be strengthened and phased to ensure its effective implementation based on feedback provided by selected pilot regions.

A critical factor in finalizing the government program for developing the beef industry is a market analysis for final products, consumer preferences and forecasting medium- and long-term demand. The demand for beef in China from 1961 to 2015 grew by more than 10,000%,
and that demand continues to grow. Timely identification of strategies for entering such markets will influence the successful development of the country’s livestock industry.

According to data from the World Resources Institute, 99.2% of Kazakhstan’s land area is occupied by land prone to desertification. It is estimated that the total area of degraded pastureland is over 48 million hectares (26% of the total grazing acreage).

Several studies show that the critical economic consequence of overgrazing is a decline in livestock productivity, leading to reduced livestock profitability and export capacity. Eventually, such a situation will lead to stagnation in developing the food industry and a decline in tax revenues from agricultural and service manufacturing industries.

Unfortunately, the patterns of erosion, crop growth and yield, and health of grazing lands have not been well documented. The lack of reliable data on land cover and related water resources prevents the identification of the major challenges or the means to address them.

Nutritional deficiencies during the grazing period must be addressed to optimize livestock productivity. Rangelands in poor health conditions have low forage potential because of the reduction in species composition, and an increase in invasive weeds and poisonous plants that typically have reduced feed nutrient density.

The key economic consequence of the poor use of grazing lands is a reduction in livestock numbers, livestock profitability and export capacity of the beef industry. Stagnation of the food industry will result in declines in tax revenues from the agricultural and manufacturing industries. The economic losses resulting from the non-rational use of pasture areas in Kazakhstan are estimated at $700 million per year. This primarily affects the development of small and medium agribusiness in livestock.

Identifying available land for grazing opportunities is a prerequisite to ensure the development of the livestock industry. To strategically develop the beef cattle breeding sector, it is necessary to conduct a comprehensive resource assessment of soil, water and vegetation conditions supported by capacity building. Studies on the potential of pastures are well documented, however, they are not well integrated into a systems approach with dynamics of changes in the soil and vegetation of pastures and how best to integrate grazing management with pasture productivity.

Aside from this desire to establish a baseline for rangeland carrying capacity, there is an increasing interest from the climate change perspective regarding the country’s rangeland ecosystems. Carbon sequestration in this ninth-largest land-locked country and its water-energy-food-system security and other risks resulting from a changing climate are additional incentives to compile accurate information of the rangeland production and carrying capacity (Mirzabaev et al. 2019; Chen et al. 2020; Henebry et al. 2020; Qi et al. 2020). There is potential for rangelands to become carbon sinks with appropriate investments in programs to restore degraded areas (Spaeth et al. 2020; Kerven 2021), which may offset the country’s carbon emissions from other sectors.

The challenges are to sustainably manage rangelands to produce meat to meet increasing demands and thus global food security (Leake and Qi 2018; Kerven 2021). Kazakhstan has rangelands full of potential for further growth in livestock production if appropriately managed. Opportunities exist for local ranchers to expand and enhance their management practices and for investors to develop modern livestock production operations (Li et al. 2020; Kerven 2021).
Project Goals and Objectives

This project aims to better understand rangeland potential for sustainable economic development and establish baseline information on livestock carrying capacity. The overall objective is to provide technical assistance through capacity building and onsite training efforts for scientists and decision-makers to holistically assess livestock carrying capacities by considering forage production and water, soil, climate, animal health and basic infrastructures for sustainable livestock production systems. The specific objectives are:

i. To assess current rangeland ecological and environmental conditions, ranch management practices and livestock carrying capacity.

ii. To conduct hands-on training workshops for local scientists and rangeland decision-makers on the methods and techniques to holistically assess rangeland conditions and sustainable livestock management.

iii. To survey animal health conditions to better understand livestock management practices and identify challenges and opportunities.

APPROACH

The approach builds on our extensive research experience and knowledge in rangeland assessments, animal health, remote sensing, and capacity building. The project adopted a framework with six phases to assess rangeland conditions and estimate stocking rates (Figure 2).

Figure 2: Project Design to Assess Akmola Oblast Rangeland Conditions and Stocking Rates

Phase I: Conduct Training Workshops on Rangeland Assessment

The first step is to conduct training workshops to train local scientists on rangeland assessment and methods to estimate stocking rates at the ranch and regional level. The objectives are to (i) understand rangeland management principles and how to use this knowledge when assessing indicators of rangeland health; (ii) acquire the essential skills for assessing rangeland vegetation productivity; (iii) understand the basic principles of using geographic information systems and remote sensing to assess annual production on rangelands; (iv) acquire the skills to estimate initial stocking rates for grazing livestock and estimating forage for the year at the producer or regional scale; (v) develop an understanding...
of the rangeland hydrology and erosion model inputs and outputs and how to use this tool for assessing sustainability and benefits of conservation.

**Phase II: Hands-on Experience and Onsite Data Collection**

The second step is to gain practical experience and collect field data for rangeland health assessment and stocking rate estimates and data collections, including:

a. Plant information: species, density, biomass, heights and seasonality
b. Soil information: texture, color, organic matter and hydrological properties
c. Management information: grazing periods, animal numbers, species, feeds, water, and other physical facility information
d. Environmental information: climate, topography, erosion, and degradation

**Phase III: Field Data Analysis, Modeling, Assessment**

The third step is to use hydrological and ecological models to assess erosion potential, species composition, plant nutrition and carrying capacity. The modeling work allows for identifying hotspots where alternative management or conservation scenarios would be beneficial and enhance sustainability and production capabilities. Once the ecological conditions and environmental information such as access to water, topographic slopes, feeding information and forage availability data are collected, stocking rate is calculated as a function of forage quantity, water distance, slope, grazing period, and management options.

**Phase IV: Scaling up Stocking Rate with Geospatial Technologies and Models**

The fourth step is to analyze field data and modeling results, including plant information such as forage and biomass from the remotely sensed net primary productivity with MODIS and Landsat data. The analysis allowed us to build a geospatial model to scale the onsite stocking rate model to the entire Akmola Oblast.

A suite of land-use and land-cover products were used in this step to identify rangelands in the Akmola Oblast, compute the slopes at 90 m spatial resolution and calculate the water distances, along with NPP and climate information. These geospatial data were then integrated with the in-situ stocking rate model to build a scaling up model.

**Phase V: Database Development and Decision Support System**

The fifth step is to develop a decision support system for information dissemination. Data and associated products were stored in an open-source database to be delivered to the relevant parties, including ADB, the Ministry of Agriculture of Kazakhstan and others. The database includes data collected during the project period, their derivatives and modeling tools and outcomes. A simple decision support system (DSS) on the Google Earth Engine platform was built to include all remote sensing data sources used for the project, geospatial models for stocking rate calculations, interactive tools to extract statistics information and visual analysis tools to give users access to the data and visually analyze rangeland information at individual or oblast level for sustainable livestock management purposes. The GEE codes, stocking rate maps and other data have been transferred to the KazNARU and other platforms as needed.
Phase VI: Results Synthesis

The final step is to synthesize the results. The results were discussed with local experts to better understand rangeland ecosystems in Kazakhstan. This effort included i) analyzing results with local experts to obtain an indirect validation and consensus, ii) comparing results with the literature to identify discrepancies and agreements and iii) discussing with external international experts to interpret the results.

PROJECT ACTIVITIES AND OUTCOMES

Phase I: Training Workshops on Assessment Tools and Field Protocols

The first training workshop (Photo 2) was conducted for three days in Nur Sultan, Kazakhstan from August 1–3, 2019. With over 40 people participating in the workshops, Mark Weltz, Ken Spaeth and Phil Guertin provided detailed theories, methods and field protocols on rangelands assessments. The purposes of the workshop were to i) better understand the concept of rangeland assessments, ii) build practical skills to assess ecological and environmental conditions, and iii) introduce modeling tools that people can use to build scenarios for different climate, environment, and soil conditions.

Photo 2: Training Workshops, Local and International Experts, Hands-On Field Sampling Exercises and Drone-Based Imagery Collections

The Covid-19 pandemic disrupted training and fieldwork in 2020 and 2021. However, training on data collection and analysis continued with a second round of virtual workshops, which took place in the summer of 2021 supported by the Kazakhstan National Agrarian Research University. The first lecture seminar was held on 12 May 2021. Opening remarks were given by Nariman Manrapbekov, Country Director, ADB Resident Mission, Kazakhstan; Kanat Tireuov, Deputy Chairman of the Board and Provost of Kazakhstan National Agrarian Research University; Kairat Mutayev, Deputy Director of the Department of Production and Processing of Livestock Products of the Ministry of Agriculture. The session was delivered by Mark Weltz, ARS-USDA, on qualitative methods to assess rangeland health at the pasture scale. Over 70 people participated and gained knowledge on indicators and attributes of rangeland health. On 19 May 2021, Mark Weltz lectured on quantitative methods to assess the status and trends in rangeland production and sustainability at the pasture scale. The total
number of participants in the second seminar was over 60 people.

The third seminar was on techniques to scale estimates of rangeland productivity to the ranch, regional or national assessments, which was presented by Jiaguo Qi, Director of the Center for Global Change and Earth Observations and Professor at Michigan State University's Department of Geography. Over 50 people participated in the third seminar, which was held on 26 May 2021. Two remaining training lectures were delivered; one on 2 June on methods to estimate initial stocking rate and carrying capacity and forage demands for the herd at the ranch and regional scale. The second lecture was on 9 June on quantitative tools to assess sustainability as a function of hydrologic and soil erosion processes. Mark Weltz, ARS-USDA, delivered both seminars. During these lectures, over 60 people participated. Only those who participated in all five seminars were issued a certificate. Hans Woldring, Asian Development Bank, gave closing remarks for the online five-day training.

All seminars were presented in English with simultaneous translation into Russian. Material presented was in both English and Russian to facilitate understanding. For each lecture, background reference material was provided on each technique presented. In addition, videos of the major field applications to collect data were provided to enhance the application of the techniques when used in Kazakhstan.

The detailed presentations, videos and supplementary materials can be found in Appendix A and links to the recorded lectures in English at:

i. https://youtu.be/dUfzVSRMuf0 (Workshop opening)
iii. https://youtu.be/x6YH-xEfX4I (Rangeland hydrology and erosion assessment)
iv. https://youtu.be/ghPNY7fBc4s (Determining initial stocking rates)
v. https://youtu.be/7o8vp701CTE (Scaling up field measurements to regional level)

**Phase II: Training on Field Sampling Protocols and Data Collections**

Trained personnel joined the project team members in field data collections in the Akmola Oblast. The first field trip was conducted from August 3–12, 2019 (Photo 2), with a random sampling design protocol. The team visited 29 ranches and sampled 51 sites to obtain plant, soil, water, environment, and management information.

The team initially proposed to travel to Nur Sultan, Kazakhstan, in the first week of November 2020 for the second field trip to collect data for validation. However, it was cancelled due to Covid-19 pandemic restrictions. However, the team developed a collaborative approach to participate remotely and engage in a second field data collection campaign from September 30 to October 5, 2021, to continue fieldwork to collect data for validation and database expansion. The local team trip was arranged with the assistance of local scientists who had attended the training workshops in 2019 and conducted the field data collection following the provided protocols. Team members have expertise in ecology and botany, animal science, soils, coordination and data analysis. The Akmola Oblast has been classified into eight zones from north to south and east to west. Within each zone, rangelands have been classified into three categories (1 = sustainable, 2 = at risk and 3 = degraded) based on an analysis of 20 years of remote sensing images and climate. Through Zoom meetings, all field procedures were worked out to implement the field sampling and survey by local collaborators and team members.

The data collection design has the team sampling one of each status condition within each zone. This provided an additional 17 samples used to verify the current estimate of condition and forage potential. The sampling design consisted of taking a surface soil sample to identify soil color, texture and pH. A simple point-step transect was conducted over a 100-
pace transect to determine foliar canopy cover by species and ground cover by categories and slope of the site. Detailed landscape photos and nadir (looking straight down) photos at 1.25 m elevation were collected. Photos were taken to document vegetation species, percent grazed, vegetation gaps, exposure, and connectivity of bare ground. Species diversity and estimated density were determined using similar protocols used in 2019 in the large macro plot surrounding the crossed transects (Photo 3).

**Photo 3: Sampling Plot, Samples Collected and Geographic Location**

![Sampling Plot](image)

Source: Author’s field data.

A simple producer survey was developed to collect data on ranch management practices in the pasture sampled. The information collected included the start and end of the grazing season, number and type of animals grazed, distance to water, grazing system, winter confinement practices and feed rations, breeding practices and calving season. If any manure management practices were employed, further information was collected including calving rate, the replacement rate for bulls and mother cows, ways to sell livestock, winter feed or hay sources, energy supplement (grow onsite or purchase) and vaccination practices.

**Phase III: Data Analysis and Modeling**

- Hydrological conditions of the Akmola Oblast

Rangelands are dynamic and commonly influenced by many perturbations, natural and anthropogenic, which affect rangeland ecosystem function over a wide range of spatial and temporal scales. Climatic extremes such as drought and periods of intermittent above-average precipitation can profoundly influence vegetation composition and biotic integrity, soil nutrient fluxes, soil surface stability and hydrology and erosion processes. Considering climate extremes with other disturbances such as insect infestations, plant diseases, wildfires and diversity of grazing practices, the matrix of influencing factors on rangeland community functions becomes quite complex. Besides vegetation composition, changes in runoff and soil loss are effective indicators of current management impacts.

Hydrologic indicators have been used to infer impacts of vegetation changes due to grazing and drought on water availability and quality, forage availability for domestic livestock and wildlife, which ultimately influence the protective capacity of the plant community. We examined potential hydrologic and water erosion dynamics at 51 sites across the Akmola Oblast. Our objective was to correlate hydrology and erosion modeling methods for holistic
rangeland assessment to demonstrate the feasibility of this technology for rangeland management decisions in ranking the site's sustainability. Each study site, slope, aspect, vegetation classification, five-clip quadrats for production estimates, estimates for foliar cover and grounds and a brief description of the soil profile with surface soil texture identification were made. Plant species, foliar cover, and ground cover parameters were determined from two 100 m transects aligned north to south and east to west. The line-point intercept method was used every two meters along the transects for 100 intercept points.

The Rangeland Hydrology and Erosion Model (RHEM v2.3, update 4) was used to evaluate runoff and erosion risk for different vegetation conditions found on the day the site was assessed. The wide range of sites visited allowed for determining sites representing a historical plant community reference state, transitional states, with higher bare ground and decreased species diversity and degraded conditions with introduced annual weedy species on the site or sites with excessive bare ground and minimal plant foliar and ground cover (Figure 3). Site environmental variables are used as RHEM model inputs (soil texture, slope length, slope steepness, slope shape, dominant plant life form, percentage of canopy cover, and percentage of ground cover by component rock, litter, basal area, and biological soil crusts).

Climate precipitation intensity, duration and frequency is estimated with the CLIGEN stochastic weather generator containing 300 years of daily precipitation data derived from down-scaled satellite data of daily precipitation. The RHEM model provides estimates of the average annual soil loss over a 300-year period and for 2-, 10-, 25-, 50-, and 100-year return runoff events, which provide an assessment of site vulnerability from heavier than average rainfall storm events and the consequences of accelerated soil loss from raindrop splash and sheet flow and rill soil erosion processes.

Average annual precipitation was estimated to vary from a minimum of 313 mm to a maximum of 401 mm/year across the 51 sites evaluated. Runoff varied from 1.7 mm to 20.6 mm/year, with an average annual runoff of 7.6 mm/year (Figure 4). The ratio of runoff mm/year to precipitation mm/year is an indication of susceptibility to onsite soil erosion and sediment being transferred to water bodies which may affect water quality. The higher the ratio, the more runoff leaves the site providing the energy to detach and transport sediments off-site (Figure 5). The second way of interpreting the data is that it may be possible for sites with higher runoff ratios to use the site and develop onsite water harvesting approaches to meet livestock water requirements.

Figure 3. Proposed ecological site description an alternative stable vegetation states

Note: Data collected in July 2019.
Source: Author’s elaboration.
Figure 3: Estimated Annual Precipitation and Runoff for 51 Sites Evaluated Across Akmola Oblast

Note: Data collected in July 2019. Return period soil loss rate and soil loss rate in tonne ha\(^{-1}\). Source: Author’s elaboration.

Figure 4: Ratio of Average Runoff to Precipitation for 51 Sites Evaluated Across Akmola Oblast

Note: Data collected in July 2019. Source: Author’s data.

Overall soil erosion from rainfall detachment and sediment leaving the site is low, as indicated by the 2-year runoff return period of soil loss (Figure 6). This is due primarily to the shallow slopes across the oblast. Typical slopes are less than 3%. When sites are evaluated
as a ratio of the 25-year runoff return period of soil loss to the average annual soil loss, there is an 8-fold increase in soil loss at Site 29 (Figure 6). This indicates the sites are not stable and at risk of losing site productivity. The greatest risk of erosion is not from water but wind. Sites with bare soil over 50% are susceptible to accelerated wind erosion. Sites with a 25-year return period soil loss ratio to the average annual soil loss greater than 3 are at risk of degradation and sustainability (Figure 7). Site 29 has the highest soil loss rate, but a lower runoff rate and is more than two-fold higher than Site 25. This is due to the differences in foliar and ground cover between the two sites because of grazing pressure.

The second consequence of low standing biomass and ground foliar cover is increased runoff due to reduced infiltration in the bare interspaces between the bunchgrasses (Figure 7). As bare soil increases, there is a corresponding increase in runoff and soil erosion results. This results in reduced onsite soil moisture and the effectiveness of precipitation for forage production. This can induce a negative feedback loop where the site becomes more droughty due to overgrazing, increased loss in species diversity, and loss of forage production with the risk of water and wind erosion.

Figure 5: Soil Loss for 2-Year and 25-Year Return Period Runoff Return Period

Note: For 51 sites in Akmola Oblast. Data collected in July 2019.
Source: Author’s elaboration.
**Figure 6:** Ratio of 25-Year Return Period Soil Loss Rate (tonne ha\(^{-1}\)) to Average Annual Soil Loss Rate (tonne ha\(^{-1}\)) for 51 Sites Across Akmola Oblast.

Source: Author’s field data collected in July 2019.

**Figure 7:** Relationship of Soil Loss to Ratio to Runoff (mm yr\(^{-1}\)) to Precipitation (mm yr\(^{-1}\)) for 51 Sites Evaluated Across Akmola Oblast

\[ y = 0.0079e^{0.6805x} \]

\[ R^2 = 0.5933 \]

Source: Author’s data collected in July 2019.
Figure 8: Relationship of Standing Biomass (Top) and Foliar Cover (Bottom) to Average Annual Runoff for 51 Sites Evaluated Across Akmola Oblast

Source: Author’s data for 51 sites in Akmola Oblast collected in July 2019.

Foliar and ground cover are essential elements in maintaining low runoff and soil loss from overland flow. Species lifeforms and individual species can be highly correlated with infiltration, runoff and erosion. Over time, consistent, continuous heavy grazing will cause a transition where bunchgrasses are reduced, and weedy forbs or half-shrubs increase. The shrub component can also increase, resulting in increased runoff and sediment yield. An adequate cover of bunchgrasses must be maintained on steeper sites to provide low potential soil loss from water erosion. The transition from a stable grassland plant community to an unstable hydrologic condition with lower plant cover and undesirable species can occur quickly on steeper slopes. This can be documented by observing the gap frequency between plants and the connectivity of flow paths as bunchgrasses are replaced with single stem forbs.

Increases in distances between plant stems result in concentrated flow through the gaps and accelerated soil erosion from wind and water. There are no simple thresholds for vegetation cover required to meet sustainability requirements due to the complex interactions of storm dynamics, slope, soil texture, foliar and ground cover and the low soil erosion rates. An estimated threshold would be approximately 3.5% of runoff as a percentage of precipitation to retain enough soil moisture for optimal plant growth for this climate, as indicated by a change.
in slope on the rising limb of Figure 8.

The negative slope of standing biomass, foliar and ground cover to runoff illustrates that as a site is overgrazed and standing biomass and foliar and ground cover is reduced, the risk of increased surface runoff will occur (Figure 9). This increases the rate of soil erosion at a non-linear rate and the potential of the site to cross a threshold in sustainability (Figure 8). If we use the 3.5% of runoff as a percentage of precipitation as an estimated threshold, then approximately 20% of the sites evaluated are degraded, and management changes are warranted to increase standing biomass, foliar and ground cover retained onsite to prevent further degradation.

a. Ecological and environmental analyses

Based on field surveys, the upland rangelands in the Akmola Oblast largely comprise grasses, forbs and sub-shrubs. These rangelands have evolved with grazing animals throughout history and are naturally resilient with proper grazing and resistant to degradation. Consistent removal of more than 50% of the current year’s production results in a loss of the preferred native grasses, increases in undesirable and invasive plants and a loss of forage production, which leads to a reduction in livestock carrying capacity.

The plant census within the macro plot revealed that the number of plant species ranged from 9 to 32 species across the sites sampled. Across all sites sampled, there were 141 plant species identified. Forbs were the dominant lifeform (102 species), followed by grasses (18), shrubs (15), and rushes/sedges (6). Rushes were only found in wetland sites and have minimal forage value to beef cattle. Most plants identified (95%) were native to Kazakhstan. The invasive species leafy spurge (Euphorbia virgata Waldst & Kit) was found on six pastures. Leafy spurge is noxious (i.e., high potential to spread) and poisonous to beef cattle. Specific management plans should be implemented to eradicate this plant to prevent it from further spreading. Once established, it is difficult to remove, and there is a high probability of further spreading which will reduce forage availability in the affected pasture.

Soil pH ranged from acid (5.35) to basic (7.45). Soil organic carbon levels ranged from 2–8%. High soil organic carbon levels are due to cool climates, slow decay rates, and sites being near their potential with near-maximum annual production.

An ordination of the plant species census density data collected on the ranch sites illustrates there were five main clusters of plant species groups (Figure 10). These five plant cluster groups include ranches and sites sampled at the ranch and represent plant communities with similar plant compositions and can be used in the future to develop plant associations with broad-scale ecological sites. At some ranches, several sample locations exist. In the review of the cluster groups and species, palatability values for cattle are given for the species if available (Damiran 2005, Palatability: P: preferred, D: desirable, U: consumed but undesirable, N: not consumable, T: toxic, and N/A: information not available. First value June-September, second value January to March).

Cluster Group 1 includes nine ranches and 13 sites. This cluster is highly correlated with two species: Stipa lessingiana (D, D), which is sensitive to overgrazing, and Artemisia sericea (N, U) sagebrush species, commonly known as wormwood, which can increase with heavy grazing use. This cluster indicates a high rangeland condition and a historic plant community. We associated this cluster with State I in the provisional Ecological Site Description (Figure 3). There were nine grass species found in Group 1. The main subdominant common grasses in this group include Festuca valesiaca (U, U) and Stipa capillata (D, D). Nine shrub species were found in Group 1. The common species included Artemisia sericea and Spiraea hypericifolia (D, U). Thirty-nine forb species were identified in Group 1. The common forb species included Achillea millefolium (U, U), Galatella hauptii (U, U), Medicago falcata (P, D),
Cluster Group 2 includes 14 ranches and 19 sites. Cluster 2 is correlated with *Festuca valesiaca* (U, U) (Volga fescue), and two sagebrush species, *Artemisia sublessingiana* (U, U) and *Artemisia glauca* (U, U). All respond as ‘increasers’ in the plant stand with heavier grazing and disturbance. *Festuca valesiaca* is cold and drought tolerant (Genckan 1983) and is an indicator of rangeland degradation. As *Festuca valesiaca* becomes more dominant, it alters the successional trajectory, decreasing plant diversity and undesirable species composition (Firinciog et al. 2008). We associated this cluster with State III in the provisional Ecological Site Description (Figure 3). Fourteen grass species, 10 shrub species and 58 forb species were identified in Group 2. Other subdominant grasses in this group include *Stipacapillata*, *Elytrigia repens* and *Agropyron cristatum* (D, D). Four additional sagebrush species were present in Group 2 but occurred as subdominants (*A. scoparia* U, U), *A. sericea* (U, U), *A. dracunculus* (U, U), and *A. austriaca* (U, U). *Spiraea hypericifolia* (U, U) is also a common subdominant shrub. The predominant forb species were *Achillea millefolium*, *Potentilla virgata* (U, U), *Veronica incana* (N, N), *Thymus marshallianus* (U, U), and *Medicago falcata* (P, D).

Cluster Group 3 included 11 ranches and 14 sites and was correlated with *Festuca alesiaca* and *Calamagrostis epigeios* (U, U) (feathertop reed grass), a rhizomatous grass species associated with degrading grasslands. *Calamagrostis epigeios* is a dominant species degrading Central European meadow communities (Hazi et al. 2011, Pruchniewicz and Żołnier 2014, 2019). We associated this cluster with State III in the provisional Ecological Site Description (Figure 3). Cluster Groups 2 and 3 express the range of stable states that can occur within a state. Thirteen grass species were associated with Group 3, including subdominants *Stipa capillata* (D, D) and *Elytrigia repens* (D, U). Nine shrub species were recorded on ranches in Group 3. The dominant species were *Artemisia sericea*, *A. dracunculus*, *A. sublessingiana*, and *Spiraea hypericifolia*. Fifty-four forb species were included with Group 3, and the ordination shows that three forb species were also highly correlated: *Plantago major* (U, U) (great plantain), *Glycyrrhiza glabra* (N, U) (licorish), and *Sanguisorba officinalis* (D, D) (great burnet).

Cluster Group 4 includes two sites. Two grass species, one shrub species and 13 forb species were identified. *Agrostis tenuis* (U, U) common bent grass (A. capillaris) and *Calamagrostis epigeios* (U, U) were present in this group, both having limited forage potential. We associated this cluster with State IV in the provisional Ecological Site Description (Figure 3). *Agrostis capillaris* is rhizomatous and stoloniferous perennial native to Eurasia and grows in moist grasslands and nutrient-poor pastures and is also found in cultivated areas, roadsides and invading disturbed areas (CAB International 2021). *Artemisia frigida* (D, D) was the only shrub species in this group. Some dominant forb species were *Potentilla anserina* (U, U), *Achillea millefolium*, and *Plantago major*.

Cluster Group 5 includes two ranches and three sites. Five grass species, four shrub species and 21 forb species were identified. The shrub species *Artemisia sericea* was the most frequent and dominant plant from a density viewpoint. Of the five grass species, only *Stipa capillata* has forage value to cattle. This cluster indicates a degraded state. We associated this cluster with State V in the provisional Ecological Site Description (Figure 3).
As standing biomass decreases, there is a negative and non-significant trend with species diversity increasing (i.e., weedy and undesirable species), indicating the site is degrading (Figure 11). Based on published literature and local expert knowledge, plant species were classified as forage or non-forage plants by livestock species. All grasses and upland sedges were classified as forage plants. The dominant shrub species was Artemisia spp. It is not considered a major forage plant for beef cattle and only 10% of its biomass was used to calculate forage.
Total foliar cover varied from 19 to 100% (Table 1), with a large standard deviation of 22%. Shrubs and rushes are non-forage species for beef cattle. Some shrubs may be eaten when no other forage is available but shrub consumption on these sites by cattle is an indication of overutilization and may lead to degradation and loss of production. Only 18.2% of the forbs were classified as forage for beef cattle. Three poisonous plants for cattle and horses were identified. Several additional plant species that are noxious and a sign of degradation were recorded. These species were found on the sites with the lowest cover and highest interconnected bare interspace, indicating potential degradation. Controlling these poisonous, noxious and invasive plants at the earliest stage is key to preventing spread and further rangeland degradation.

Based on data collected from 20 sample points along each 100 m transect, plant height varied from 25 to 57 mm. All plants were within reach of grazing livestock and a potential forage resource. There was no direct relationship between average plant height and standing biomass ($R^2$ 0.00). Using plant height is not recommended for assessing the status and condition of rangelands in the Akmola Oblast.

### Table 1: Foliar Canopy and Ground Cover at 51 Grassland Sites in Akmola Oblast

<table>
<thead>
<tr>
<th>Category</th>
<th>Average ±SD</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foliar Canopy Cover</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual grass</td>
<td>0 ± 0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Rhizomatous and stoloniferous grass</td>
<td>27 ± 20</td>
<td>83</td>
<td>0</td>
</tr>
<tr>
<td>Bunchgrass</td>
<td>19 ± 24</td>
<td>74</td>
<td>0</td>
</tr>
<tr>
<td>Unknown perennial grass</td>
<td>9 ± 12</td>
<td>45</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Sampling during August 2019.
Source: Author’s elaboration.
Biomass production by weight and life/growth form was based on data from five-clipped 0.25 m² plots, dried and weighed for each micro plot. Standing biomass and litter mass was estimated in early August, which generally represents full-season productivity. Standing biomass varied from 468 to 3,959 kg ha⁻¹ (Table 2). There is a significant relationship between standing biomass and forage (R² 0.77) (Figure 12). This is because the dominant vegetation by frequency of occurrence and by biomass is a perennial grass. The seven points below the linear trend line in the relationship between standing biomass and forage fall into two classes. The first set of sites is on sub-irrigated or seasonally flooded sites where rushes are the dominant vegetation type and are not considered forage for beef cattle. The second are sites where perennial forbs were a major component of the plant community (i.e., leaf spurge or other noxious weeds were present). These weedy forbs are not considered forage but can produce substantial biomass. These results highlight why remote sensing alone cannot set livestock carrying capacity as not all standing biomass is forage for livestock. Ground-based sampling by species is required to validate remote sensing images and develop appropriate non-forage adjustment factors.

Table 2: Measured Biomass by Lifeform Class of Rangeland Vegetation Evaluated on 28 Ranches in Akmola Oblast

<table>
<thead>
<tr>
<th>Lifeform</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial Grass</td>
<td>939</td>
<td>3587</td>
<td>0</td>
<td>760</td>
</tr>
<tr>
<td>Annual Grass</td>
<td>2</td>
<td>116</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Annual Forb</td>
<td>28</td>
<td>864</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>Perennial Forb</td>
<td>161</td>
<td>1544</td>
<td>0</td>
<td>263</td>
</tr>
<tr>
<td>Rush/Sedge</td>
<td>76</td>
<td>1803</td>
<td>0</td>
<td>304</td>
</tr>
<tr>
<td>Shrub</td>
<td>249</td>
<td>1732</td>
<td>0</td>
<td>314</td>
</tr>
<tr>
<td>Tree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cactus</td>
<td>49</td>
<td>1568</td>
<td>0</td>
<td>251</td>
</tr>
<tr>
<td>Litter</td>
<td>807</td>
<td>2415</td>
<td>0</td>
<td>509</td>
</tr>
<tr>
<td>Standing Biomass</td>
<td>1505</td>
<td>3959</td>
<td>468</td>
<td>886</td>
</tr>
<tr>
<td>Forage</td>
<td>1163</td>
<td>3959</td>
<td>114</td>
<td>858</td>
</tr>
</tbody>
</table>

Note: Biomass measured in kg ha⁻¹. Data collected in August 2019
Source: Author’s data.

Several ranches did not have enough standing biomass to meet forage and nutritional requirements through the end of the grazing season in October 2019 based on livestock numbers and the area grazed. This indicates that overgrazing occurs at these sites and may
reduce long-term sustainability if the trend continues over many years. Available forage at the
time of sampling (near the end of the grazing season in mid-August) ranged from 0–95% of the
standing biomass. A high standard deviation indicated significant variation in the ecological
condition across the upland sample areas based on grazing pressure in 2019.

Typical peak standing biomass occurs in late June to early July with a range of
maximum production of 1,260 to 3,260 kg ha\(^{-1}\) (Eisfelder et al. 2014; Propastin et al. 2012).
Zhang et al. (2016, 2018) evaluated central Asian desert rangelands using MODIS data for
2000 and 2014 and determined it was highly variable due to reoccurring drought (i.e., variability
in annual precipitation). Zhao et al. (2014) reported that annual estimates of grassland
productivity in northern PRC in the Xilingo grassland region varied by 40% from 2005 through
2012 due to precipitation variation. Xu et al. (2015) analyzed precipitation data from 344
meteorological stations across Central Asia from 1950 through 2000 and found that the
average duration of extreme drought in Central Asia was five years. The average annual water
class was 34.6 mm during the drought, approximately 11.2% of the average annual
precipitation. They reported that the occurrence probability of more than five consecutive wet
years was 5.8%, while the occurrence probability of more than five consecutive dry years was
6.2%.

Understanding the spatial and temporal span of drought is crucial to sustainable
rangeland development. Guo et al. (2018) reported 60 droughts in Central Asia between 1966
and 2105 lasting for a minimum of three months. The rangelands of Central Asia (Kazakhstan,
Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan and the northwestern region of China) is one
of the most vulnerable regions of the world to droughts with limited open water resources and
low-adaptive capacity for meeting the needs of grazing animals (Qi et al. 2012). Thus, it is
essential to include drought reserves when estimating stocking rates in Central Asia to avoid
rangeland degradation during a drought and economic disruptions in livestock markets.

**Figure 11: Relationship Between Standing Biomass and Forage at 28 Ranches
Sampled at 51 Sites**

![Graph showing the relationship between standing biomass and forage](image)

Source: Author’s data.

We estimated that the maximum peak standing biomass was 3,960 kg ha\(^{-1}\) on the sites
sampled from the field data. Chen et al. (2019) indicated that about 58% of the grasslands in
Kazakhstan saw a reduction in vegetation productivity between 1999 and 2015. Anthropogenic
factors were the main driver of this loss, followed by climate. The total costs of land degradation
in Central Asia are estimated to be about $6 billion annually (Mirzabaev et al. 2016).

Access to water is critical in ranch management. During the 2019 field survey, no pastures were fenced on the ranches we sampled. On the ranches evaluated, a herder moved animals from a central facility where animals overnighted and then, after grazing, returned the animals to the facility in the evening to have access to water. This management practice limits the number of animals that can be sustainably grazed due to the distance they can travel in a day. It also increases trailing across the landscape (Photo 4). Where there is significant trailing, the trails provide a linear connection of bare soil and facilitate both wind and water soil erosion. The bare ground along the trails provides an opportunity and a path for undesired species to spread, further reducing livestock carrying capacity.

Photo 4: Trails from livestock Grazing and Off-Road Vehicles Increase Chance of Soil Erosion and Spread of Invasive Species and Reduces Site Productvity

Photos: Author’s collection.

f. Modeling stocking rate

Stocking rate (Equation 1) is defined as the number of animals allotted to an area for a given length of time. The stocking rate is expressed as animal units per unit of land area. It is a vital grazing management tool that a rancher or land manager can manipulate, regardless of the grazing system, vegetation type or class of livestock (USDA-NRCS 2003). The stocking rate has the most significant impact on ecosystem services as it directly impacts animal performance and the health of the plant community. Carrying capacity is the stocking rate sustainable over time per unit of land area.

Factors that affect stocking rate include the animal species, class of livestock (e.g., dry cow, lactating cow, bull, steer), area available for grazing, time of year grazed, rainfall, topography, water distribution, forage species, forage productivity including regrowth characteristics and facilitating practices, such as fencing and water access and development. Non-forage will vary by livestock species as goats will browse shrubs that beef cattle would not normally consume. Non-forage for beef cattle is typically defined as woody stems of shrubs, plant height above livestock reach, vegetation too low for cattle to access, or as unpalatable and cattle will not eat. To correctly calculate stocking rates, non-forage must be determined for
each species if a mixed herd of animals is grazed on a common pasture.

Plant tolerance needs to be understood to determine how much forage should be grazed or removed by animals. Plants have a tolerance to grazing but if vegetation removal exceeds a critical point, most plants will lose vigor and produce less. If excessive removal continues, the plants will eventually die, increasing bare ground or leaving areas more vulnerable to invasion by potentially undesirable plants. Proper use is the approximate point of forage harvest that will not lead to range or pasture deterioration or decreased animal performance. The key to appropriate use is to provide enough leaf area to allow the plant to restore depleted energy reserves in response to grazing and thus maintain desirable productivity and composition of the plant community.

The default utilization is 50% of annual forage production (USDA-NRCS 2003). However, grazing animals also damage plants by trampling, defecation and urination and other losses from non-livestock factors such as loss to insects or use by wildlife. This loss can vary from 15–25%. For this project, a conservative grazing efficiency of 35% (Smart 2010, Green 2012, Carter, 2019) was adopted as the default maximum utilization of annual forage produced in a year. It was close to the 40% value used by Hankerson et al. (2019) for modeling grazing intensity in Kazakhstan.

The 40% is conservative and high for grazing efficiency. The number was established based on high stocking rate grazing typically implemented on areas with community-based grazing in Akmola Oblast. When grazing, the whole herd is kept together as a single unit with a herder and moved through the landscape as a single unit, thus concentrating the animals and their respective grazing behavior and trampling impact. The application of grazing efficiency in determining available forage is illustrated in Equation 2.

A common approach to address the use of grazing lands of mixed species is to use an animal unit equivalent (AUE) based on a 453.6 kg beef mother-cow with a calf younger than four months of age (USDA-NRCS 2003; Kussainova et al. 2020). Methods to calculate an AUE vary depending on how daily forage requirement is estimated by animal species, age, climate, topography, health, pregnancy status, forage, water quality and other constraints that impact animal daily forage intake. The AUE for this project is calculated on an air-dry base to be 13.6 kg of forage per day (3% of animal body weight or 453.6 kg per cow). For every increase or decrease of 45.36 kg of animal weight, there should be an AUE adjustment by +/-10%. Multiplying the days in the pasture by the daily feed requirement will determine the forage required to sustain a cow during the defined grazing season. Based on this standard, other classes and types of livestock forage requirements can be calculated using the standard AUE approach.

A more in-depth investigation of the above factors is required when determining stocking rates at a ranch level. To calculate the number of animals that could sustainably graze a pasture, we used the following equations in this project:

\[
NA = \frac{(GA \times AF \times D \times W \times S)}{(DU \times DFI)} \quad \text{(Equation 1)}
\]

\[
AF = (ANPP - ANFP) \times GE \quad \text{(Equation 2)}
\]

where

- AF: Available forage (kg/ha/year)
- ANPP: Above-ground net primary production (kg/ha/year)
- ANFP: Annual non-forage standing biomass (kg/ha/year)
- GE: Grazing efficiency (default value is 35%)
- GA: Grazing area (ha)
**DFI**: Daily feed intake (kg/day)
**DU**: Days of use allowed
**D**: Percent adjustment for climate-induced variations in production
**W**: Percent adjustment for distance to water
**S**: Percent adjustment for slope
**NA**: Number of animals

g. Accounting for management and environmental factors

Water is a critical requirement that determines the stocking rate. Limited water quality and quantity can negatively affect animal performance, animal health, grazing distribution and thus stocking rates. Water usage by beef cattle varies by weather conditions, feed type, class of livestock and if pregnant or lactating. For Akmola Oblast, the daily water requirement varies from 43 to 68 liters day⁻¹ for a 408 kg lactating cow as a function of temperature (NRC 2000). An estimated 50 liters per day per animal is average for cow reproductive status, bulls and calves.

As the distance to the water source increases, stocking rates must be decreased to avoid overutilization and degradation of areas close to water. Adequate high-quality water supplies strategically located throughout a grazing area can help increase grazing distribution, grazing efficiency and stocking rates (Table 3) (USDA-NRCS, 2003). It is recommended that the maximum distance animals travel per day to and from watering points is 3.2 km. At this distance, the recommended stocking rate should be reduced by 50% to avoid overgrazing. Alimaev et al. (2008), when addressing livestock grazing in central and southern Kazakhstan, reported that household livestock owners are forced to graze their animals within a 5 km radius from their village due to socioeconomic constraints. These villages can comprise up to a hundred households, each of which has numerous livestock grazed on the same pastures adjacent to the village. This has resulted in serious degradation of pasture productivity and reduced animal performance. This situation restricts the ability of the rancher to increase herd size, economic well-being, and pasture productivity. Wang et al. (2014) found that the peak standing crop of desert grasslands decreased by 40% with repeated heavy season-long grazing by sheep in Inner Mongolia. The ideal distance to water is less than 1.25 km on level terrain. This would equate to an area of 4.91 km² (491 ha) as a maximum grazing area for a single herder using a central watering point if a circle is used to describe the pasture/grazing area from a central water point.

The steepness of a rangeland also significantly influences grazing patterns. As slope increases, stocking rates should be adjusted downward to avoid overuse of more readily grazed locations (lower slope gradients) (Table 3). There is a considerable annual/interannual variation in precipitation in Akmola Oblast, which corresponds to a significant variation in annual net primary production (40% between the maximum and minimum production) over the last 20 years (Zhang et al. 2016, 2018; Qi et al. 2022). It is recommended that a drought mitigation plan be developed for each ranch. Besides a drought plan for the grazing season, ample feed resources are required in the winter.

<table>
<thead>
<tr>
<th>Distance to Water (km)</th>
<th>Adjustment</th>
<th>Slope</th>
<th>Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0-15</td>
<td>100</td>
</tr>
<tr>
<td>1.6</td>
<td>90</td>
<td>15-30</td>
<td>70</td>
</tr>
<tr>
<td>2.4</td>
<td>70</td>
<td>31-60</td>
<td>40</td>
</tr>
<tr>
<td>3.2</td>
<td>50</td>
<td>&gt;60</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Author’s data.
A simple approach is having an additional 25% to 40% land available for grazing, hay, and barley production for winter feedstocks to address annual variation in precipitation and therefore forage production (Figure 13 and 14). In non-drought years, the area can be hayed if appropriate or rested as part of a multi-pasture rotational system to enhance sustainability. Therefore, stocking rates should be adjusted by drought factor (D), water distance factor (W), and slope (S) factor to avoid degradation around the areas nearest the water sources to obtain more uniform and sustainable grazing resources (Equation 1).

Figure 12: Estimated Recommended Stocking Rate and Standard Deviation in Stocking Rate 2001–2019 in Akmola Oblast

Note: Based on remote sensing estimate of annual net primary productivity (kg ha\(^{-1}\)) (Qi et al. 2022) for the 51 ranch sites sampled in 2019. Source: Qi et al. 2022.
Figure 13: Estimated Recommended Stocking Rate Based on Remote Sensing Estimate of Annual Net Primary Productivity

Note: See Qi et al. (2022) for 2 ranches sampled in 2019 illustrating the variation in annual production by year and ranch in Akmola Oblast, Kazakhstan.

Source: Qi et al. 2022.

Feed resources can affect the overall performance of a cow herd, especially if the cows are in a stage of postpartum and lactation. The timing of calving for the herd should be considered when planning for a year-round feed budget. Supplemental feeding is required during the 155-day non-grazing season in the winter. An additional 2,108 kg of forage (dry
weight) is needed for a cow during the non-grazing period, with up to an extra 40% of forage required for bulls. The primary supplemental resource fed to cows in the winter is traditionally dryland hay. This hay may not provide adequate protein, energy and other nutrients if used as the sole feed source during the winter. Native meadows of mixed species of grasses and forbs, when harvested for hay, should leave a residual stubble height of approximately 10 cm to ensure enough energy reserves for the plants to regrow. This residue would equate to 50 to 60% of the standing biomass removed for hay, depending on the grass or forb species hayed.

If a ranch is designed in a circle with a 2 km radius from a central facility, it would have a 12.57 km² area or 1,257 ha for grazing. Assuming a median annual net primary production of 2,200 kg ha⁻¹ year⁻¹, 35% grazing efficiency, 0.216 non-forage coefficient (1725 kg ha⁻¹ year⁻¹), no adjustment for slope and a distance to water coefficient of 0.9, the grazing forage demand for 210 days is 2,856 kg cow⁻¹ using Equation 3. This results in 499 ha for grazing forage resources with a carrying capacity of 105.6 AUE for the average production year with a continuous grazing system over a 210-day grazing period. Additional land would be required for winter feeding (hay: 369 ha and barley: 14 ha). If a drought reserve of 25% is used to minimize degradation risks, an additional 223 ha for all feed requirements is required. The total land required would be 1,114 ha. If the drought reserve is set at 40% to account for long-term variation in documented climate and annual forage production, the total land required is 1,247 ha. Therefore, the ranch stocking rate is appropriate and allows for adaptation and mitigation of drought impacts in the first two years of moderate drought. If the drought persists over two years, then destocking should be considered to minimize degradation to the pasture and loss of animals due to lack of forage.

Poor-quality hay has a high proportion of fiber to protein, thus slowing digestion. Cows can eat only 1.5% of their body weight (BW) per day of low-quality hay, and additional mineral supplements may be required. If the forage is high quality, cows can consume up to 3% of their BW daily of hay. With supplementation, cows can digest more low-quality forage, up to 2% of their BW. Supplemental grain, primarily barley, has been identified as the primary feed supplement during the non-grazing period. Production of barley in Akmola Oblast varies annually with weather and has ranged from 1,300 to 1,600 kg ha⁻¹ in recent years (USDA-FAS, 2019). We used 1,400 kg ha⁻¹ for estimating annual barley production in Akmola Oblast to determine the area needed to raise winter feed and sustain animal productivity during the winter non-grazing season.

Alternative feed rations other than barley can be used. Free resources are available to develop least-cost-feed rations and still meet livestock nutritional requirements during the non-grazing winter months. Grain supplementation should be no more than 0.5% of the cow's BW. Feed rations are typically balanced by comparing dry matter, energy (Total Digestible Nutrients), calcium and phosphorus. Information on beef cattle nutrient requirements is available in the updated National Research Council (2000) book on beef cattle nutrition. It was estimated that a minimum of 1 kg of barley per day and up to 3 kg should be available to cattle during the non-grazing season to meet nutritional needs.

Proper planning and installation of a manure management system must be considered to develop a sustainable beef cattle system and prevent point source pollution and excess greenhouse gas emissions. Planning tools are available such as COMET-FARM (http://comet-farm.com). A by-product of confining cattle during the winter is managing manure and urine. A beef cow can generate between 12 and 26 kg of manure and 13 L of urine per day depending on their diet, SMF temperature and if confined or on open rangelands (USDA-NRCS 1992; Gonzalex-Avalos and Ruiz-Suarez 2001). This would produce a maximum of 419,000 kg of manure for a herd of 105.6 AUE during the 155-day winter-confined feeding period. By adjusting diets, the emissions of greenhouse gases and the quantity of manure and urine can be altered to minimize non-point source pollution (Hristov et al. 2013 a, b; Montes et al. 2013;
Manure management provides opportunities for a variety of uses of manure and urine as a source of energy and nutrients and preventing point source water pollution and emissions of greenhouse gases into the atmosphere.

Land resources were estimated for reported livestock numbers on an AUE of cattle, horses, sheep and goats by the Kazakhstan government in Akmola Oblast on September 1, 2019, using Equation 3 for the annual average above-ground annual net primary productivity of 2,200 kg ha\(^{-1}\) and forage availability of 1,725 kg ha\(^{-1}\). Feed and land requirements were calculated under the following scenarios: grazing period 210 days; non-grazing 155 days; daily forage intake 13.6 for 1 AUE; grazing efficiency 0.35; drought reserve 25%; and availability of water and slope coefficients set to 1.0. The AUE for cattle was estimated as 1.0, horses 1.4, and sheep and goats at 0.20. The daily water requirement was calculated at 50 L per AUE (Table 4).

**Table 4: Estimated Resources Based on Livestock Numbers on an Animal Unit Equivalent (AUE) and Estimated Annual Net Primary Production for September 2019 in Akmola Oblast**

<table>
<thead>
<tr>
<th>Total</th>
<th>Animal # (AUE)</th>
<th>Grazing (ha)</th>
<th>Hay (ha)</th>
<th>Barley (ha)</th>
<th>Drought Reserve (ha)</th>
<th>Water (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>463,020</td>
<td>2,190,191</td>
<td>1,131,598</td>
<td>51,260</td>
<td>843,262</td>
<td>23,150,000</td>
</tr>
<tr>
<td>Horse</td>
<td>282,240</td>
<td>1,869,165</td>
<td>965,735</td>
<td>46,872</td>
<td>720,443</td>
<td>14,112,000</td>
</tr>
<tr>
<td>Sheep/Goats</td>
<td>115,700</td>
<td>109,462</td>
<td>56,555</td>
<td>2,561</td>
<td>42,144</td>
<td>5,785,000</td>
</tr>
<tr>
<td>Total</td>
<td>860,940</td>
<td>4,168,818</td>
<td>2,153,889</td>
<td>100,694</td>
<td>1,605,850</td>
<td>43,047,000</td>
</tr>
</tbody>
</table>

Source: Kazakhstan Ministry of Agriculture

**Phase IV: Scaling Up with Geospatial Technologies and Models**

h. Geospatial Modeling of Stocking Rate

The results from the 51 sites showed significant spatial variability in rangeland productivity across the oblast (Figure 13), similar to findings from other studies in the region (Hankerson 2019 and Dara et al. 2021). The reason is a wide range of environmental conditions and livestock management practices leading to the high stocking rate variability.

Based on the field survey and a literature review (e.g., Eisfelder et al. 2014 and de Leeuw et al. 2019), there was a consensus that significant annual variability exists in rangeland productivity (Figure 14) due to climate variation. The annual variability in precipitation, which has tremendous implications for rangeland forage production and thus the stocking rate, is a much more significant concern for ranchers to decide how many animals they can graze and how long they can graze each year. Given the variable nature of stocking rates in both space and time, there is a need to develop a practical method to effectively capture these variabilities to arrive at a realistic assessment of rangeland carrying capacity at oblast and regional scales.

Remote sensing has proven effective in capturing both spatial and temporal dynamics of rangeland conditions (e.g., Hilker et al. 2014; Zhou et al. 2018) due to its long-term record of pixel-level observations of the Earth’s surface. For example, Vargas et al. (2019) showed that remote sensing images could be combined with models to scale up from field measurements to regional assessments for ecosystem services. Efforts have been made to assess livestock carrying capacity (e.g., de Leeuw et al. 2019) from the MODIS NPP products. Most of these studies assumed a percentage of NPP was consumed by livestock and grazing occurred on specific slopes. They estimated that animal density was more than two-fold the carrying capacity and overgrazing was the dominant factor in the degradation of the region evaluated.

Previous research efforts proved successful in estimating large-scale vegetation
information such as vegetation cover, total leaf area index, NPP and biomass from remotely sensed data. Livestock carrying capacity, however, is related to forage quantity and other environmental and management factors, including forage quality, species composition, toxic weeds, accessibility to water, terrain (slope), soil quality, weather conditions, animal species and supplemental rations (Weitz et al. 2022).

A geospatial modeling approach (Figure 15) was developed to map rangeland stocking rate considering slope, water distance, duration and availability for quality forage and other management factors. The stocking rate of a ranch, measured in the number of animals per unit land area per year, can be expressed as a function of grazing area, above-groundnet primary production (ANPP) and available forage adjusted by slope and accessibility to water.

**Figure 14: A Scaling Approach to Assess Stocking Rates at Regional Scales**

![Diagram showing the relationship between remote sensing and geospatial data, field-based assessments, and the semi-empirical stocking rate model.](image)

Note: D, S and W are environmental adjustment factors determined from field-based assessments specified in Equations 1 to 2. D: Adjustment for drought; S: Percent adjustment for slope; W: Percent adjustment for distance to water.
Source: Author's elaboration.

Among these variables, ANPP, ANFP and GA information can be derived from remotely sensed imagery. Other variables can be estimated based on the field data and ranch surveys with additional GIS information. Using Equation 1 and geospatial data, we designed a scaling approach to estimate the stocking rate in Akmola Oblast (Figure 15). The information derived from remote sensing imagery is integrated with Equations 1 and 2 to pixelize the stocking rate for the Akmola Oblast.

i. **Remote Sensing Data Acquisition and Processing**

The remote sensing data and products used in this study (Table 5) included the land use, land cover and water surface areas derived from Landsat imagery, net primary productivity...
from MODIS sensors and digital elevation model from the Shuttle Radar Topography Mission (SRTM). These data products have been rigorously validated and used in this study to determine those variables in Equation 1 to calculate the stocking rate.

### Table 5: Remote Sensing Datasets Used

<table>
<thead>
<tr>
<th>Name Variables</th>
<th>Spatial resolution (m)</th>
<th>Temporal resolution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPP (MOD17A3HGF)</td>
<td>500</td>
<td>2001-2019 (annual)</td>
<td><a href="https://doi.org/10.5067/MODIS/MOD17A3HGF.006">https://doi.org/10.5067/MODIS/MOD17A3HGF.006</a></td>
</tr>
<tr>
<td>Land use land cover (MCD12Q1/CGLS-LC100 collection 3)</td>
<td>500 / 100</td>
<td>2001-</td>
<td><a href="https://doi.org/10.5067/MODIS/MCD121.006">https://doi.org/10.5067/MODIS/MCD121.006</a></td>
</tr>
<tr>
<td>Elevation (NASA SRTM Digital Elevation Data)</td>
<td>30</td>
<td>2019/annual</td>
<td>doi:10.1038/nature20584</td>
</tr>
</tbody>
</table>

Note: NPP=Net Primary Productivity

Source: Author's elaboration.

b. Grazing Land Delineation to Determine Grazing Area

Several additional remote sensing analyses were made. The first was to delineate rangeland areas using the land-use and land-cover products from remote sensing (Table 5). Figure 16 is the land use and land cover at 500 m spatial resolution derived from MODIS imagery and rangelands extracted from this dataset. The original attribute of this dataset contains the percentage information of different land-use and land-cover types within each pixel (soft classification).

Therefore, we delineated those pixels with grass covering over 30% and water surface covering less than 30% as grasslands, using references from our field-based data and high-resolution imagery. These thresholds were based on our field observations, but they are subject to change depending on the area of study or other environmental conditions.

Figure 15: 2019 Dominant Land-Use and Land-Cover (Left) and Grazing Area (Right) in the South and Croplands in the North Akmola Oblast

Source: Author's elaboration.
j. DEM Data and Terrain Slope (S)

The steepness of the terrain affects animal travel distance and thus influences the grazing distribution (Weltz et al. 2022). As slope increases, stocking rates should be adjusted downward to avoid overuse of more readily grazed locations (USDA-NRCS 2003; Weltz et al. 2022). An analysis of the digital elevation model data for Akmola Oblast suggested that slope steepness (Figure 17) was not an issue as most parts of the oblast have slopes of less than 15%. However, this adjustment must be addressed for Kazakhstan as slopes in mountainous regions are greater than 15%. Weltz et al. (2022) provided slope adjustment factors to stocking rates and the digital elevation model data, with a 30-meter spatial resolution (Farr et al. 2007), was used to quantify the slope for the entire Akmola Oblast (Figure 17) and the adjustment factors are listed in Table 6.

<table>
<thead>
<tr>
<th>Slope</th>
<th>0-15%</th>
<th>15-30%</th>
<th>30-60%</th>
<th>&gt;60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaler</td>
<td>1</td>
<td>0.7</td>
<td>0.4</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Figure 16: Digital Elevation Model Data (Left) and Derived Slope Scale (Right) of Akmola Oblast

Source: Author’s elaboration.

k. Water and Distance to Water (W)

Water is another critical requirement that determines the stocking rate. As the distance to water source increases, stocking rates must be decreased to avoid overuse and degradation of areas closer to water (USDA-NRCS 2003). Water is unevenly distributed in the Akmola Oblast and varies from year to year depending on regional precipitation. There are some permanent water areas such as lakes and reservoirs, but these are used primarily for recreation and are inaccessible to animal grazing. The seasonal water areas in ponds and streams within the grazing lands are accessible to livestock. The water distribution within an administrative boundary is critical for water access assessment when calculating stocking rates.

In this project, we used the 2018 water data (Figure 18) derived from Landsat imagery.
to represent the situation in 2019, and a lookup table (Table 7), based on field surveys, was created to compute the water distance adjustment \((W)\).

**Table 7. Water Distance Adjustment Scaler for Cows in Akmola Oblast Rangelands**

<table>
<thead>
<tr>
<th>Distance to water (m)</th>
<th>&lt;1000</th>
<th>1000-1600</th>
<th>1600-2400</th>
<th>2400-3200</th>
<th>&gt;3200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaler</td>
<td>1</td>
<td>0.9</td>
<td>0.7</td>
<td>0.5</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Note: Based on an assumption that cows should not travel over 3.2 km to water.  
Source: Author’s field data.

**Figure 17:** Seasonal Water Surface Area (Left) Using 2018 Data as an Example and Water Accessibility Factor \(W\) (Right) Calculated Using Table 7

Note: \(W\): Percent adjustment for distance to water.  
Source: Author.

I. **Above-ground Net Primary Productivity and Available Forage**

The net primary productivity (NPP) is readily available from several agencies, including the MODIS NPP products operationally available from NASA and USGS since 2001 (Figure 19). However, this NPP product includes both below and above-ground biomass. Thus, there is a need to estimate the above-ground portion of the biomass available for livestock grazing. Based on the field data and the literature on the type of grasses, it was determined that a conversion factor of 0.37 was appropriate for Central Asia (Sala and Austin, 2000; Sun and Yang et al. 2020; Weltz et al. 2022). This means that 37% of the NPP is assumed to be above-ground biomass or above-ground NPP (ANPP) available for livestock consumption.

ANPP contains biomass from all species, some of which are not consumable by livestock. This non-forage component varies by livestock and plant species and was 20% for Central Asia grasslands, leaving 80% of the ANPP available as forage as shown in Figure 19.
Figure 18: Mean values of Net Primary Production and Available Forage in Akmola Oblast

Source: Derived from MODIS data.

m. Other Environmental Factors Affecting Stocking Rate

Other factors affecting stocking rate include grazing pressure, climate variability, soil erosion and ecological degradation. Grazing pressure, defined as the demand for forage within an environment compared to the amount available for consumption that substantially reduces vegetation and ground cover and compacts and disturbs surface soils, will likely increase water and soil losses through erosion. High-intensity grazing, particularly over many years, can alter plant composition such that the biotic structure triggers long-term site degradation through abiotic-driven losses of water and soil resources. Weltz and Wood (1986) and Weltz et al. (1986) found that stocking at high density and concentrating grazing in a small area (i.e., short-duration grazing) had adverse impacts on both surface runoff and sediment yield. The intensive removal of standing biomass leaves the site at an elevated risk of erosion if intensive rainfall events occur before vegetation can regrow.

Climate extremes and frequency of droughts and cold weather can also cause damage to plants and forage production. Overgrazing during droughts can cause shifts in species dominance which may adversely affect forage production. The reduced plant cover during drought and shifts in bunchgrass, sod grasses and shrubs resulted in increased surface runoff exacerbating the drought by reducing soil water available for plant growth (Thurow et al. 1986; Warren et al. 1986a).

Plant species, composition and diversity vary spatially and affect stocking rates. The default value for plant tolerance is 50% but considering other factors such as animal trampling and use by wildlife, the tolerance is further reduced to 35% for the Akmola Oblast (Smart 2010; Green 2012; Carter 2019; Weltz et al. 2022).

n. Stocking Rate of Akmola – Spatial Characteristics

The stocking rate for the Akmola Oblast was calculated from 2001 to 2019 (Figure 20). The dark areas are non-rangeland and were excluded from the calculations. The estimated stocking rate was based on optimal or ideal management practices. We assumed an optimal travel distance to water with sufficient winter feed. These estimates did not include other management options such as mixed livestock.

Geographically, the southern part of the oblast appears to have high stocking rates, especially the areas along streams and rivers. The high stocking rate areas are in the southeastern and along the river corridor with up to 0.5 cattle per hectare.

The mean stocking rate in the Akmola Oblast ranged from 0.099 to 0.17 during the
2001–2019 period. The largest variability is in the maximum stocking rate (ranging from 0.31 to 0.42 or 34% difference), suggesting variable rangeland conditions from year to year, resulting most likely from climate variability. There appears to be a declining trend in the oblast mean stocking rate up to 2012 before reaching a relatively stable rate for the region. The minimum stocking rate has a declining trend, possibly related to overall land degradation.

If we assume a median annual forage of 1,725 kg ha⁻¹, a grazing season of 210 days, minimal terrain slope (<15%), and water distance less than 1.5 km, then an area of 1,114 to 1,248 ha is required for a herd of 100 cows and four bulls (105.6 AUE), assuming winter feeding requirements are met and reoccurring drought reserves are considered (25% to 40%). The ranch will require 1,898,000 liters of water for direct consumption by the herd and produce about 419,000 kg of manure during the confined winter months.

**Figure 19: Estimated Stocking Rate for Mother Cows and Calves <4 Months**
To assess the stocking rate and a plan for the entire oblast, we need to consider spatial and temporal variabilities. The interaction between spatial and temporal variabilities may result in a complex stocking rate pattern. The pixelized, temporal coefficient of variation of the stocking rate between 2001 and 2019 (Figure 21) shows hotspots (red and orange areas), where high variability is likely due to climate variations between years. The larger the coefficient of variation value at a location, the more vulnerable it is to climate variability, suggesting a high risk for livestock grazing. The high-risk hotspots appear to be in the lower stocking rate areas, mainly in the southwest and some in the northeast. There are other environmental factors and management practices that may also contribute to the higher coefficient of variation in stocking rates.

The overall temporal pattern is shown in Figure 22. The mean stocking rate in the Akmola Oblast ranged from 0.099 to 0.17 during 2001–2019. The largest variability is in the maximum stocking rate (ranging from 0.31 to 0.42 or 34% difference), suggesting quite variable rangeland conditions from year to year, most likely resulting from climate variability. There appears to be a declining trend in the oblast mean stocking rate to 2012 before reaching a relatively stable rate for the region. The minimum stocking rate has a declining trend, possibly related to overall land degradation.
Figure 20: Coefficient of Variation of Annual Stocking Rate 2001–2019

Source: Author’s field data.

Figure 21: Mean Stocking Rate (Cow/ha) in Akmola Oblast from 2001 to 2019

Note: Estimated with conservative livestock management options.
Source: Author’s data.

i. Grazing Suitability

Knowledge of sustainability and future investment potential may be further assisted by grazing-suitability indicators based on spatial and temporal variability along with other environmental factors as discussed in Weltz et al. (2022). Using ISO cluster analysis, which separates all cells into distinct unimodal groups, one can classify the grazing risk into different levels and identify a new spatial pattern (Figure 23). Compared to the initial stocking rate (Figure 21), the grazing suitability (Figure 23) has a much more complex spatial pattern, suggesting that grazing practices must be adjusted to avoid risks from climate extremes or other environmental impacts.
Figure 22: Cluster Analysis of Akmola Oblast

Note: Stocking rates used to classify rangelands into three categories (less suitable, suitable and optimal) based on spatial and temporal variability resulting from climate and other environmental factors. Source: Author’s elaboration.

Phase V: Database Development and Decision Support Development

All data have been archived on a shared OneDrive in two places, one at Michigan State University and another in USDA-ARS Box and the links have been shared with colleagues in Kazakhstan.

A decision support system (DSS) for stocking rate assessment was developed on the Google Earth Engine platform to disseminate information. GEE is an open-source platform that embeds most publicly available satellite and other geospatial data, images and products (https://earthengine.google.com). Photo 5 is a snapshot of the platform that allows users to code their programs or adapt existing programs shared in public.

Photo 5: Google Earth Engine (GEE) platform

Source: Google Earth Engine [https://earthengine.google.com/](https://earthengine.google.com/)
Our initial effort was made for the whole of Kazakhstan to gain a general knowledge of the country’s rangelands (Photo 6). We populated the DSS with rangeland maps, permanent water, seasonal water, soil texture, DEM, land use and land cover and climate information such as precipitation and temperature to allow users to browse these properties.

**Photo 6: GEE Data and Information System for The Republic of Kazakhstan**

A new version was later created to allow users to browse and zoom in and out, draw specific ranch areas and calculate the defined ranch or grazing area stocking rates and other information related to their ranches. This version also contains 30 m, 100 m and 500 m resolution stocking rate information. The high-resolution stocking rate information is available for 2019 only but the 500 m resolution stocking rate is provided from 2001 to 2019, allowing for a long-term change analysis of these data (Photo 7).

**Photo 7: GEE Stocking Rate Distribution Across the Akmola Region**
Phase VI: Result Synthesis

All results from previous phases have been analyzed and summarized in the progress reports (Appendix B). Here, a synthesis is provided to address rangeland carrying capacity, the current state and the potential in the Akmola Oblast.

As a reference, two peer-reviewed journal articles have been prepared and are in the final stage for submission to The Rangeland Journal. These two articles focused on the technical validity of stocking rate modeling and are supported by findings in the relevant literature to justify the modeling approach. A review of the literature and reference manuals published by USDA and other agencies gave us confidence that the methods and techniques used are sound and the findings align with those in the published literature.

a. Rangeland Management

With the vast rangelands in Kazakhstan, there is an opportunity to increase livestock production to diversify the nation's exports while assisting the rural poor with economic opportunities. In a survey of 60 livestock operations, 98% used herders to manage livestock in pastures and operated out of a central facility where animals overnighet (Table 8). Only a single operation used fencing to control livestock. The majority (71%) of operators used mixed herds of livestock (beef cattle, sheep and horses) and grazed in common herds. Only 41% of producers had goats along with beef, sheep and horses. Twenty percent of producers solely raised beef cattle. Distance to water varied, with 54% having access to water within 1 km and 39% of producers stated access was an issue and water sources were more than 3 km from their main facility. The remaining 7% of ranches had access to water between 1 to 2 km. The most common source of water was from natural sources such as rivers, lakes and ponds (78%). Wells accounted for 22% of water sources and one ranch trucked in water to their pasture for livestock use.

The largest operation survey covered 85,000 ha. Small village backyard producers grazed on common lands and had no precise information on the area available for their use. Renting was the most frequent form of land tenure (54%), with owned-land (39%), common-land (7%), and a mixture of owned and rented at 7%. Of concern is that 37% of operators said that multiple operators grazed the same land, resulting in significant overgrazing if there is not considerable coordination among the operators. Only one producer said they were using a defined rotational grazing system. Days in pasture ranged from 153 to 228 with a median of 182 days. This requires that 137 to 212 days of feed be available for winter operation.

Livestock producers all said they were using all vaccines prescribed by the Kazakhstan government. Bloat was not reported as a problem, likely because leguminous pastures (alfalfa, clover or other legumes) were not reported as a major component of livestock grazing systems or used during winter feeding periods. Calf scours were reported on less than 5% of ranches.

Producers with herds of more than 100 animals said they were using common management practices. They reported cow weights ranging from 450 kg to 500 kg and bulls from 500 kg to 600 kg. Rebreeding cows varied from 70% to 98%, the calf crop ranged from 77% to 98% and only 2% of calves were reported dying within the first week after birth. Pregnancy testing was used on the largest commercial ranches. Body condition scores were used on numerous ranches as indicators of animal health and condition. Calves were typically sold at 7 months, and the target weight was 200 kg. Open cows were culled if they failed to breed in the second year. Bulls were commonly purchased, semen tested for virility, used for breeding at two years of age and kept for two years. The number of cows per bull varied from 22 to 30. Heifers were typically bred at 18 months, and cows were kept for up to seven years if productive. The breeding season varied from year-long to three months in winter or spring. Marking cattle techniques included ear tags to chipping the animals. Growth promotors and

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estrous synchronization compounds are used on a few ranches. These techniques and artificial
semination were commonly used only on the largest commercial ranches. Antibiotics were
used as necessary.

In general, the larger producers had access to farm equipment and raised hay and used
it for winter feed or converted it to silage as a feed source. Several producers said that pastures
were weedy and required restoration and one said their pasture had been renovated. All
producers reported providing supplemental grain (barley, oats and wheat) or a concentrated
commercial feed during the winter. The reported winter feed ration varied from 1 to 5 kg animal⁻¹
day⁻¹ of grain or concentrated and hay at 10 to 15 kg animal⁻¹ day⁻¹. Silage was used on some
ranches and feeding rates varied from 3 to 15 kg animal⁻¹ day⁻¹. As silage increased as a
percent of the diet, there was a corresponding reduction in dry hay feed to animals. Feed
supplement to enhance the use of poor-quality forages (i.e., straw or hay) was rarely used. Salt
blocks were reported on 97% of the operations, while 56% used salt and mineral blocks.

The survey shows that knowledge of best management practices and herd
management is available in Kazakhstan and is being implemented by some operations. Using
all available techniques in animal management varies as a function of the size of the operation.
Livestock producers with the largest operations by the number of animals or land used the most
updated approaches and reported the highest calf crops sold. As the number of livestock per
operator decreased, there was a corresponding decrease in the calf crop sold.

Local producers implemented the minimum number of animal management options
(i.e., no artificial insemination as an example) and had the lowest calf crop. Improvements in
access to information, tools, techniques, financing, and land would allow them to expand
operations, increase productivity and contribute to the expansion of the livestock industry. This
would also reduce rural poverty and increase productivity and efficiencies, a stated goal of the
Minister of Agricultural at the onset of this project.

Table 8. General Ranch Characteristics from 60 Ranch Surveys, Akmola Oblast

<table>
<thead>
<tr>
<th>Land Ownership</th>
<th>Percent</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own</td>
<td>39%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent</td>
<td>54%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own &amp; Rent</td>
<td>3%</td>
<td>6,321</td>
<td>85,000</td>
<td>85.00</td>
</tr>
<tr>
<td>Pasture size (ha)¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal Unit Equivalent</td>
<td>1,199</td>
<td>6,400</td>
<td>6.64</td>
<td></td>
</tr>
<tr>
<td>Days grazed</td>
<td>181</td>
<td>228</td>
<td>153</td>
<td></td>
</tr>
<tr>
<td>Distance to water (≤ 1 km)</td>
<td>54%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to water (≤2 km)</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to water (&gt; 3 km)</td>
<td>39%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herder used</td>
<td>98%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No fences</td>
<td>98%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single ranch graze pasture</td>
<td>63%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. Ranches that used common village lands (4 ranches) had no estimate of the size of pasture available for
use and the village grazed animals in a common herd (2). Large ranches reported multiple sources of water available
(i.e., reservoirs, natural ponds, lakes, rivers, and wells).
b. Global Climate Impacts on Livestock Production

The severity of climate change impact on livestock production in the Akmola Oblast will depend on adaptation and mitigation strategies. Climate change will influence global weather patterns and alter temperature and precipitation timing, amounts and type (i.e., rain versus snow). The Intergovernmental Panel on Climate Change has released numerous reports over the last two decades that estimate the impacts of climate change at global to regional scales. Because of the complex terrain and the continental location of Kazakhstan, the general conclusion is that Global and Regional Climate Models typically perform poorly in Central Asia. These tools tend to overestimate the precipitation over arid and semi-arid areas in the north (e.g., Small et al. 1999; Gao et al. 2001; Elguindi and Giorgi 2006). The projected decrease in mean precipitation in Central Asia is accompanied by an increase in the frequency of very dry spring, summer and autumn seasons. In the winter, these models project increases in the mean precipitation. Intense precipitation storms could become more common (Christensen et al. 2007). Soil erosion is common on croplands and rangelands within Kazakhstan and will increase if projected changes in precipitation intensities and frequency occur and overgrazing continues (Saparov 2014; Mirzabaev et al. 2016). The total cost of land degradation in Central Asia was estimated to equal about $6 billion annually (Mirzabaev et al. 2016).

In Central Asia, some areas could benefit from increased temperatures, longer growing seasons, warmer winters, and a slight increase in winter precipitation (cereal production in northern and eastern Kazakhstan). All of Asia is likely to warm during this century and warming is expected to be well above the global mean of 3.7° C (Christensen et al 2007). Western Kazakhstan is projected to have temperature increases and precipitation decreases in the western and southern regions (Hijioka 2014) that could negatively affect livestock production. This could increase drought frequency and impact livestock production through reductions in forage availability during the grazing season, hay production for winter feed and water availability. Chen et al. (2019) and Mohammam et al. (2013) indicated that drought and spring cooling induced recent decreases in vegetation growth in Central Asia. About 58% of the grasslands in the Central Asia region had reductions in their vegetation productivity between 1999 and 2015. Projected regional changes in climate may exacerbate this variability in interannual production.

The adoption of sustainable land management, conservation, and restoration practices depends on the compatibility and adoption of the technology within the existing social, economic, and environmental and ecological constraints of the region (Sanz et al. 2017). It has been demonstrated that every US dollar invested in restoring degraded lands provides significant social returns and ecosystem services. The investment return ranges from US $3 to US $6 over 30 years (Nkonya et al. 2016; Mirzabaev et al. 2016, 2019).

Global and regional climate change predictions are not precise enough to predict changes in interannual variability and seasonal variability in temperature and precipitation to develop operational plans for implementing grazing systems on rangelands for any specific year. However, given the high historical interannual variability in climate and reoccurring drought, adaptation and mitigation strategies should be established and implemented to reduce the immediate impacts of droughts. Drought mitigation plans should include developing drought reserve grazing areas, hay and silage storage and supplemental feed such as wheat and barley. Additionally, plans on when to sell livestock based on forage availability, if available, should be developed to allow animal movement to areas not affected by drought or irrigated pastures. The effectiveness of drought mitigation plans will depend on land availability and the region's social, economic, environmental, and ecological constraints. It will also depend on the national policies established to address drought and livestock production (i.e., grass banks or crop and forage insurance programs).
c. On-Ranch Livestock Production Impact on Climate Change

The global demand for beef is rapidly increasing (FAO 2019). This has raised concerns about climate change impacts from increased greenhouse gases transferred to the atmosphere in the beef livestock production cycle. There is concern that greenhouse gas (GHG) emissions will increase with the increasing intensification of livestock production on Kazakhstan rangelands. Most literature indicates that temperate grasslands sequester carbon (Follett et al. 2001; Derner and Schuman 2007; Lal and Follett 2009). Schlesinger (1997) estimated that atmospheric carbon dioxide (CO$_2$) sequestration by soil organic matters in grassland ecosystems was approximately 0.5 Pg C yr$^{-1}$. Follett et al. (2001) estimated grasslands could sequester 0.04 to 0.21 Mg C ha$^{-1}$ yr$^{-1}$. Cusack et al. (2021) reported that net beef GHG emissions could be reduced substantially via management changes. They reported that overall, a 46% reduction in net GHG emissions per unit of beef was achieved at sites using carbon sequestration management strategies on grazed areas, and an 8% reduction in net GHGs was achieved at sites using growth efficiency strategies. Net-zero emissions were only achieved in 2% of the 292 studies evaluated.

All estimates of greenhouse emissions depend on the climate, soils, and management of the area being evaluated. Greenhouse gas intensity (GHGI) is like global warming potential (GWP) in that negative values indicate a net sink of GHG to the soil, while positive values indicate a net source of GHG to the atmosphere (Mosier et al. 2006). However, greenhouse gas intensity expresses GHG results per unit of animal production is defined as kg CO$_2$equiv. kg$^{-1}$ animal gain. Liebig et al. (2010), working in North Dakota USA on soils, climate, and vegetation similar to the Akmola Oblast found that both heavily and moderately grazed pastures had negative GHGI (moderate grazing GHGI: $-145 \pm 38$ kg CO$_2$equiv. kg$^{-1}$ animal gain; heavy grazing GHGI: $-26 \pm 9$ kg CO$_2$equiv. kg$^{-1}$ animal gain). Both native vegetation pastures were found to have a negative GHGI (MG GHGI: $-145 \pm 38$ kg CO$_2$equiv. kg$^{-1}$ animal gain; HG GHGI: $-26 \pm 9$ kg CO$_2$equiv. kg$^{-1}$ animal gain). Per unit of animal production, GHG benefits from heavy grazing were reduced to a greater degree than from moderate grazing given the significantly greater weight gain by livestock on moderately grazed pastures. Results for both GWP and GHGI document grazing management systems employing moderate stocking rates on native vegetation in northern temperate grasslands effectively achieve net reductions in GHG emissions.

The GHG life cycle analysis for beef cattle systems can be estimated using FAO (2019) GLEAMS modeling approach. The GHG budget will be determined by how increases in livestock production occur, if energy is used to harvest and store hay and grain supplements, to irrigate hay or to grow grain supplements and transportation to feedlots and markets and other aspects of the full lifecycle assessment of livestock production from ranch to table. There is an opportunity to increase carbon sequestration from on-ranch production, given minimal external inputs used currently in beef livestock grazing systems in Akmola Oblast if ranches can increase efficiency to produce more beef per unit of GHG emitted and enhance land-based carbon sequestration to offset cattle GHG emissions (i.e., restore degraded lands and graze at moderate intensities).

Increased efficiency approaches often focus on improving feed quality or genetic improvements to aid in digestion and increase rates of weight gain while reducing enteric CH4 emissions per unit of beef (Henderson et al. 2015). Land-based strategies, by comparison, emphasize soil and plant carbon sequestration via improved management of grazed land (Cusack et al. 2021). Lal et al. (2003) reported that land restoration could sequester 0.05 to 0.12 Mg of carbon per ha$^{-1}$ yr$^{-1}$. With approximately 40% of rangelands in Akmola degraded to some degree, a significant amount of carbon could be sequestered if the lands were restored to indigenous plant community species diversity and managed with appropriate grazing intensity and stocking rates. There are significant underused areas of land in Akmola Oblast.
Therefore, it is possible that on-ranch grazing systems in the northern rangelands in Kazakhstan can be optimized to gain a neutral to slight increase in carbon sequestration based on published literature on northern temperate grasslands if appropriate land management, grazing strategies and animal herd management systems including manure management are implemented.

Use of the FAO Gleams model and rangeland the decision support system developed in this project could be linked to estimate GHG emissions and carbon sequestration rates and determine a net-zero balance of GHG for on-ranch production of beef cattle at both the enterprise and the oblast scale. GHG emissions will increase from the feedlot sector of beef cattle production. The increases can be estimated with FAO GLEAMS Life Cycle Analysis tool. Increases should be proportional to increases in livestock in feedlots. GHG emissions in feedlots can be minimized through manure, urine, water management and diet (Cusack et al. 2021). It is an open question in the literature if finishing cattle in feedlots is more beneficial than finishing on pastures when evaluating GHG emissions (Cusack 2021). Overall, Cusack et al. (2021) concluded that substantial GHG emissions reductions are possible in beef production systems, both via increased efficiency and land-based carbon sequestration. The actual reductions achieved will be determined on the basis of initial baseline conditions and the suite of practices implemented.

IV. Conclusions and Recommendations

A rangeland stocking rate baseline was established for Akmola Oblast. It was found that only 80,292.5 km² of its total 236,965 km² rangeland is needed to sustain the current 860,940 animal unit equivalent (AUE). However, approximately 40% of Akmola rangelands are degraded to some extent. A significant amount of carbon could be sequestered if the lands were restored to indigenous plant community species diversity and managed with appropriate grazing intensity and stocking rates.

Research into the most promising methods to restore and revegetate degraded rangelands and abandoned cropland is required to achieve optimized livestock production. Future research needs to address appropriate species mixes and the availability of rangeland plant materials for seeding to increase the productivity of forages to achieve the twin goals of sustainably increasing livestock production and addressing rural poverty. This will provide a new industry focused on developing and selling plant materials used in rangeland revegetation and restoration efforts.

There is still an opportunity to increase livestock production in the Akmola Oblast by three-fold based on a grazing period of 210 days. To achieve this requires expanding beef cattle grazing to all current rangelands in the Akmola Oblast. This assumes that ranchers have secure access to land, equipment, labor and skills to manage livestock and grow or have the capital to purchase hay, grain (barley, oats, wheat) or concentrated commercial feed for winter supplemental feeding.

Increasing livestock production assumes the oblast is not in an extended drought and adequate water is available to meet livestock needs. It is essential to include drought reserves when estimating stocking rates to avoid degradation of the rangelands and economic disruptions in livestock markets. The maximum annual net primary production variation in Akmola Oblast was 79% at a specific ranch and the average variation across the oblast was approximately 40% due to weather variability between 2001 and 2019. To reduce the impact of drought, a minimum reserve of 25% to 40% of grazing lands, hay lands, and lands used to raise grain should be established as part of a sustainable ranching system.

A consequence of low standing biomass and ground and foliar cover during a drought
is that increased runoff occurs due to reduced infiltration in the bare interspaces between the bunchgrasses. This results in reduced onsite soil moisture and the effectiveness of precipitation for forage production. This can induce a negative feedback loop where a corresponding management-induced drought occurs due to overgrazing during a drought. The site becomes increasingly dryer, increasing the loss of species diversity and forage production and increasing water and wind erosion risks.

Management improvement is needed in areas where current operations involve grazing local areas around ranch headquarters. A herder moves animals around the grazing unit and returns to a protected facility each night. Before and during the Soviet era, it was the tradition that large herds of animals migrated north to south and from lowlands to mountain pastures covering great distances annually following weather patterns. The trend now is sedentary, no migration, and grazing in the local area around the ranch headquarters with a herder managing the livestock that returns to the facility each night. This mode of rangeland management severely limits the herd size and distance animals can travel and graze, which can foster land degradation and limits economic opportunities for the household farmer as herd expansion is not feasible without increasing the existing degradation surrounding local villages.

The most challenging aspect of increasing livestock production will be allocating grazing rights to ranches such that ranches have the appropriate land base and forage resources for the desired herd size and a mixture of animals (i.e., land rights and availability). An associated challenge is developing a system where multiple livestock producers do not graze the same ground, as there is minimal fencing across the Akmola Oblast. There is little incentive to invest in infrastructure and implement appropriate grazing systems to achieve sustainable grazing practices without a clear title to land and grazing rights.

Methods and policies to address severely degraded lands and appropriate grazing systems need to be developed. This may include the reintroduction of fire and controlled grazing to return ecosystems to near-natural steppe vegetation. Based on our sampling, some lands should be removed from active grazing as they are severely degraded and adversely impact livestock production. Therefore, policies that address how the land is rested and what type of restoration is required (i.e., active or passive) need to be developed. These policies need to address where the existing producer moves their herd while the land is being revegetated and the availability of water on all lands used or proposed to be used for grazing.

Livestock water infrastructure and facilities need to be evaluated in more detail and improved. Water sources at less than 1 km in pastures are critical for sustained grazing pressure. Systematic water distribution will minimize excess travel distance that reduces weight gains and increases the degradation of rangelands.

An increase in hay and grain production is required to meet the winter feed supplementation requirements to maintain animals in good health. On many ranches, the above-ground annual net production was so low that onsite production of hay and grain was not feasible. In this case, herders would need to purchase winter feedstocks.

There is a need to address labor issues, specifically, migration from rural communities to the city and finding individuals who want to ranch in remote areas. More labor will be needed for haying, growing winter supplemental feed and managing an expanded livestock population.

The concentration of capital and land resources has resulted in a minority of large-scale ranching enterprises expanding operations by combining mobility with selective intensification, including an increased reliance on cultivated feed. Limitations in access to capital, land and equipment are leaving out small-scale livestock owners. This current practice limits economic opportunities and results in social inequality of household ranchers through limited herd size and minimal growth opportunities.
Access to capital to purchase livestock to increase herd sizes and farming equipment is required to develop the non-grazing season forages required to meet current and anticipated forage demands as livestock production increases. An associated challenge is the development of cost-effective drought, crop and herd insurance to reduce risks to small and medium livestock producers from climate extremes or disease outbreaks.

There is a need to increase veterinary services and animal tracking to facilitate documenting when and what vaccinations were received and which cows were open or produced a calf. These efforts will facilitate herd management and tracking animal performance in feedlots and the quality of meat produced. The breeding season should be synchronized so calving can occur during a single time period, thereby facilitating vaccination and selling animals as a cohort. These new efforts should increase efficiency in labor and costs and provide a standardized calf crop when selling.

Infrastructure development such as roads is required to efficiently move resources (i.e., livestock and feed) across the region to facilitate increases in production from the ranch through meat processing, meet national demands and deliver to international markets. Infrastructure enhancement also includes long-term observation stations to describe vegetation plant communities, forage production and early warning signs or thresholds of degradation. This new observation capability should allow documenting continuous and reversible and discontinuous and nonreversible vegetation dynamics and changes. Adopting the National Rangeland Monitoring System (NRMS) infrastructure will provide regional and national trends in rangeland conditions and health and systematically develop appropriate coefficients to estimate forage and non-forage species to assess carrying capacity accurately.

Capacity building is a significant part of this project. Over 40 scientists were trained on ecological and environmental assessment and geospatial technologies, including:

i. field qualitative methods, theories, and models,
ii. ways to assess the current status and trends in rangeland production and sustainability,
iii. tools and frameworks to scale estimates of rangeland productivity to the ranch, regional or national assessments,
iv. methods to estimate initial stocking rate/carrying capacity, and
v. modeling tool to assess sustainability as a function of hydrologic and soil erosion processes.

Training materials were developed, including hard copies of assessment manuals and presentation videos. These workshops provided the foundation for local experts to understand techniques used in establishing initial rangeland carrying capacity. The seminars and training material are archived and can be accessed. Additional field training is needed to fully understand and execute the development of sustainable rangeland grazing plans. This aspect was not possible due to the pandemic restrictions on travel and in-person meetings.

A decision support system (DSS) was developed on the Google Earth Engine platform to allow users to browse, visualize, draw specific ranch areas and statistically calculate the defined ranch or grazing areas stocking rates and other information. It is advised to operationalize the DSS using Kazakhstan’s national remote sensing capabilities to update the status of rangeland production monthly to provide the current status, trends and drought warnings to minimize disruptions in livestock production and degradation in rangeland resources.

It is recommended to initiate a new project to use FAO Gleams or COMET-farm USDA carbon models and the rangeland decision support system developed in this project. These
models can be linked to estimate greenhouse gas emissions and carbon sequestration rates to determine a net-zero balance of greenhouse gases for on-ranch production of beef cattle at both the enterprise and the oblast scale. Overall, substantial GHG emission reductions are possible in beef production systems, both via increased efficiency and land-based carbon sequestration. The actual reductions achieved will be determined on the basis of initial baseline conditions, climate and the suite of practices implemented. There is also a need to avoid point source pollution induced by confining animals during the harsh winter for more than 5 months each year. Effective on-ranch manure and urine management practices are required.

It is further recommended to develop and enhance ecological site descriptions that describe vegetation plant communities, range in annual production and early warning signs or thresholds of degradation. Plant community assessment procedures must document continuous and reversible and discontinuous and nonreversible vegetation dynamics and changes.

New programs such as the NRMS using principles demonstrated in this project are also recommended to provide national and regional trends in rangeland conditions and health. Data from the NRMS can be used to systematically develop coefficients to estimate forage and non-forage species to estimate carrying capacity across the nation accurately. Similar platforms were previously created but on completion of these scientific projects they became unavailable for use (http://kazniizhik-pastures.kz/Maps). The Ministry of Rural Republic of Kazakhstan, represented by JSC NASEC, has deployed a new database to identify farm animals (ILI, https://portal.iszh.kz). This system of accounting for animals includes information about the sex, breed, color, age and accounting for animal diseases. On the website (https://pastures.goldau.kz/ru/pastures-help) there are plans for pasture management and its uses. Using these platforms together with ours, we could automatically deliver solutions for productive use of pastures and conservation of pastures for years to come.

It is further advised to enhance international rangeland management training programs. This capacity-building may include developing an exchange program for undergraduate and graduate students with international universities to provide standardized training on rangeland management. The training program should consist of a summer field camp where principles of applied range management are taught. Training materials may include rangeland planning, rangeland improvements, indicators of rangeland health, rangeland hydrology and erosion management, development of ecological site descriptions, livestock carrying capacity calculation, and use of GIS tools for scaling stocking rates from the ranch to oblast to national estimates. Enhancing extension services to provide training in the best rangeland management practices to ranchers is also advised.

The rangelands in Akmola Oblast have the potential to increase their stocking rate as much as three-fold, thereby contributing to food security in the country. However, there are challenges to be overcome that include infrastructure improvements such as access to water and roads, management improvements such as winter feeds and revegetation and social structures and policies to allow efficient livestock grazing. The recommendations and suggestions should provide some guidance to address these challenges while protecting the rangelands from further degradation.

The potential increase in livestock production also raises concerns about climate change impacts from increased greenhouse gases transferred to the atmosphere in the beef livestock production cycle with the intensification of livestock production on Kazakhstan rangelands. There is also an opportunity to increase carbon sequestration from on-ranch production, given the minimal external inputs used in beef livestock grazing systems if ranches can increase efficiency to produce more beef per unit of greenhouse gases emitted and enhance land-based carbon sequestration to offset cattle greenhouse emissions.
The approach developed in this project and the decision support system can help decision-makers visualize location-specific stocking rate information and thus plan for sustainable livestock production. The capacity-building effort trained over 40 local scientists and technicians with the capabilities and skills to continue this line of research to address issues in sustainable rangeland management.

V. References


a field-based approach. Submitted to Rangeland Journal.


VI. APPENDICES

Appendix A: Presentations and Training Seminars
  Provided on request from KARM ADB.

Appendix B: Progress Reports
  Provided on request from KARM ADB.