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Data Article

Data from multi-scaled measurements for soil, hydraulic, vegetative, and meteorological variables in the Xilin River Basin, Inner Mongolia

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A R T I C L E I N F O

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Dataset link: Data collected from various scales of measurements of soil, hydraulic, vegetative, and meteorological variables in the Xilin River Basin, Inner Mongolia (Original data)

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A B S T R A C T

The grazed grasslands of Inner Mongolia offer a critical research setting for studying the impacts of long-term grazing on soil, hydraulic, vegetative, and meteorological variables, and potentially contribute to examine threshold responses to grazing activity or climate dynamics in colder Eurasian temperate grasslands. The dataset consists of long-term observations of soil temperature and moisture, as well as other related parameters across three scales: pedon, field, and catchment scale. This includes: i) At the pedon scale, data collection was conducted on five sites: long-term grazing exclusion since 1979 (UG79), short-term grazing exclusion since 1999 (UG99), continuous grazing (CG), heavy year-round grazing (HG), and moderate winter grazing (WG), from May 2004 to August 2008. Profiled soil moisture at depths of 5, 20, and 40 cm was continuously monitored using theta-probes, while soil temperature at depths of 2, 8, 20, 40, and 100 cm was monitored using Platinum ground temperature probes. Since 2016, newly automated monitoring instruments were also used for continuous monitoring of soil temperature and moisture at depths of 10, 30, 50, 70, and 100 cm at the UG79, UG99, and CG sites. ii) At the field scale, during the growth

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period from 2004 to 2008, a regular sampling grid (about 100 points) was established in all five sites using differential GPS and UTM systems. Soil water content, water drop penetration time, shear strength, and hydraulic conductivity were measured once per week/month. At the beginning, soil organic carbon concentration, bulk density, soil texture, and plant parameters were also taken at each grid point. iii) At the catchment scale, a field sampling scheme was designed, using land use and soil type as stratification variables. A total of 30 sampling points were selected. At each sampling point, detailed soil surveys were conducted to measure soil profile characteristics, including soil colour, texture, structure, and chemical elements. Additionally, some soil hydrological properties were recorded on site. This dataset offers critical insights into the factors influencing livestock carrying capacity in Mongolian grasslands. The integration of these data types can substantially enhance our understanding and management of these ecosystems.

Specifications Table

Subject	Agricultural Sciences
Specific subject area	Multi-scale soil water and temperature sampling design, field-based long-term *in-situ* monitoring, grazing experiment.
Type of data	Excel files, pdf
Data collection	The related open-access datasets include *in-situ* monitoring data from five different plot settings in different grazing intensities, weekly manual measurements of soil hydrological properties at grided points for three consecutive years, and regional scale measurements of soil hydrological properties following soil types and land use maps of the Xilin River Basin. Field and Laboratory experiments were conducted utilizing the following instruments: HH2 Moisture Meter (Theta-probe Type ML2x, Delta-T devices Ltd, England), Hand-held vane tester (Geonor H-60, Norway), Mini-disk Infiltrometer (Decagon devices, USA), Theta-probes (Type ML2x, Delta-T Devices, Cambridge, UK), Platinum ground temperature probes (Pt-100), Differential GPS with UTM system, Micrometeorological station, and Automatic monitoring instrument (EM50 data recorder connected with ECH2O 5TE sensor, DECAGON, USA). Land use at the Xilin River Basin: https://doi.org/10.1007/s11104-010-0425-z.
Data source location	The data was collected at the long-term experimental sites of the Inner Mongolia Grassland Ecosystem Research Station of the Chinese Academy of Sciences (IMGERS), and a 3600 km^2 section of the Xilin River basin (43°24′ to 44°40′ N and 115°20′ to 117°13′ E) located in the Xilingol steppe in the autonomous province of Inner Mongolia, China. The Xilingol Grassland (41°35′ N to 46°46′ N, 115°32′ E to 123°10′ E) is located in the eastern central part of Inner Mongolian Autonomous Region, China. IMGERS is located at 43°37′50″ N, 116°42’18″ E, with five long-term experimental sites: long-term grazing exclusion since 1979 (UG79) at 43°33.0′ N, 116°39.9′ E, short-term grazing exclusion since 1999 (UG99) at 43°38.0′ N, 116°42.0′ E, continuously grazed (CG) at 43°32.9′ N, 116°39.7′ E, heavy year-round grazed (HG) at 43°32.9′ N, 116°39.7′ E, and moderate winter grazed (WG) at 43°33.0′ N, 116°40.0′ E.
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/msbrg4dm6m.1 Direct URL to data: http://doi.org/10.17632/msbrg4dm6m.1

1. Value of the Data

- The data can be utilized to evaluate the dominant spatiotemporal patterns of soil moisture, to determine how terrain, soil, and vegetation influence these patterns depending as a function of scale, initial moisture, and depth, and to assess feedback mechanisms between various meteorological and hydrological components. Data from field monitoring sites can be used to establish validation systems and formulas, as well as to generate tested datasets.
- The same type of datasets (e.g., soil moisture) were measured at three different scales (pedon, field, and catchment), which is advantageous for understanding scale-dependent properties and developing scaling methods.
- The data, combining the mapping and monitoring of soil moisture datasets, are integrated through a framework introduced by the experimental design for data collection, based on the concepts of slow and fast soil physical and hydrological functions, improves data efficiency, enables study of multiscale hydrological processes, and offers a potential method for integrating spatially and temporally extended datasets.
- The dataset can not only support studies investigating the impact of human activities on soil hydrological processes in grasslands, but can also be integrated with other datasets derived from aerial and geophysical measurements to facilitate more comprehensive investigations of the catchment.
- The data presented in this study provide a comprehensive profile of the features of semi-arid areas from Eastern Europe to East Asia within the temperate Eurasian grassland zone, and essential support for research into the potential threshold responses of standard Eurasian temperate grassland ecosystems, which is particularly important for ecological conservation in colder regions.
- The data presented in this study provide a comprehensive profile of semi-arid areas from Eastern Europe to East Asia within the temperate Eurasian grassland zone and essential support for researching potential threshold responses of standard Eurasian temperate grassland ecosystems, crucial for ecological conservation in colder regions.

2. Background

Estimates indicate that grasslands, which cover between 30 to 50% of the Earth's land surface and include many rangelands, are significantly influenced by soil moisture and temperature conditions, particularly in arid and cold regions [1]. A comprehensive understanding of how ecosystems respond to varying levels of grazing intensity is essential, as livestock production plays a key role in agriculture, especially given the potential impact of climate change [2]. Selecting appropriate sampling strategies and monitoring (or modeling) sites that can effectively represent the entire study area can significantly reduce the measurement load required for the research, which is crucial for watershed-scale studies [3,4]. The implementation of the MAGIM project (Matter fluxes of Grasslands in Inner Mongolia as affected by grazing) and numerous other projects have made the Xilin River Basin an experimental site for studying the realistic range of long-term grazing impacts [5], providing an ideal opportunity to explore the potential grazing threshold response of typical Eurasian temperate grassland ecosystems, especially in colder regions. This is crucial for the study of the effects of land use and climate change on soil thermal and hydrological processes, as well as their impact on plant production, the environment, and the support of ecological conservation efforts.

3. Data Description

The dataset, entitled "Multi-scaled measurements of soil, hydraulic, vegetative, and meteorological variables in the Xilin River Basin, Inner Mongolia" is stored in three folders. The folders correspond to three measurement scales, and a comprehensive list of the files contained within each folder will be provided subsequently.

3.1. Pedon scale

The site-scale folder, contains two subfolders: one for soil and plant properties and another one for soil thermal-hydraulic data.

3.1.1. Soil physical data

In June 2004, samples for the measurement of soil properties were collected at a depth of 0-4 cm of soil concurrently with the installation of water and thermal monitoring equipment at each site (UG79, UG99, CG, HG, and WG). These samples were collected in order to determine soil texture, bulk density, and soil organic carbon. Undisturbed soil samples (cylinders 100 cm^3, n=7) were also collected from three corresponding horizons of 4-8, 18-22, and 40-44 cm. These samples were used for laboratory measurements of various physical properties, including water retention curves, hydraulic conductivity, bulk density, and soil mechanical stability. Additionally, vegetation parameters (e.g., vegetation and residue cover) were recorded during root measurements [2].

The data presented here were collected prior to the implementation of the soil hydrothermal measurements. For detailed information regarding seasonal fluctuations in data, please refer to the CERN website, where you will find data from the National Ecosystem Observation Research Network and the China Ecosystem Research Network and he National Ecosystem Observation Research Network The science and Technology Resource Service System (DB/OL) can be accessed through the following link: http://www.cnern.org.cn (2015).

The "soil and plant properties" file includes some basic soil and plant characteristics, showing the average values of soil texture, selected hydraulic/mechanical parameters, soil organic carbon content and above ground biomass in the subsoil (18-44 cm) and topsoil layers (4-8 cm) across all five sites. Additionally, the file lists the van Genuchten parameters and saturated hydraulic conductivity obtained from water retention data analysis using RETC software [6] (Table 1).

3.2. Soil temperature and soil moisture

The data has been divided into two folders based on temporal categorization. The first temporal category covers the period from June 2004 to September 2008 (Figs. 1 and 2), while the second temporal category covers the period from 2016 to 2020 (Figs. 3 and 4).

(1) 2004-2008
Monitoring was conducted on five distinct treatment plots (UG99, UG79, CG, HG, WG plots) over the course of four years from June 2004 to September 2008. At each site, soil water contents and temperatures were monitored for three soil profiles, with a 15-meter distance between profiles and a 30-meter transect with a slope of less than 5%. All measured water contents are referenced to unfrozen water content at three depths (5, 20, and 40 cm) (Fig. 1). Soil temperatures were measured at five depths (2, 8, 20, 40, and 100 cm) (Fig. 2). All sensors in the three soil profiles were connected to one solar powered automatic data-logger, which recorded data at 30-minute intervals during the summer and at one-hour intervals during the winter.

(2) 2016-2020
Since October 2016, a continuous real-time monitoring of soil temperatures (Fig. 3) and water contents (Fig. 4) have been conducted at five soil depths of 10, 30, 50, 70, and 100 cm in the three plots UG79, UG99, and CG. The sensor readings refer to the volumetric unfrozen water content. The monitoring data was recorded at a 10 min time interval.

Table 1
Soil and plant properties at the five investigated sites. UG79: ungrazed since 1979, UG99: ungrazed since 1999, CG: continuously grazed, and HG: heavily grazed, WG: moderately grazed only in winter time [2,7].

Characteristics	UG79	UG99	WG	CG	HG
Height above sea level (m)	1259	1, 275	1, 273	1, 273	1211
Slope (o)	2.6-3.0	2.6-3.0	2.5-2.7	2.7-2.9	2.7-2.9
pH, 0-4 cm	6.6(0.2)	6.6(0.2)	6.7(0.3)	-	6.6(0.3)
Bulk density, 0-4 cm (g cm^{-3})	1.14(0.02)	1.11(0.02)	1.18(0.02)	1.2	1.30(0.02)
Organic C content, 0-4 cm (g kg^{-1})	3.10(0.55)	2.55(0.63)	2.59(0.45)	2.22	1.70(0.42)
Precompression stress at -30 kPa (kPa)	38	36	57	-	76
Soil texture, 0-10 cm				-	
Sand (%)	62.0(2.6)	55.2(3.1)	53.7(4.0)	-	67.9(3.5)
Silt (%)	22.2(5.4)	27.8(4.3)	27.2(5.6)	-	20.6(2.9)
Clay (%)	15.8(3.0)	17.0(1.3)	19.1(1.6)	-	11.5(1.0)
Soil water content (%) (pF 1.8), 4-8 cm	42.5(4.1)	41.7(2.8)	42.0(8.7)	41.4	46.5(6.1)
Soil water content (%) (pF 4.2), 4-8 cm	8.0(2.6)	9.8(0.7)	8.7(2.6)	9.2	6.1(0.7)
Hydraulic conductivity (cm day^{-1}), 4-8 cm	165.0(113)	82.3(47)	54.7(13)	126	93.0(18)
Aboveground net primary productivity 2006 (g m^{-2})	107(12)	107(12)	96(4)	-	75(7)
Belowground net primary productivity 2006 (g m^{-2})	203(14)	203(14)	171(3)	-	139(8)
Maximum root length density 2006 (g m^{-2})					
0-10 cm	4.59	4.59	4.22	-	4.48
10-20 cm	3.42	3.42	3.02	-	2.76
20-50 cm	1.09	1.09	0.96	-	0.55
Soil cover 2006 at plant peak time (%)					
Living green plants	54	54	33.9	-	28.4
Litter + standing dead plants	37.9	37.9	37.4	-	4
Bare soil	8.1	8.1	28.7	-	67.7

3.3. Field scale

The field-scale dataset comprises a total of five files: shear strength (SS), water drop penetration time (WDPT), hydraulic conductivity at a suction of 0.5 cm (HY), volumetric soil water content (SWC), and soil textural properties.

At each plot (UG99, UG79, CG, HG, WG), volumetric soil water content (0-6 cm) was measured on a weekly basis and following rainfall events exceeding 3 mm, for 3 years during the growing season, starting in 2004. *In-situ* measurements were also conducted, including shear strength (SS), water drop penetration time (WDPT), and hydraulic conductivity at a suction of 0.5 cm (K). In total, measurements were made on 50 occasions. Additionally, the total available water content was calculated as the difference between the field capacity (-6 kPa, pF 1.8) and the wilting point (-1,500 kPa, pF 4.2). From June to August 2004, samples were collected at each grid point at a depth of 0-4 cm. These samples were used to measure soil properties, including soil texture, bulk density (BD) and soil organic carbon (SOC). Separately, 0.25 m × 0.25 m square plots were randomly established to measure vegetation properties, including vegetation cover (VC) and aboveground biomass (AGB) (Fig. 5, Table 2).

3.4. Catchment scale

In the Catchment scale dataset, there are three PDF files and two Excel files: the PDF files contain the land use distribution map, the soil type distribution map, and the final distribution map of the sampling points; two Excel files consist of the measurement records for each sampling point and the summary table of all measurements.

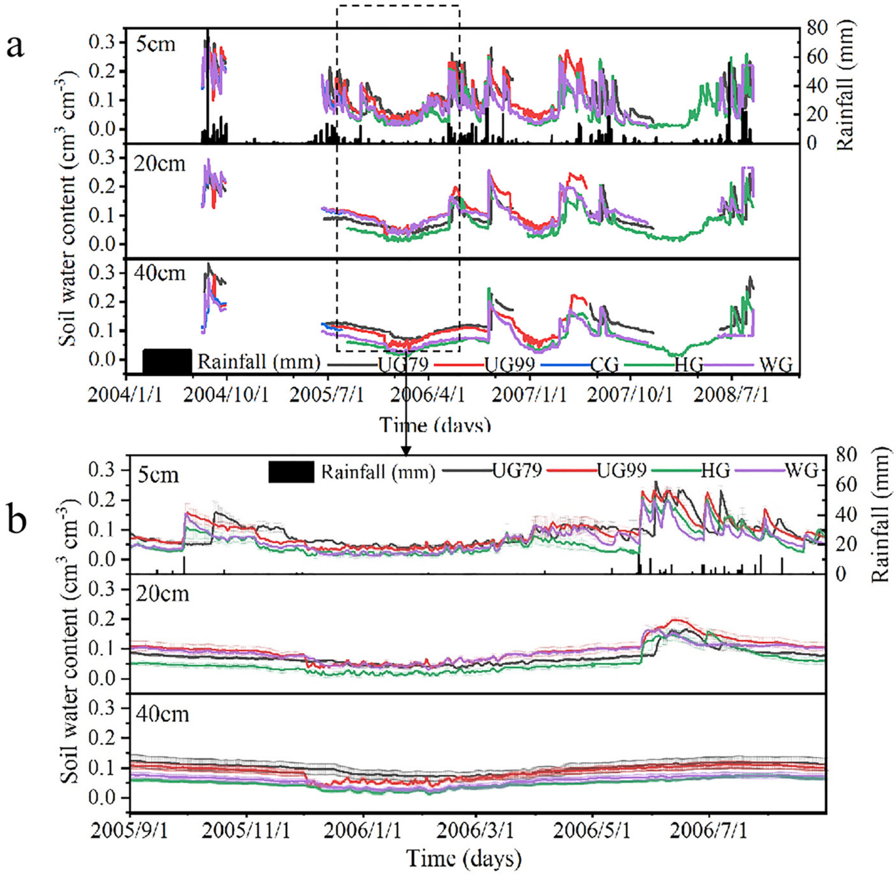

Fig. 1. a, Daily changes of soil water content (from 2004 to 2009) at the five sites, at depths of 5, 20, and 40 cm; b, Annual distribution of soil water content in a typical hydrological year (from September 2005 to August 2006) at the four sites (data in CG is missing). UG79: ungrazed since 1979, UG99: ungrazed since 1999, CG: moderately grazed, and HG: heavily grazed, WG: moderately grazed only in winter time.

The data set comprises a classification of each horizon of the soil profile at each location to a depth of 1 meter, based on the World Reference Base for Soil Resources (IUSS Working Group WRB2006). Furthermore, the data incorporates the use of the Munsell color system to describe the colors of different soil horizons, soil texture (Sand/Silt/Clay), Rock fragment (>2 mm), area of land use unit (Area), bulk density (BD), pH, total nitrogen (N_{tot}), inorganic carbon content (C_{inorg}), organic carbon content (C_{org}), total sulfur (S_{tot}), organic carbon to nitrogen ratio (C_{org}/N), total carbon (C_{tot}), total nitrogen (N_{tot}), and total sulfur (S_{tot}). The dataset also includes field-measured soil saturated hydraulic conductivity and laboratory-determined saturated water content, as well as contact angle (Table 3). Measurements were conducted in the laboratory on the horizontal and vertical soil hydraulic conductivity at different depths (0 cm, 10 cm, 30 cm, 70 cm, 100 cm).

Since the Ordinary Kriging method may not be the most suitable approach for interpolating data at the catchment scale, we utilized this approach only for basic mapping of the large-scale data in our dataset (Fig. 6).

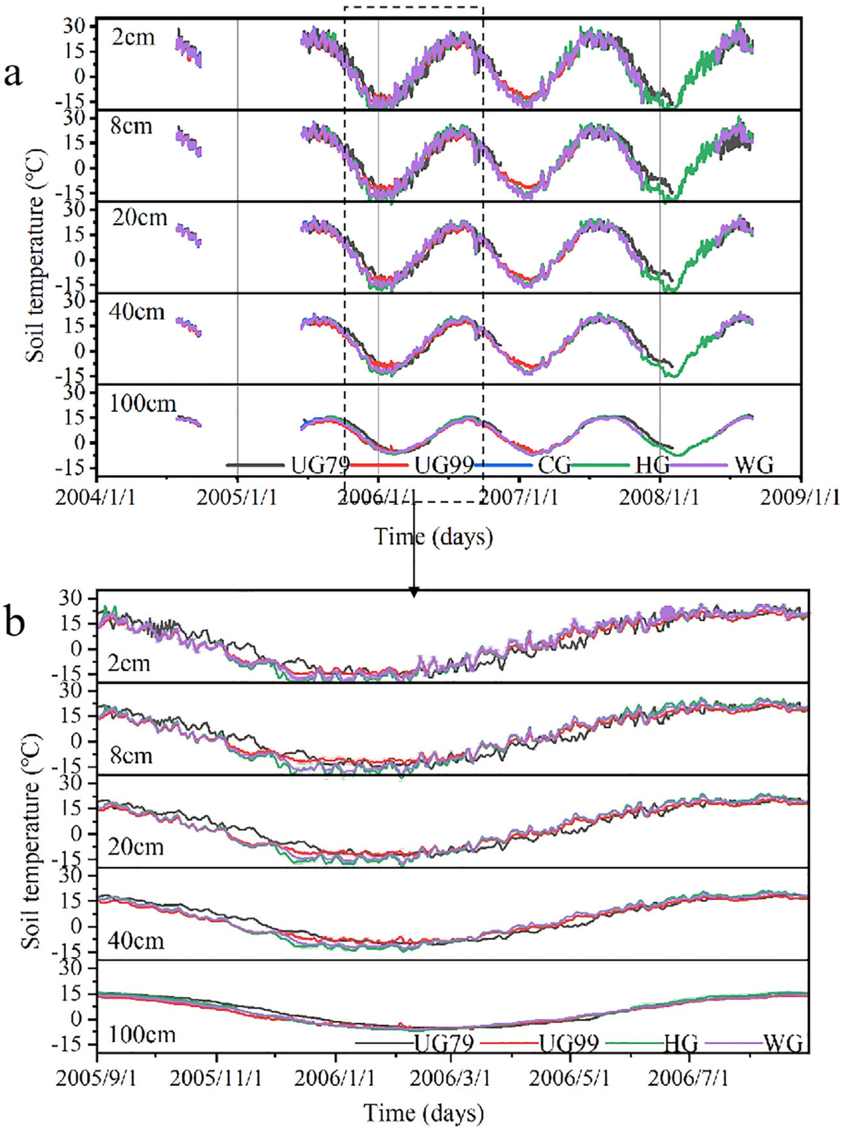

Fig. 2. a, Daily changes of soil temperature (from 2004 to 2009) at the five sites, at depths of 2, 8, 20, 40, and 100 cm; b, Annual distribution of soil temperature in a typical hydrological year (from September 2005 to August 2006) at the four sites (data in CG is missing). UG79: ungrazed since 1979, UG99: ungrazed since 1999, CG: moderately grazed, and HG: heavily grazed, WG: moderately grazed only in winter time.

4. Experimental Design, Materials and Methods

4.1. Experimental site

The data were collected at the long-term experimental sites of the Inner Mongolia Grassland Ecosystem Research Station of the Chinese Academy of Sciences (IMGERS), specifically a 3600 km^2 section of the Xilin River basin (43°24′ to 44°40′ N and 115°20′ to 117° 13′ E) located in

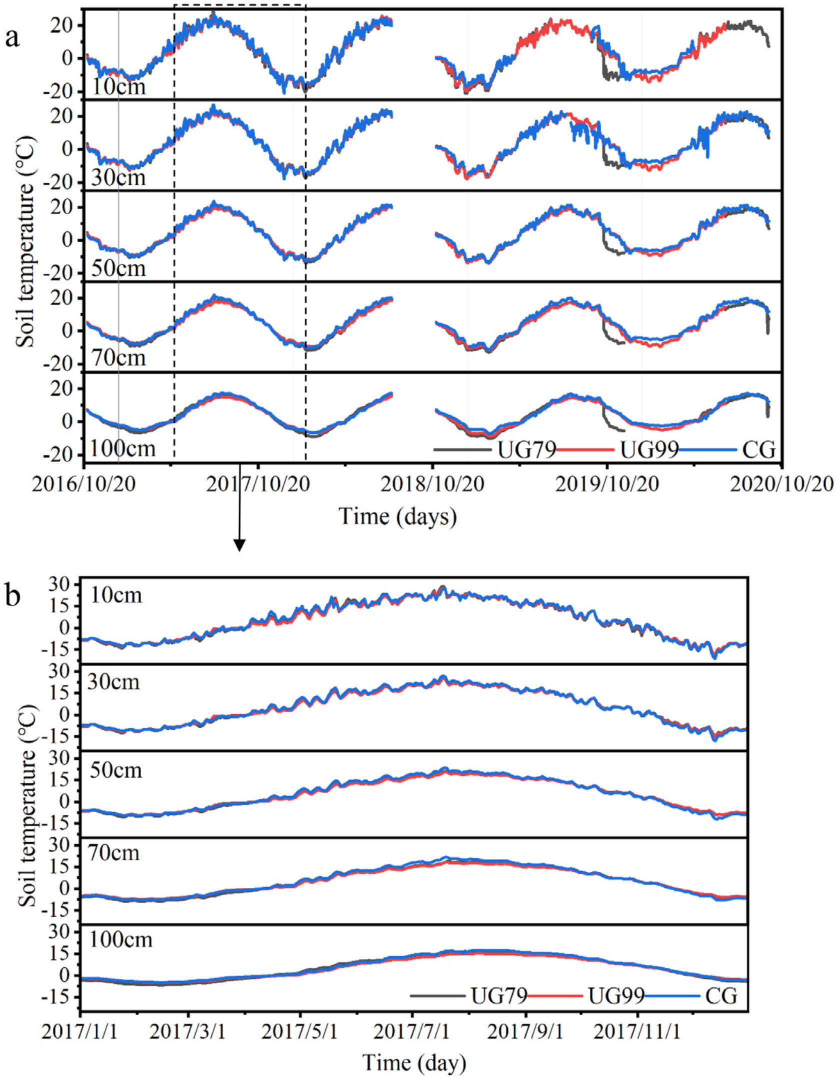

Fig. 3. a, Daily changes of soil temperature (from Oct. 2016 to Oct. 2020) at the three sites, at depths of 10, 30, 50, 70, and 100 cm; b, Annual distribution of soil temperature in 2017. UG79: ungrazed since 1979, UG99: ungrazed since 1999, CG: moderately grazed.

the Xilingol steppe in the autonomous province of Inner Mongolia, China. Prior to the implementation of the enclosure in 1979, the entire area was lightly grazed by herds consisting of 70-90% sheep and 10-30% goats (Fig. 7). The grazing intensity was measured at the field scale in five distinct ways: two ungrazed plots, one of which had remained so since 1979 (UG79, 24 ha), and the other one experienced moderate grazing (2 sheep ha^{-1} yr^{-1}) until 1999 when it was enclosed (UG99, 35 ha), and three grazed plots were also included, one of these was continuously grazed at a rate of 1.2 sheep units ha^{-1} yr^{-1} (CG, 250 ha), the second one was heavily grazed at a rate of 2.0 sheep units ha^{-1} yr^{-1} (HG, 100 ha) and the last one was winter grazed only at a rate of 0.5 sheep units (ewe and lamb) ha^{-1} yr^{-1} (WG, 40 ha). It should be

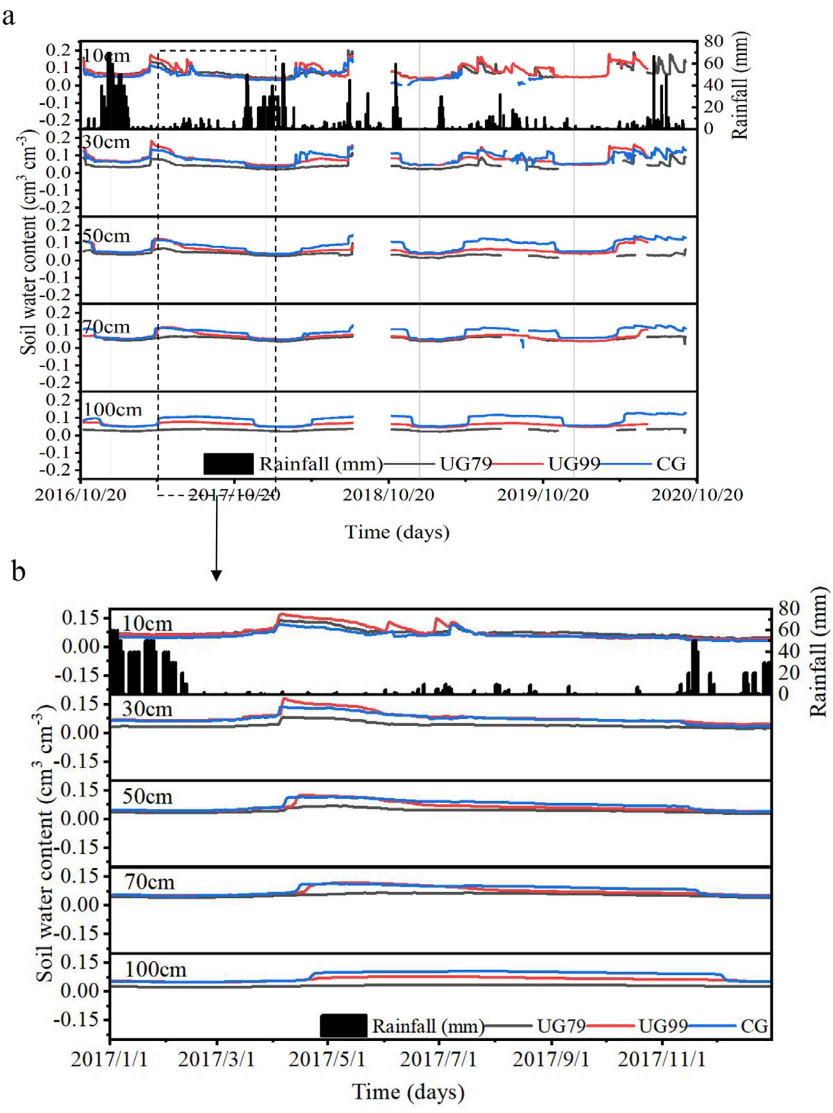

Fig. 4. a, Daily changes of soil water content (from Oct. 2016 to Oct. 2020) at the three sites, at depths of 10, 30, 50, 70, and 100 cm soil depths; b, Annual distribution of soil water content in 2017. UG79: ungrazed since 1979, UG99: ungrazed since 1999, CG: moderately grazed.

noted that no additional fertilizers, such as nitrogen or else, were applied to any of the grazed plots.

The vegetation composition and coverage of the grazed plots differs from that of enclosed plots, yet the soil and terrain are similar. The soil type is calcareous black soil. The distribution of the five long-term experimental sites is shown in Fig. 6.

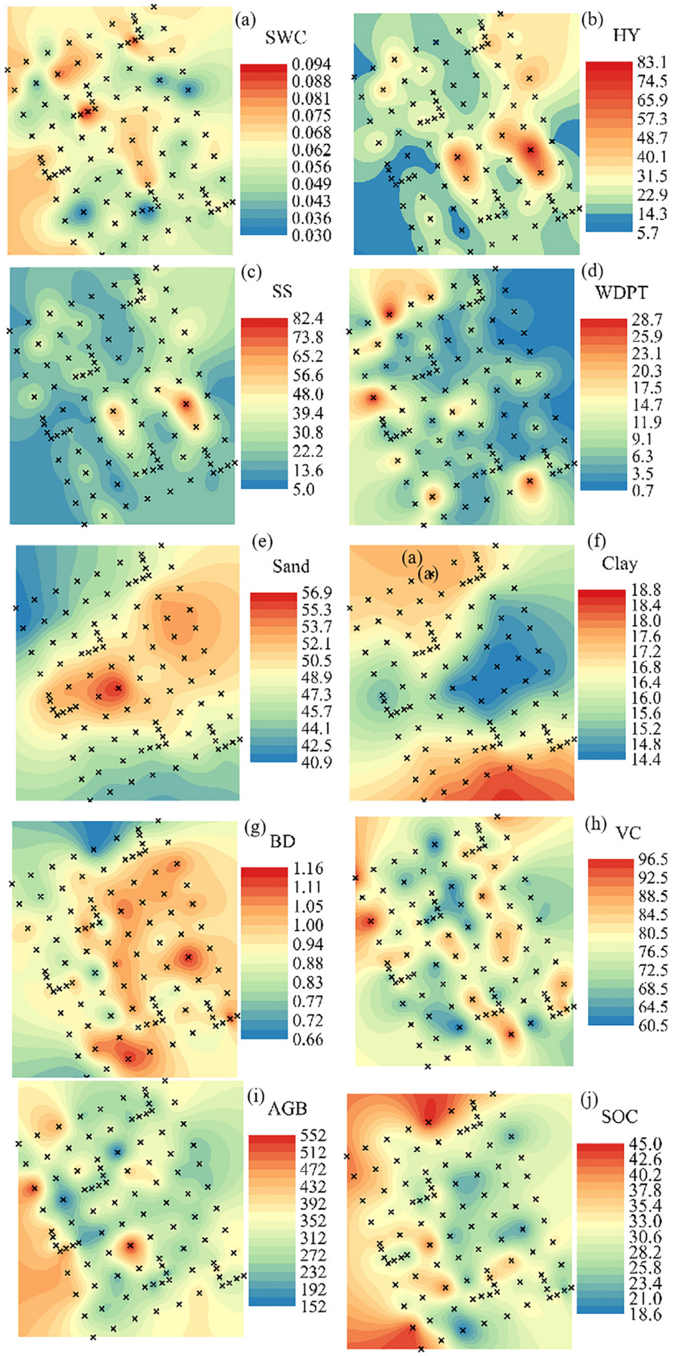

Fig. 5. Ordinary kriged maps at the UG79 grid point of (a) SWC, (b) HY, (c) SS, (d) WDPT, (e) Sand, (f) Clay, (g) BD, (h) VC, (i) AGB, (j) SOC in UG 79. SWC, soil water content (cm^3 cm^{-3}); HY, hydraulic conductivity (cm d^{-1}); SS, shear strength (kPa); WDPT, water drop penetration time (s); Sand, sand content (g / 100 g); Clay, Clay content (g / 100 g); BD, bulk density (g cm^{-3}); VC, vegetation coverage (%); AGB, aboveground biomass (g m^{-2}); SOC, soil organic carbon (g kg^{-1}); UG79: ungrazed since 1979.

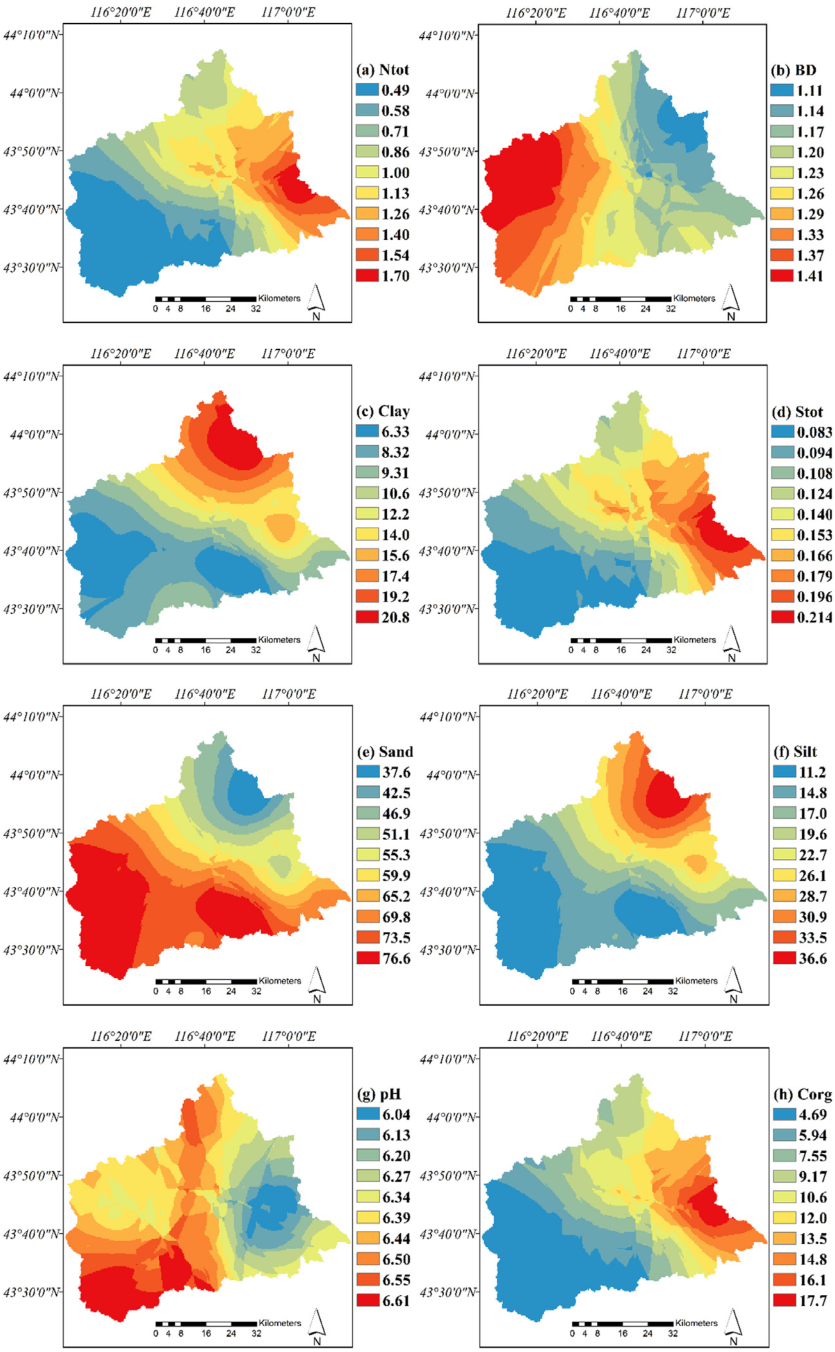

Fig. 6. Ordinary kriged maps for the Xilin River Catchment of (a) Ntot, (b) BD, (c) Clay, (d) Stot, (e) Sand, (f) Silt, (g) pH, (h) Corg. BD, bulk density (g cm^{-2}); pH ($CaCl_2$); Ntot, total nitrogen (kg m^{-2}); Corg, organic carbon content (kg m^{-2}); Stot, total sulfur (kg m^{-2}); Sand, sand content (g / 100 g); Clay, Clay content (g / 100 g); Silt, Silt content (g / 100 g).

Table 2
The main mean soil and vegetation properties at each grid points. UG79: ungrazed since 1979, UG99: ungrazed since 1999, CG: continuously grazed, and HG: heavily grazed, WG: moderately grazed only in winter time [8].

Parameters	UG79 (n=98)	UG99 (n=99)	WG (n=100)	CG (n=88)	HG (n=98)
Sand	48.6(3.2)	46.1(4.9)	47.1(5.5)	44.6(5.6)	68.1(4.7)
Silt	35.2(2.5)	37.4(3.4)	35.2(4.1)	36.6(3.5)	20.9(3.2)
Clay	16.3(1.0)	16.5(1.8)	17.8(1.6)	18.07(2.2)	11.0(1.9)
SOC	31.0(5.5)	25.5(6.3)	-	22.2(3.7)	17.0(4.1)
BD	0.9(0.10)	1.1(0.12)	-	1.2(0.06)	1.3(0.08)
SS	29.3(8.3)	32.2(7.2)	35.1(5.1)	36.6(9.9)	43.6(10.9)
WDPT	16.4(5.1)	12.1(4.8)	6.0(3.7)	5.2(2.1)	1.7(1.1)
HY	69.9(19.1)	157.8(14.7)	114.3(23.1)	126.0(11.0)	148.5(11.8)
SWC (pF = 1.8) a	42.5(4.1)	41.7(2.8)	42.0(8.7)	41.4(5.9)	46.5(6.1)
SWC (pF = 4.2) a	8.0(2.6)	9.8(0.7)	8.7(2.6)	9.2(2.0)	6.1(0.7)
VC	76.4(8.8)	68.0(7.7)	69.3(3.9)	54.5(10.7)	69.3(11.6)
AGB	313.1(78.3)	404.6(70.5)	160.8(16.0)	142.6(17.9)	131.3(41.3)

Values in parentheses denote the standard deviation.
Different letters give significant differences (p=0.01).
-, no data available; sand, sand content (%); silt, silt content (%); clay, clay content (%); SOC, soil organic carbon (g kg^{-1}); BD, bulk density (g cm^{-3}); SS, shear strength (kPa); WDPT, water drop penetration time (s); HY, hydraulic conductivity (cm d^{-1}); SWC, soil water content (%); pF, log matric potential in hPa; VC, vegetation coverage (%); AGB, aboveground biomass (g m^{-2}).
a: Value was derived by the prediction tool ROSETTA [8] based on data of soil texture and density.

5. Experimental Design and Methods

5.1. Sample at the site scale

(1) *In-Situ* Monitoring Setup
From June 2004 until the end of 2008, a four-year monitoring program was conducted, with five representative sample points selected for varying grazing intensities. The following sites were selected for monitoring: UG79 site, UG99 site, CG site, HG site, and WG site. At each site, three replicate profiles were established at a distance of 15 meters from one another. Data were collected at 30-minute intervals during the summer and 1-hour intervals during the winter using an automatic data logger (DL2e Data Logger, Delta-T Devices Ltd, Cambridge, UK). In each of the three profiles at each site, Theta probes ((Type ML2x, Delta-T Devices Ltd, Cambridge, UK) were horizontally inserted at depths of 5, 20, and 40 cm. The Theta probes were calibrated for this specific soil using a gravimetric method according to the ML2x model user manual. All measured water contents were referenced to the unfrozen water content. Soil temperature was measured at five depths (2, 8, 20, 40, and 100 cm) using platinum resistance temperature probes (Pt-100).

Since 2016, a continuous real-time monitoring of soil thermal and moisture conditions under various grazing intensities (UG79, UG99, CG) has been conducted in Inner Mongolia grazing grasslands. Soil temperatures and volumetric soil water contents were recorded at 30-minute intervals using an automated monitoring instrument (EM50 data recorder connected with ECH_2O 5TE sensor, DECAGON, USA). For each treatment, three monitoring instruments were installed, and data were collected at soil depths of 10, 30, 50, 70, and 100 cm. The sensor reading refers to the volumetric unfrozen water content in cases where the soil was frozen.

(2) Measurement of soil properties
During the initial setup, intact soil samples (7 cylinders of 100 cm^3 each) were collected from three layers at depths of 4–8, 18–22, and 40–44 cm to assess physical properties such as water retention curves, hydraulic conductivity, bulk density, and soil mechanical stability in the laboratory. The van Genuchten parameters were estimated using the RETC

Table 3
General information, reference soil groups (IUSS Working Group WRB 2006), and mean values of chemical and physical soil properties of land use units and the entire catchment derived from 30 sampling locations.

Land use unit	Arable land	Bare soil	Marshland water	Mountain meadow	Steppe	Sand dunes	Total catchment
Area (km^2) [14]	99	180	170	203	2605	351	3608
Proportion (%) [14]	3	5	5	6	72	10	100
Reference Soil Group	Chernozem	Arenosol Cambisol	Arenosol Cryosol Gleysol	Calcisol Chernozem Phaeozem	Calcisol Cambisol Chernozem Phaeozem	Arenosol	Arenosol Calcisol Cambisol Chernozem Gleysol Phaeozem
Depth (cm)	103.3	83.3	103.3	88	88.9	61.0	85.4
C_{org} (kg m^{-2})	7.4(2.7)	3.7(1.9)	7.7(4.2)	22.8(19.1)	11.1(7.1)	1.5(1.4)	7.4(2.7)
N_{tot} (kg m^{-2})	0.8(0.3)	0.4(0.2)	0.8(0.5)	2.1(1.8)	1.1(0.7)	0.2(0.1)	0.8(0.3)
S_{tot} (kg m^{-2})	0.14(0.04)	0.09(0.04)	0.1(0.1)	0.3(0.2)	0.2(0.1)	0.02(0.01)	0.14(0.04)
BD (g cm^{-2})	1.4(0.2)	1.5(0.2)	1.2(0.3)	1(0.2)	1.3(0.1)	1.3(0.3)	1.4(0.2)
pH ($CaCl_2$)	7.2(0.4)	5.9(0.6)	6.8(0.6)	5.8(0.6)	6.5(0.5)	6.4(0.2)	7.2(0.4)
Sand (%)	70.2(12.7)	82.5(14.1)	85.9(6.7)	39.5(19.4	65.1(11.9)	83.5(8.6)	70.2(12.7)
Silt (%)	18.8(8.9)	11.1(9.4)	8.8(4.7)	39.3(13.4)	21.4(7.2)	11.0(6.0)	18.8(8.9)
Clay (%)	11.0(4.0)	6.4(4.8)	5.3(2.1)	21.2(6.2)	13.5(5.2)	5.5(2.6)	11.0(4.0)

Values in parentheses denote the standard deviation.
BD, bulk density (g cm^{-2}); pH ($CaCl_2$); Ntot, total nitrogen (kg m^{-2}); Corg, organic carbon content (kg m^{-2}); Stot, total sulfur (kg m^{-2}); Sand, sand content (%); Clay, Clay content (%); Silt, Silt content (%); Depth, Depth to bedrock (cm).

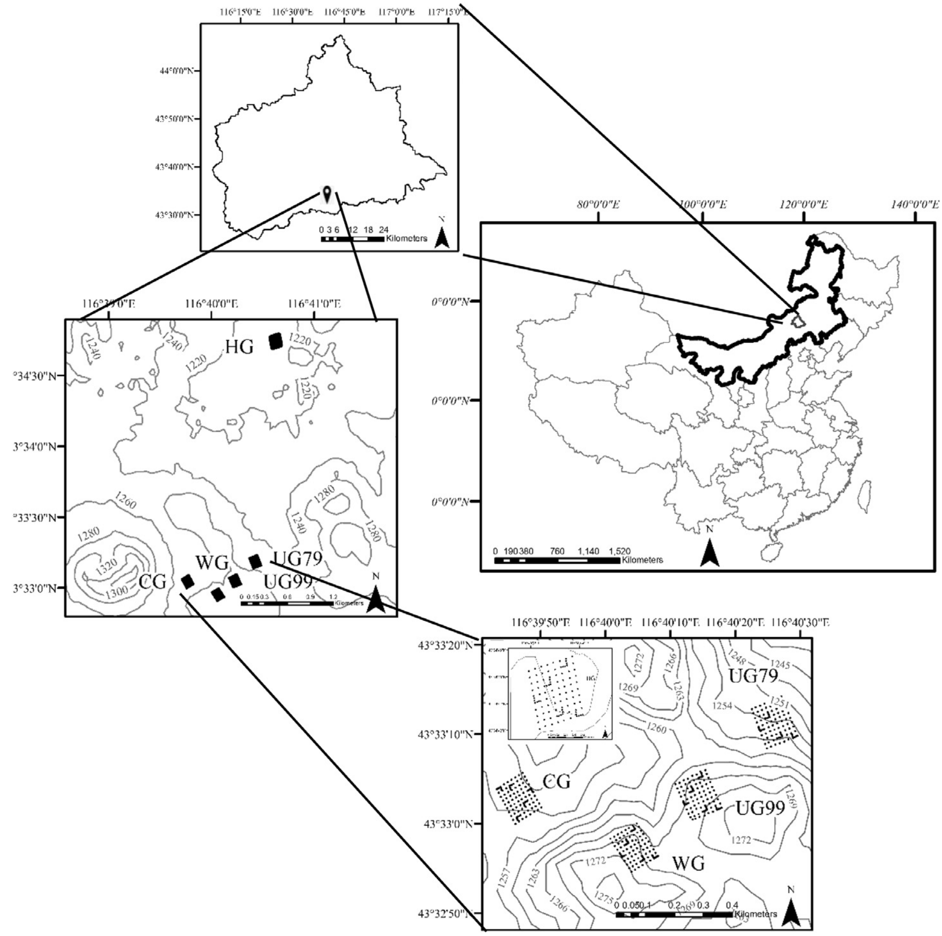

Fig. 7. Location of the sampling plots delineated as: UG79: ungrazed since 1979, UG99: ungrazed since 1999, WG: winter grazed, CG: continuously grazed, and HG: heavily grazed. Each plot has an area of 105 m×135 m. Sampling points were spaced at 15 m with a sub-grid spacing of 5 m (the orthogonal boxes with dash line in WG and CG).

software [6], using measured soil the water retention curves. Subsequently, the aforementioned estimated parameters were employed to derive hydraulic conductivity functions based on the van Genuchten Mualem equation [9]. The soil water potential was calculated from the adjusted van Genuchten parameters at each monitoring date and depth in order to assess the soil water content. From our field research, we calculated the total water content available by subtracting the field capacity (-6 kPa, pF 1.8) from the wilting point (-1,500 kPa, pF 4.2). To determine the genuine water content that is accessible by plants, the disparity between the water content measured on a specific day and the wilting point value was derived. The actual plant-available water in each soil layer was calculated by multiplying the current water content by the layer's thickness.

Root distribution and root length were analyzed across five soil layers (0-10, 10-20, 20-50, 50-70, and 70-100 cm) using an 8× magnifying glass and the line intersection method [10]. Concurrently, vegetation parameters, comprising vegetation and litter cover, leaf area index, and biomass, were also noted during the root measurements.

Vegetation cover was assessed using a non-invasive method as described in [11]. Sampling of aboveground biomass was performed on 0.25 m × 0.25 m plots by cutting plants at a height of 10 mm, which include standing dead material.

5.2. Spatial sampling at the field scale

(1) Sample Point Design.
Our measurements were carried out in five field plots with different grazing intensities UG79, UG99, WG, CG, HG. In each area, a regular sampling grid was set up using a differential GPS with the UTM system (a lateral resolution of 2 m and vertical resolution of 0.1 m) for geostatistical analysis. The individual grid covered an area of 105 m × 135 m, with all measurements randomly placed on a rectangular sampling grid consisting of 100 points, with a sampling spacing of 15 m and sub-grid spacing of 5 m. The 100 points of each area were used for geostatistical analysis.

(2) Spatial Sampling Measurement Method
In each plot, soil volumetric water content (SWC) (0-6 cm) was measured weekly for three years starting with the 2004 growing season. These measurements were made using a soil-calibrated HH2 moisture meter (Theta-probe Type ML2x, UK Delta-T Devices Ltd.) inserted into the surface of each point. In total, 50 different time points were measured. Additionally, the following *in-situ* measurements were taken after rainfall exceeding 3 millimeters: shear strength (SS) was measured using a handheld anemometer (Norwegian Geonor H-60); the water drops penetration time (WDPT) testing estimated the water resistance by measuring the time it took for 0.5mm^3 water droplets to penetrate the soil. A longer time indicates greater water resistance; hydraulic conductivity (HY) was measured using a Mini-disk infiltrometer (US Decagon Devices) at a suction value of 0.5 cm.

From June to August 2004, undisturbed soil samples were collected three times at each grid point using stainless steel cylinders (100 cm^3) for laboratory analysis. The bulk density of the soil was calculated by dividing the dry soil mass of the oven-dry soil (105°C) by the sample volume [12]. Total carbon concentration was determined by two dry combustion measurements using a Vario Max CNS elemental analyzer (Elementar Analysensysteme GmbH, Hannover, Germany). All samples were free of carbonates, so the total carbon concentration was equal to the organic carbon concentration. Soil particle size distribution was measured using the pipette method. Vegetation cover was analyzed using a non-destructive method based on [11]. Aboveground biomass was determined by sampling plants at a height of 10 millimeters on a 0.25 square meter plot, including standing deadwood.

5.3. Spatial sampling at the catchment scale

(1) Sample Point Design
A design-based, stratified two-stage sampling scheme was used for field sampling, with land use and soil types as stratifying variables [13,14]. Land use classification was based on the Landsat 7 Thematic Mapper image of August 17, 2005. Land use was classified into six units using supervised and unsupervised classification [14]: (1) arable land, (2) bare soil, (3) marshland/water, (4) mountain meadow, (5) steppe, and (6) sand dunes. Eight soil types were distinguished, namely (1) Arenosol, (2) Calcisol, (3) Chernozem, (4) Cryosol, (5) Gleysol, (6) Kastanozem, (7) Phaeozem, and (8) Regosol. The combination of these six land use classes with eight soil types resulted in 10 different environments, which were randomly sampled at 30 sites.

(2) Determination of soil properties
Field surveys and sampling began on July 1, 2007 (early in the growing season) and lasted for 12 days, covering a total of 30 sampling points. At each location, each horizon of the

soil profile to a depth of 1 m was classified according to the World Reference Base for Soil Resources (IUSS Working Group WRB2006). The sediment layer of the grassland soil is not very thick, generally around one meter. At each vegetation survey site, a soil profile was excavated and soil color, texture, and rock fragment content of the soil profile, and horizontal stratification was mapped. The saturated hydraulic conductivity of different soil layers in the soil profile was measured using a hood infiltrometer. The soil layers were categorized, and undisturbed soil samples were collected from each layer using a 100 cm^3 steel cylinder [10].

Soil sampling was conducted simultaneously with the vegetation survey. The size of the grass sample plot was 1 m × 1 m. Information such as dominant species, latitude and longitude, elevation, and plant names within the sample plot were recorded. After evenly cutting the aboveground biomass within the sample plot and recording its fresh weight, the vegetation cover was analyzed using a non-destructive method [10]. The falling head method was used to determine the saturated hydraulic conductivity from vertically oriented samples. The contact angle was measured by the Wilhelmy plate method [15]. For soil texture analysis, soil samples (<2 mm) were oxidized with H_2O_2 to remove organic matter [16]. The remaining material was dispersed with $Na_4P_2O_7$ and shaken for 16 to 24 h, followed by wet sieving to isolate sand fractions >63 µm. To determine silt and clay fractions, approximately 3 grams of the <63 µm fraction were suspended in deionized water with $Na_4P_2O_7$ and sonicated at 75 J ml^{-1} for 3 min.

The distribution of silt and clay was obtained by measuring the X-ray absorption of the soil-water suspension during the sedimentation of soil particles in a Micromeritics Sedigraph 5100 (Micromeritics, Norcross, USA) [17]. Soil pH values were measured at room temperature in a 0.01 M $CaCl_2$ solution, at a soil/solution ratio of 1:2.5 [18]. Total nitrogen, and total sulfur were determined by two dry combustion measurements using a Vario Max CNS elemental analyzer (Elementar, Hanover, Germany) [19]. For samples where the measured total carbon concentration did not contain carbonates, it represents the organic carbon concentration. Samples containing $CaCO_3$ were heated to 500°C for 4 h to remove organic carbon, and the concentration of inorganic carbon in the residue was determined by dry combustion. The organic carbon content is calculated by subtracting the inorganic carbon content from the total carbon concentration of the untreated material.

5.4. Meteorological data

Precipitation data involved in the figure was obtained from the Xilin Hot Climate Monitoring Station site (XILIN HOT CH; 43.95, 116.12), sourced from the climate data provided by the National Centers for Environmental Information (NCEI), which is under the National Oceanic and Atmospheric Administration (NOAA). The plot code is 54102099999, and the website is: https://www.ncei.noaa.gov/data/global-summary-of-the-day/archive/.

Limitations

In-situ monitoring data may experience damage due to various uncontrollable factors or may contain outliers. Being in remote locations, the equipment repair may be delayed, leading to significant data gaps in some cases.

Ethics Statement

Authors have read and follow the ethical requirements for publication in Data in Brief and confirming that the current work does not involve human subjects, animal experiments, or any data collected from social media platforms.

Declaration of Competing Interest

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Data Availability

Data collected from various scales of measurements of soil, hydraulic, vegetative, and meteorological variables in the Xilin River Basin, Inner Mongolia (Original data) (Mendeley Data).

CRediT Author Statement

W. Zhang: Data curation, Writing – original draft; **H. Wang:** Methodology, Software, Writing – review & editing; **S. Peth:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing; **R. Horn:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing; **Y. Zhao:** Conceptualization, Methodology, Software, Validation, Writing – review & editing.

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Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2024.110812

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