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Development of the Simulation Dataset on Livestock Systems in Four Soums of Northern Mongolia (2022–2050)

Xu, Z. R.[1*] Wang, J. L.[1] Zhang, B.[2] Davaadorj, D.[3] Xian, Y. F.[1]

1. Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China;
2. Baotou Teachers' College, Baotou 014030, China;
3. National University of Mongolia, Ulaanbaatar 210646, Mongolia

Abstract: Climate change and rapid increase in livestock have considerably degraded the ecosystem in Northern Mongolia, thereby threatening regional sustainable development. Based on socio-economic statistics, land cover data, and Net Primary Productivity (NPP) data from 2015 to 2022, and in combination with future land cover and NPP data under the SSP-RCP scenarios of the CMIP6 framework, the author used Vensim DSS to construct a system dynamics model of the grassland-livestock system in four soums (Tumurbulag, Khutag-Undur, Zuunburen, and Orkhon) located in the Selenge River Basin in northern Mongolia. The model projected the dynamics of livestock under 3 socio-economic-climate scenarios: SSP1-RCP2.6, SSP2-RCP4.5, and SSP5-RCP8.5. As a result, a dataset for the simulated and projected development of grasslands and livestock in the 4 Soums was obtained, covering the period from 2022 to 2050. The dataset includes: (1) boundaries of the study area and (2) estimated forage production, carrying capacity, livestock inventory and livestock output under the 3 socioeconomic–climate scenarios such as SSP1−RCP2.6, SSP2−RCP4.5 and SSP5−RCP8.5. The dataset is archived in the .shp and .xlsx formats and comprises 9 data files of 142 KB (compressed into one file of 113 KB).

Keywords: forage production; carrying capacity; livestock inventory; livestock output; Mongolia

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2024.10.03.V1.

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***Corresponding Author:** Xu, Z. R., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, xuzr@igsnrr.ac.cn

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[2] Xu, Z. R., Wang, J. L., Zhang, B., *et al*. Simulation dataset of livestock system in four soums in Northern Mongolia (2022–2050) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.10.03.V1.

1 Introduction

The Mongolian Plateau, located at the eastern edge of the Eurasian temperate grasslands, belongs to the temperate arid and semi-arid ecological fragile zone[1]. Overgrazing and climate change have increased the area of high ecological risk zones on the Mongolian Plateau by 30% between 2001 and 2020[2]. Moreover, ecological degradation[3] and sandstorms have threatened the ecological security and sustainable development of the country and East Asia[4]. Livestock husbandry has been the traditional pillar industry in Mongolia[5], and the number of livestock has increased rapidly from 55.98 million in 2015 to 71.12 million in 2022[6]. Grassland overloading occurred in the desert steppe of southwest, central and northern Mongolia[7].

The Selenga River Basin (SRB) in northern Mongolia is the upstream area of Lake Baikal, which is the world's largest freshwater lake. The basin is predominantly characterised by temperate grasslands and forests that cover 66% and 29% of its total area, respectively[8]. The SRB is the main pastoral area of Mongolia, providing more than 60% of its livestock products. However, over the past 30 years, extreme climate events, overgrazing, and population growth have intensified desertification, threatening regional ecological security and sustainable development[9]. Herein, four typical Soums in the SRB, including Tumurbulag in the upstream area, Khutag-Undur in the midstream, Zuunburen along the downstream mainstream and Orkhon in the downstream tributaries, were studied (Figure 1). By integrating socioeconomic statistics, spatial data, and field survey data, future development scenarios of livestock husbandry in these Soums over the next 30 years were simulated using Vensim DSS. Results provided support for the coordinated development of livestock husbandry and ecological conservation.

2 Metadata of the Dataset

The metadata of Simulation dataset of livestock system in four soums in Northern Mongolia (2022–2050)[10] is summarized in Table 1. It includes the dataset full name, short name, year of the dataset, temporal resolution, data format, data size, data files, etc.

3 Methodology

3.1 Data Sources

Statistical data on livestock inventory, survival of young animals, number of herder households, average household income and expenditure and forage prices in the four typical Soums of Tumurbulag, Khutag-Undur, Zuunburen and Orkhon in the SRB of Northern Mongolia since 2015[6] were collected. Land cover data from 2015 to 2022 were derived from MCD12Q1[12], whereas future land cover[13] and NPP[14–16] were referenced from the CMIP6 SSP-RCP dataset. ANPP/NPP ratio, grass edible ratio (EGR) and supplementary rate were obtained from field surveys conducted during 2023–2024, respectively. The system dynamics process was simulated using Vensim DSS to predict livestock scenarios over the next 30 years.

3.2 Technical Route

A resilient grassland livestock system has 3 subsystems: primary production, secondary livestock production and pastoralism. The primary production subsystem includes variables

Table 1 Metadata summary of Simulation dataset of livestock system in four soums in Northern Mongolia (2022–2050)

Items	Description
Dataset full name	Simulation dataset of livestock system in four soums in Northern Mongolia (2022–2050)
Dataset short name	LivestockSoumsMongolia2022–2050
Authors	Xu, Z. R., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, xuzr@igsnrr.ac.cn Wang, J. L., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, wangjl@igsnrr.ac.cn Zhang, B., Baotou Teachers' College, zhangb8010@126.com Davaadorj, D., National University of Mongolia, davaadorjd@gmail.com Xian, Y. F., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, a326376678@outlook.com
Geographical region	4 soums in Northern Mongolia
Year	2022–2050
Temporal resolution	Year
Data format	.shp, .xlsx
Data size	142 KB
Data files	Variables of Tumurbulag, Khutag-Undur, Zuunburen and Orkhon soums from 2022 to 2050: forage production, carrying capacity, livestock inventory and livestock output
Foundations	National Natural Science Foundation of China (32161143025, 42371283); Ministry of Science and Technology of P. R. China (2022YFE0119200, 2019QZKK0603)
Computing environment	Vensim DSS version10.2.2
Data publisher	Global Change Research Data Publishing & Repository http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the "ten percent principal" should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[11]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

such as grassland area, forage production and carrying capacity. The secondary production subsystem contains variables such as livestock population, newborn numbers and output. The pastoralism subsystem comprises variables such as the number of herding households, income, expenditure and supplementary feeding[17]. The causal relationships among these variables were analysed, and a stock-flow diagram among variables was constructed using Vensim DSS (Figure 2). These multi-source data were used for simulating the dynamic processes of grassland livestock systems. The predictive accuracy of the model was validated using historical data. The main variable equations are expressed as follows:

Forage production=NPP×ANPP/NPP ratio×Grass edible ratio×Available grassland area (1)

Carrying capacity=Carrying capacity of grassland+Carrying capacity via supplement=
(Forage production+Supplementary feeding)/CONSUME PER sheep unit (SU) (2)

Livestock=INTEG (Survival of young animals–Livestock output, Initial value) (3)

Livestock output=Livestock−Carrying capacity (4)

where, the units for each variable are: Available grassland area, ha; Forage production, Supplementary feeding, t; Carrying capacity, sheep unit，SU; Livestock, Survival of young animals, Livestock output, SU; CONSUME PER sheep unit, t/SU.

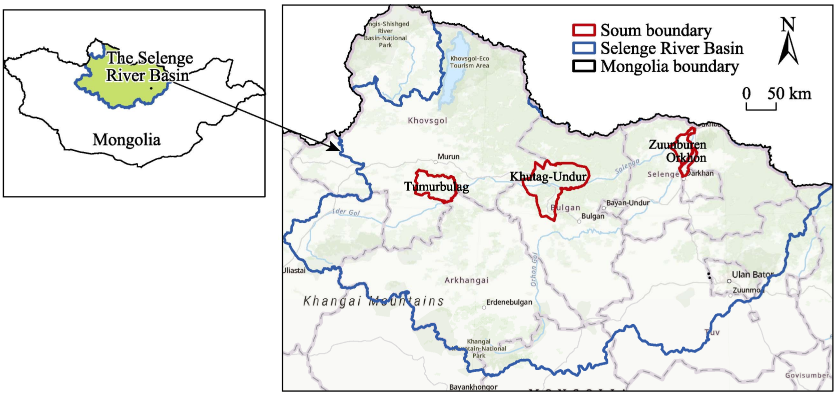


Figure 1 Geo-location map of 4 soums in Northern Mongolia

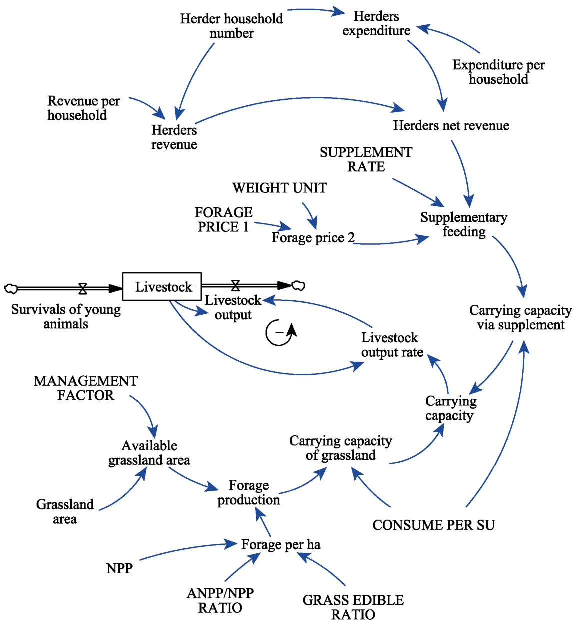


Figure 2 Stock–flow diagram of the pastoral system dynamics model
(Note: the capitalized terms in the diagram are constants)

4 Data Results and Validation

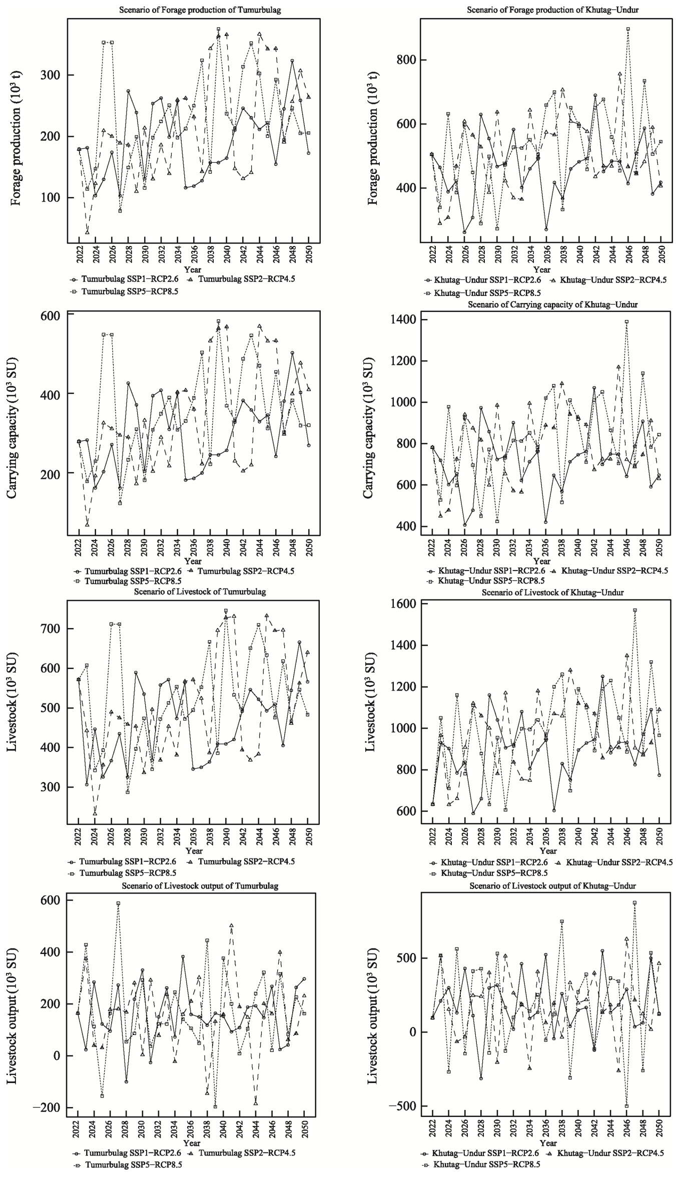
4.1 Dataset Composition

The simulation dataset of livestock systems in four soums in Northern Mongolia (2022–2050) contains 4 variables such as forage production, carrying capacity, livestock inventory, and livestock output from 2022 to 2050 for Tumurbulag, Khutag−Undur, Zuunburen, and Orkhon.

4.2 Data Results

4.2.1 Forage Production

The IPCC Coupled Model Intercomparison Project Phase 6 (CMIP6) provides coupled socioeconomic-climate system scenarios (SSP-RCPs)[18] that integrates future socioeconomic pathways (SSPs)[18] with representative concentration pathways (RCP)[19]. Among them, SSP1-RCP2.6 (SSP126), SSP2-RCP4.5 (SSP245) and SSP5-RCP8.5 (SSP585) represent the scenarios of sustainable development, intermediate pathway and economic growth priority, respectively[20]. From 2022 to 2050, the annual forage production of grasslands in Tumurbulag, Khutag-Undur, Zuunburen and Orkhon fluctuates under various scenarios. The greatest fluctuations in forage production are observed under SSP5-RCP8.5, whereas SSP1-RCP2.6 and SSP2-RCP4.5 shows relatively low inter-annual fluctuations in forage production and high system stability (Figure 3 and Table 2), which are more rational scenarios. Over the next 30 years, the average annual forage production under SSP1-RCP2.6 in Tumurbulag and Khutag-Undur is projected to be 190,260 ± 61,785 t and 458,577 ± 95,749 t, respectively, and that in Zuunburen and Orkhon under SSP2-RCP4.5 scenario are 93,400 ±



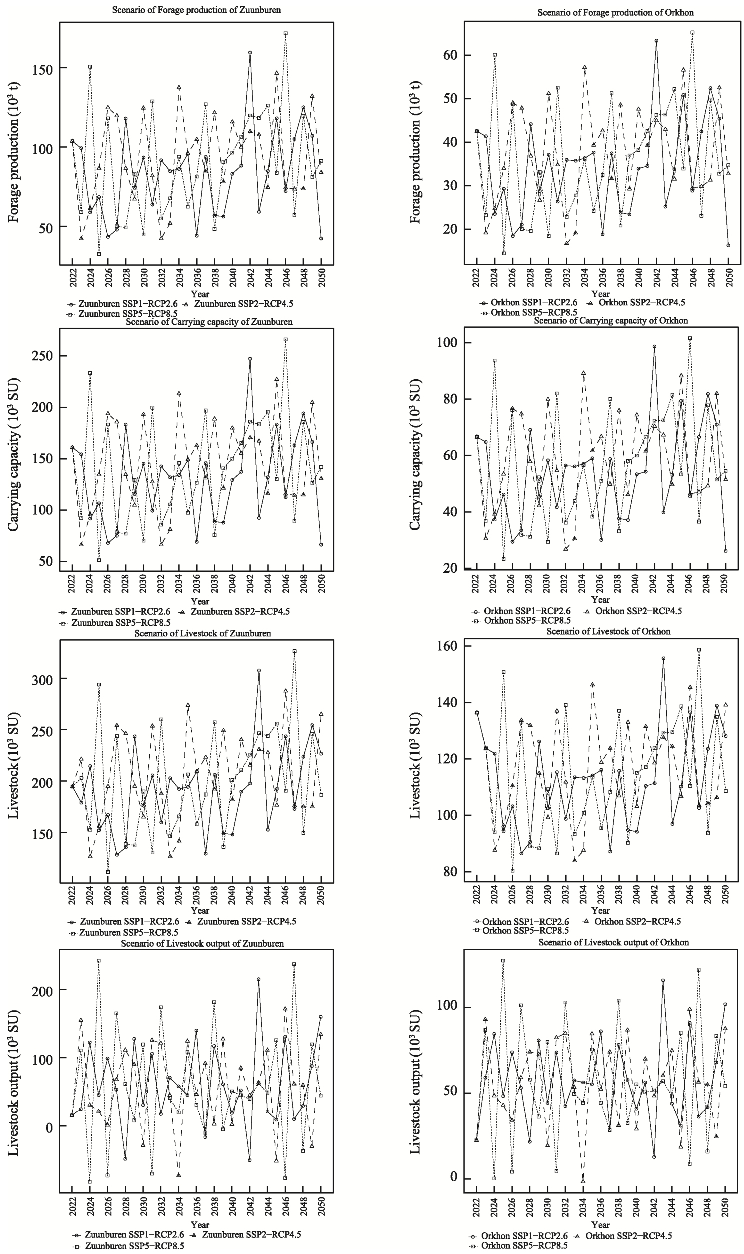


Figure 3 Forage production, carrying capacity, livestock inventory and livestock output in 4 soums of Northern Mongolia (2022–2050)

27,899 t and 37,578±11,173 t, respectively. Under SSP1−RCP2.6 or SSP2-RCP4.5, forage production across all Soums increases, but the growth rate decreases from upstream to downstream. The average annual forage production increases by 2,420 t, 1,560 t, 570 t and 200 t for Tumurbulag, Khutag-Undur, Zuunburen and Orkhon, respectively.

4.2.2 Livestock Inventory

Livestock inventory increases with fluctuations under different scenarios during 2022–2050. The average annual livestock inventories in Tumurbulag and Khutag-Undur for the next 30 years under SSP1-RCP2.6 are 464,989±97,400 SU and 886,259±155,052 SU and those in Zuunburen and Orkhon are 205,509±43,018 SU and 117,018±17,589 SU under SSP2-RCP4.5, respectively (Table 2). Under future rational scenarios, the average annual livestock population in Tumurbulag, Khutag-Undur, Zuunburen and Orkhon are projected to increase by 4,100 SU, 4,900 SU, 1,060 SU and 220 SU, respectively.

4.2.3 Livestock Output

Livestock output varies with years under different scenarios during 2022–2050 (Figure 3). Over the next 30 years, the average annual livestock outputs in Tumurbulag and Khutag-Undur are projected to be 169,373±122,082 SU and 191,782±195,890 SU under SSP1-RCP2.6 and those in Zuunburen and Orkhon are 59,738±63,366 SU and 56,427±26,318 SU under SSP2−RCP4.5, respectively (Table 2).

4.2.4 Carrying Capacity

Considering both forage from natural grassland and supplementary feeding, carrying capacity slightly increases from 2022 to 2050 (Figure 3). In the next 30 years, the annual carrying capacities for Tumurbulag and Khutag-Undur under SSP1−RCP2.6 are 296,133±95,348 SU and 710,306±147,760 SU, and for Zuunburen and Orkhon are 145,127±43,057 SU and 58,953±17,243 SU under SSP2-RCP4.5, respectively. In future rational scenarios, the average annual carrying capacities for Tumurbulag, Khutag-Undur, Zuunburen and Orkhon will increase by 1,820, 2,650, 110 and 10 SU, respectively (Table 2). The steady increase in future carrying capacity is primarily because the simulation system is a dynamic self-regulating system based on grass-livestock balance. Moreover, future climate change, variations in primary productivity, and improvements in supplementary feeding considerably influence the carrying capacity.

Table 2 Productivity, stability and sustainability of 4 soums in Mongolia from 2022 to 2050

Variable	Scenarios	Tumurbulag					Khutag-Undur				
		Mean	StDev	MV	SV	TV	Mean	StDev	MV	SV	TV
Forage production (t)	SSP126	190,260	61,785	−1	1	0	458,577	95,749	−1	1	0
	SSP245	219,591	89,172	0	−1	−1	508,202	113,803	0	0	0
	SSP585	232,255	78,684	1	0	1	533,437	139,112	1	−1	0
Carrying capacity (SU)	SSP126	296,133	95,348	−1	1	0	710,306	147,760	−1	1	0
	SSP245	341,398	137,610	0	−1	−1	786,889	175,621	0	0	0
	SSP585	360,941	121,426	1	0	1	825,832	214,680	1	−1	0
Livestock inventory (SU)	SSP126	464,989	97,400	−1	1	0	886,259	155,052	−1	1	0
	SSP245	505,415	137,582	0	−1	−1	963,438	184,251	0	0	0
	SSP585	528,047	121,461	1	0	1	995,015	225,605	1	−1	0
Livestock output (SU)	SSP126	169,373	122,082	1	1	2	191,782	195,890	1	1	2
	SSP245	159,574	147,885	−1	0	−1	184,978	225,530	−1	0	−1
	SSP585	165,001	169,971	0	−1	−1	189,844	334,522	0	−1	−1
Livestock output rate	SSP126	0.343,1	0.233,7	1	1	2	0.194,0	0.208,5	1	1	2
	SSP245	0.295,5	0.288,1	0	−1	−1	0.170,6	0.221,5	0	0	0
	SSP585	0.278,5	0.286,3	−1	0	−1	0.138,5	0.324,6	−1	−1	−2
Sustainability scores	SSP126			−1	5	4			−1	5	4
	SSP245			−1	−4	−5			−1	0	−1
	SSP585			2	−1	1			2	−5	−3

(*To be continued on the next page*)

(*Continued*)

Variable	Scenarios	Zuunburen					Orkhon				
		Mean	StDev	MV	SV	TV	Mean	StDev	MV	SV	TV
Forage production (t)	SSP126	82,712	27,552	−1	1	0	34,090	11,097	−1	1	0
	SSP245	93,400	27,899	1	0	1	37,578	11,173	1	0	1
	SSP585	89,911	34,513	0	−1	−1	36,210	13,532	0	−1	−1
Carrying capacity (SU)	SSP126	128,638	42,528	−1	1	0	53,570	17,124	−1	1	0
	SSP245	145,127	43,057	1	0	1	58,953	17,243	1	0	1
	SSP585	139,732	53,253	0	−1	−1	56,843	20,883	0	−1	−1
Livestock inventory (SU)	SSP126	191,230	40,808	−1	1	0	112,505	16,925	−1	1	0
	SSP245	205,509	43,018	1	0	1	117,018	17,589	1	0	1
	SSP585	199,733	53,265	0	−1	−1	114,804	21,286	0	−1	−1
Livestock output (SU)	SSP126	64,681	62,781	1	1	2	58,394	24,053	1	1	2
	SSP245	59,738	63,366	−1	0	−1	56,427	26,318	−1	0	−1
	SSP585	62,308	88,827	0	−1	−1	57,407	34,821	0	−1	−1
Livestock output rate	SSP126	0.301,3	0.276,4	1	1	2	0.511,9	0.166,1	1	1	2
	SSP245	0.257,6	0.290,5	0	0	0	0.474,3	0.191,1	0	0	0
	SSP585	0.232,2	0.403,1	−1	−1	−2	0.474,2	0.238,8	−1	−1	−2
Sustainability scores	SSP126			−1	5	4			−1	5	4
	SSP245			2	0	2			2	0	2
	SSP585			−1	−5	−6			−1	−5	−6

Table 3 Environmental and economic performance of pastoral systems during the historical and projected periods (2015–2050)

Soums	Period	Forage (kg/ha)	Carrying capacity (SU)	Livestock inventory (SU)	Stocking rate	Livestock output (SU)	Livestock output rate
Tumurbulag	2015–2022	880	339,773	495,822	1.46	155,993	0.31
	2022–2050	764	300,824	464,989	1.55	169,373	0.36
Khutag-Undur	2015–2022	935	768,670	560,087	0.73	110,293	0.20
	2022–2050	868	710,306	886,259	1.25	191,782	0.22
Zuunburen	2015–2022	868	155,231	166,225	1.07	37,288	0.22
	2022–2050	800	145,127	205,509	1.42	59,738	0.29
Orkhon	2015–2022	920	63,494	117,215	1.85	36,134	0.31
	2022–2050	832	58,953	117,018	1.98	56,427	0.48

4.3 Data Validation

Using livestock inventory as the validation metric, a comparative analysis was conducted between the estimated values of the model for 2015–2022 and the historical statistical values (Table 3). The analysis revealed strong agreement between the estimated and statistical trends (Figure 4). Moreover, the Pearson correlation coefficient between the forecast and statistical livestock numbers ranges from 0.11 to 0.62. With the exception of Khutag-Undur, no significant difference ($\alpha = 0.05$) was observed between the estimated and statistical livestock numbers for most Soums (Table 4). This indicates that the predictive accuracy was acceptable on the medium and long-term time scales.

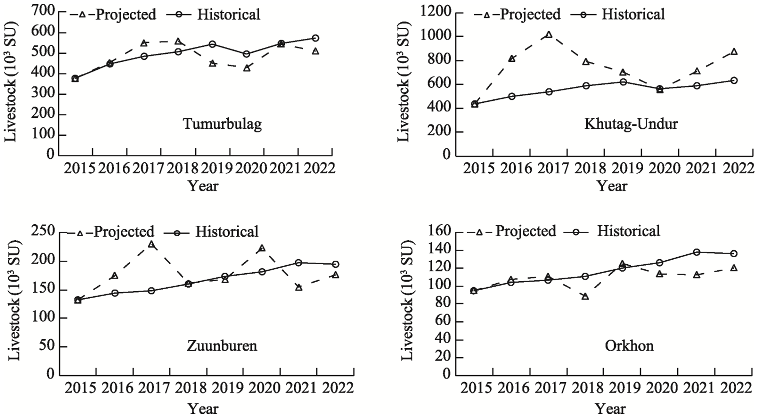


Figure 4 Comparison of the estimated and statistical values of livestock inventory (2015–2022)

Table 4 Mean difference t-test between the forecast and statistical livestock numbers

	Tumurbulag	Khutag-Undur	Zuunburen	Orkhon
(Predicted − Historical value)/ Historical value	−2.3%	32.2%	6.7%	−6.9%
Pearson correlation coefficient	0.615,8	0.419,0	0.105,1	0.621,6
T ≤ t (two-tailed)	0.578,8	0.018,5	0.442,1	0.111,5

5 Discussion and Conclusion

The simulation data of livestock system in four soums in Northern Mongolia (2022–2050) shows the future pathways of forage production, carrying capacity, livestock inventory and livestock output in each soums under three scenarios: SSP1-RCP2.6 (sustainable development), SSP2-RCP4.5 (intermediate pathway) and SSP5-RCP8.5 (economic growth priority). Compared with historical data, future rational scenarios reveals decreased forage production of 13.2%, 7.2%, 7.8% and 9.6%, as well as decreased carrying capacity of 11.5%, 7.4%, 6.5% and 7.2% for Tumurbulag, Khutag-Undur, Zuunburen and Orkhon, respectively, in the SRB. However, the livestock inventory in the basin is projected to increase by 1/4, thereby increasing the stocking rates across the SRB as well as the pressure on the grassland while threatening the security of grassland ecosystems.

Based on the historical status of grassland, livestock and pastoralists in typical Soums of Northern Mongolia from 2015–2022, the dataset integrated statistical data, spatial data and field survey data. Then, a system dynamics model of the livestock system was developed. It interfaced the natural ecological subsystem with the socioeconomic subsystem and linked the history and current situation to predict the future scenarios of key variables of the livestock system in 2022–2050. These predictions can provide reliable methodological and data support for the synergistic management of livestock and the environment.

Author Contributions

Wang, J. L. did the overall design of the dataset development; Xu, Z. R. designed the algorithms of dataset; Davaasuren, D. collected the field survey data; Zhang, B. performed data validation; and Xian, Y. F. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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