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Datasets Development on Grassland Productivity and Degradation in the Arid and Semi-Arid Regions of Northwest China (2001–2023)

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Abstract: In view of the potential threat of grassland degradation to ecological security and food security in arid and semi-arid regions of Northwest China, it is important to objectively quantify and evaluate the degree of grassland degradation to protect and sustainably utilize grassland resources. Using remote sensing and climatic data, the authors established an objective method to assess grassland degradation, taking climatic production potential as the natural baseline. This yielded a 500-m CPP_{max} dataset of arid and semi-arid region in Northwest China (2001–2023). Based on this, they further developed datasets of grassland degradation degree for the entire 2001–2023 period and for 5-year intervals within it. All three datasets share a spatial resolution of 500 m. By introducing objective natural baselines, these datasets effectively address critical challenges in current grassland degradation assessment, including inconsistent baseline definitions and difficulty in cross-study comparisons. The datasets are archived in .tif, .xlsx, .txt data formats, and consists of 160 data files with data size of 549.3 MB (compressed into 3 files with 249.9 MB).

Keywords: grassland degradation; climatic production potential; natural baseline; arid and semi-arid region of Northwest China

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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.2025.11.03.V1, https://doi.org/10.3974/geodb.2025.11.04.V1, https://doi.org/10.3974/geodb.2025.11.05.V1.

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1 Introduction

The vast grassland resources in the arid and semi-arid region of Northwest China are not only important bases for animal husbandry, but also provide important means of production for the local people. The health status of the grassland resources has a profound influence on the sustainable development and ecological security of the region, and has important ecological benefits and economic values. Over the past two decades, the government has implemented a series of ecological projects, including the Grain for Green Program, Grassland Restoration Program, and Grassland Ecological Protection Subsidy and Incentive Program, which have initially curbed the continuous deterioration of grassland ecosystems[1]. However, with consideration of climate change, the grassland in the region is still facing severe degradation pressure due to infrastructure construction, expansion of agricultural land area, overgrazing, unreasonable utilization of groundwater resources, and the inherent fragility of the grassland ecosystem[2,3]. Therefore, it is necessary to strengthen the research on the construction of the evaluation system of grassland health and grassland degradation to evaluate the status of grassland degradation and protection. The current assessment metrics for grassland degradation lack uniformity, with varying comparison baselines and research scales, making it difficult to conduct cross-study comparisons of quantified degradation levels[4–6]. Therefore, it is practically significant to determine the objective and unified reference baseline for the grassland degradation assessment, and it is also crucial to formulate the overall plan of grassland resource protection and sustainable utilization.

In current research on quantifying grassland degradation, 3 reference baselines, i.e., natural, historical, and target, are predominantly employed[3,7–10]. The target baseline is greatly influenced by subjective factors, such as the specific standards set for fenced conservation areas or nature reserves, which are usually limited to a local scope and are difficult to compare cross-regionally. Although the historical baseline is relatively objective, the selection of reference years involves a degree of arbitrariness, and the results are susceptible to environmental fluctuations. Natural baseline has a certain theoretical basis, and the statistical method is rigorous, which can effectively separate the interference of human activities, so it has high objectivity. Climatic Production Potential (CPP) denotes the maximum net primary productivity (NPP) of vegetation, determined by environmental factors such as light, temperature, water, and nutrients in the absence of human interference[11,12]. It dynamically couples with climate change and aligns spatially with the evaluated region. This baseline combines dynamic adaptability and objectivity, making the maximum CPP over a period ideal for a natural reference baseline[4,6].

To quantify grassland degradation in arid and semi-arid regions of Northwest China, this study integrates regional remote-sensing and climate data and employs multiple classical empirical models for estimating CPP, including the Miami model[13], the Thornthwaite Memorial model[11], and a Composite model[14]. On this basis, a grassland degradation dataset was developed using CPP as the natural reference baseline. It is intended that this framework will address key challenges in existing grassland degradation assessments, such as inconsistent comparison baselines and limited cross-regional comparability of evaluation results, thereby providing robust data support for regional grassland degradation assessment and the sustainable management of grassland resources.

2 Metadata of the Dataset

The metadata of 500-m CPPmax dataset of arid and semi-arid region in Northwest China (2001–2023)[15], 500-m/annual GDI dataset in the arid and semi-arid region of Northwest China (2001–2023)[16], and 500-m raster and 5-year step dataset of classified grassland degradation in the arid and semi-arid region of Northwest China (2001–2023) [17] is summarized in Table 1. It includes the dataset's names, authors, geographical region, spatial-temporal resolution, dataset composition, data publisher, and data sharing policies, etc.

Table 1 Metadata summary of grassland productivity and degradation datasets in the arid and semi-arid region of Northwest China

Items	Description
Dataset full name	500-m CPPmax dataset of arid and semi-arid region in Northwest China (2001–2023)
Dataset short name	NW_CPPmax
Authors	Cai, D. W., Lingnan Normal University, caidw@lingnan.edu.cn Zhang, Y. Q., Lingnan Normal University, 1135862445@qq.com Luo, W. H., Lingnan Normal University, 798138577@qq.com Liang, J. H., Lingnan Normal University, liang.jiahong@foxmail.com Ai, Z. Y., Lingnan Normal University, 3252154181@qq.com Dong, Z. J., Lingnan Normal University, dzj3266851472@163.com Shang, Z. H., Lingnan Normal University, shangzhihai@126.com
Geographical region	Arid and semi-arid region in Northwest China
Year	2001–2023
Spatial resolution	500 m
Data format	.tif, .txt
Data size	16.4 MB (after compression)
Data files	The maximum value of the climatic production potential of the grassland in arid and semi-arid regions of Northwest China in 2001–2023
Dataset full name	500-m/annual GDI dataset in the arid and semi-arid region of Northwest China (2001–2023)
Dataset short name	NW_GDI
Authors	Cai, D. W., Lingnan Normal University, caidw@lingnan.edu.cn Zhang, Y. Q., Lingnan Normal University, 1135862445@qq.com Luo, W. H., Lingnan Normal University, 798138577@qq.com Liang, J. H., Lingnan Normal University, liang.jiahong@foxmail.com Ai, Z. Y., Lingnan Normal University, 3252154181@qq.com Dong, Z. J., Lingnan Normal University, dzj3266851472@163.com Shang, Z. H., Lingnan Normal University, shangzhihai@126.com
Geographical region	Arid and semi-arid region in Northwest China
Year	2001–2023
Temporal resolution	Year
Spatial resolution	500 m
Data format	.tif, .xlsx
Data size	228 MB (after compression)
Data files	Spatial data of annual grassland degradation degree during the 2001–2023; inter-annual variation data of regional average grassland degradation degree
Dataset full name	500-m raster and 5-year step dataset of classified grassland degradation in arid and semi-arid region of Northwest China (2001–2023)
Dataset short name	NW_Recls_GDI
Authors	Cai, D. W., Lingnan Normal University, caidw@lingnan.edu.cn Zhang, Y. Q., Lingnan Normal University, 1135862445@qq.com Luo, W. H., Lingnan Normal University, 798138577@qq.com Liang, J. H., Lingnan Normal University, liang.jiahong@foxmail.com Ai, Z. Y., Lingnan Normal University, 3252154181@qq.com Dong, Z. J., Lingnan Normal University, dzj3266851472@163.com Shang, Z. H., Lingnan Normal University, shangzhihai@126.com

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(*Continued*)

Items	Description
Geographical region	Arid and semi-arid region in Northwest China
Year	2001–2023
Temporal resolution	5-year
Spatial resolution	500 m
Data format	.tif, .txt
Data size	5.55 MB (after compression)
Data files	Classification results of the entire time period (2001–2023) and the average classification results of grassland degradation degree every 5 years (2001–2005, 2006–2010, 2011–2015, 2016–2020, and 2021–2023)
Foundation	National Natural Science Foundation of China (42301003); Lingnan Normal University (ZL22032)
Data computing environment	Python 3.12, ArcGIS 10.8
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11 A, 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 principle" 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[18]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC, OARL

3 Methods

3.1 Data Sources

The development of these datasets requires 3 kinds of data: remote sensing, climate, and basic geography.

The MODIS (Moderate-resolution Imaging Spectroradiometer) dataset[1], including the net primary productivity (NPP) dataset (MOD17A3HGF V6.1) and land cover dataset (MCD12Q1) with a spatial resolution of 500 m from 2001 to 2023, has been employed. The MOD17A3HGF dataset provides annual total estimates based on 8-day net photosynthetic productivity, calculated from light energy utilization and photosynthetically active radiation. The MCD12Q1 dataset provides 5 land cover/use classification systems. In this study, the University of Maryland (UMD) land cover classification scheme was adopted to identify grassland types, which is consistent with the classification system used for deriving NPP data in the MOD17A3 dataset[19]. To avoid the interference of land cover/use change on the analysis of grassland degradation and ensure the comparability of the results in different periods, only the stable grassland pixels (i.e., no land cover change) in the whole study period are selected for analysis.

The climate dataset utilized China's 1-km resolution monthly precipitation dataset[20] and monthly average temperature dataset[21], covering the period from 1901 to 2024. It was generated by applying the Delta downscaling algorithm to integrate the global 0.5° climate dataset released by the Climatic Research Unit (CRU) of the UK National Centre for Atmospheric Science and the global high-resolution climate dataset released by WorldClim.

[1] NASA. https://www.earthdata.nasa.gov.

The dataset was systematically validated using observational data from 496 meteorological stations in China, with credible results[22]. The solar radiation data are sourced from the ERA5-land dataset developed by the European Centre for Medium-Range Weather Forecasts (ECMWF)[23], containing hourly surface meteorological data from 1979 to the present, with a spatial resolution of 0.1°. This study extracted the data covering 2001–2023 for these datasets' development, and interpolated the spatial resolution of climate data, aligning with the MODIS dataset grid by using a bilinear algorithm.

Furthermore, the extent of the arid and semi-arid regions of Northwest China was vectorized from the regionalization map of physical geography depicted by ZHAO Songqiao[24] using ArcGIS software. The administrative boundary data of the study area were downloaded from the National Basic Geographic Information Center of the Ministry of Natural Resources[2] in the GeoJSON format. It was rigorously converted to the Shapefile format for analysis using projection tools, and the boundaries remained unaltered during the conversion process. Finally, the administrative boundaries were spatially overlaid with the physical geography regions to delineate the study area.

3.2 Algorithm

3.2.1 Estimation of Climatic Production Potential

Three empirical models, i.e., the Miami model, Thornthwaite Memorial model, and the Composite model had been used to estimate CPP during the development of these datasets. The Miami model estimates the CPP based on temperature and precipitation data, which was initially developed using global observational data; it has been widely adopted in large-scale and even global climate production potential studies[13]. The Thornthwaite Memorial model, while accounting for temperature and precipitation, further incorporates vegetation evapotranspiration to estimate CPP, integrating the effects of light, temperature, water, and heat on vegetation productivity[11]. The Composite model incorporates actual evapotranspiration closely linked to vegetation photosynthesis, synthesizes interactions among climate factors including temperature, precipitation, and solar radiation, and incorporates vegetation samples from arid/semi-arid grasslands and deserts, thereby achieving superior simulation performance for CPP in arid regions[14]. The calculated results of these models are all expressed as dry matter (DM). To ensure dimensional consistency with the MODIS dataset, the vegetation carbon content parameter was used for conversion. Furthermore, in accordance with Liebig's minimum factor law, the final grassland CPP value is determined by selecting the minimum among the 3 model estimates, as shown in Equation 1:

$$CPP = \min(Y_t, Y_p, Y_e, Y_r) \times C_f \quad (1)$$

where CPP represents climate production potential ($gC \cdot m^{-2} \cdot a^{-1}$); $\min(\cdot)$ indicates the minimum value; Y_t and Y_p are the climate productivity estimated by the Miami model based on annual mean temperature and annual precipitation ($gDM \cdot m^{-2} \cdot a^{-1}$), respectively; Y_e is the climate productivity estimated by the Thornthwaite Memorial model ($gDM \cdot m^{-2} \cdot a^{-1}$); Y_r is the climate productivity estimated by the Composite model ($gDM \cdot m^{-2} \cdot a^{-1}$); C_f represents the vegetation carbon content parameter ($gC \cdot gDM^{-1}$), and the carbon content in leaves of typical grassland vegetation in China is 0.402,0[25]. For detailed parameters of the estimation models,

[2] National Basic Geographic Information Center of the Ministry of Natural Resources. https://www.tianditu.gov.cn/.

refer to relevant literature[4,11–14,25].

3.2.2 Quantification of Grassland Degradation

In accordance with the Grading criteria for natural grassland degradation, desertification, and salinization (GB 19377—2003)[26], the degradation degree of grasslands is determined by the grass yield loss rate, which is quantified based on the difference between the actual NPP and the natural baseline, the higher grass yield loss rate, and the more severe degradation. The Equation is:

$$GDI_i = \left(1 - \frac{NPP_i - NPP_{min}}{CPP_{max} - NPP_{min}}\right) \times 100\% \underset{NPP_{\min} \to 0}{\rightarrow} GDI_i = \left(1 - \frac{NPP_i}{CPP_{max}}\right) \times 100\% \quad (2)$$

$$CPP_{max} = max\,(CPP_i) \qquad i = 1, 2, \cdots, n \quad (3)$$

where GDI_i represents the grassland degradation index (%) in the i^{th} year, with values ranging from [0%, 100%], where higher values indicate more severe degradation. NPP_i denotes the actual NPP in the region for the i^{th} year ($gC \cdot m^{-2} \cdot a^{-1}$). CPP_{max} is the maximum CPP value ($gC \cdot m^{-2} \cdot a^{-1}$) in the region, serving as the natural baseline, calculated as the maximum CPP value for each year within the n-year period using Equation 3. $NPP_{\min}$ is the ultimate degradation NPP value ($gC \cdot m^{-2} \cdot a^{-1}$) adapted to the climatic zone, acting as the ultimate baseline. In arid and semi-arid areas, grasslands may degrade to a complete loss of productivity, so $NPP_{\min}$ can be assumed as 0. Therefore, based on the results from Equation 2 and national standards, the grassland degradation degree is classified according to the *GDI* value range: 0% to 10% indicates undegraded, 10% to 20% indicates slightly degraded, 20% to 50% indicates moderately degraded, and 50% to 100% indicates severely degraded.

In summary, the development process of these datasets is illustrated in Figure 1.

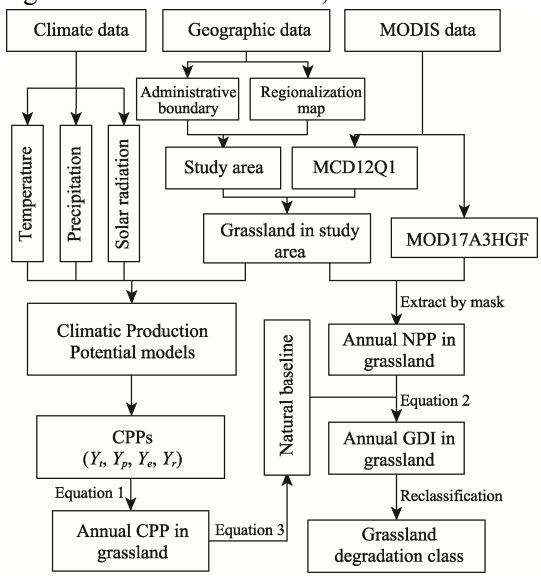


Figure 1 Flowchart of the dataset development

4 Data Results

4.1 Dataset Composition

These datasets consist of the 500-m CPP_{max} dataset of arid and semi-arid region in Northwest China (2001–2023), 500-m/annual GDI dataset in the arid and semi-arid region of Northwest China (2001–2023), and 500-m raster and 5-year step dataset of classified grassland degradation in the arid and semi-arid region of Northwest China (2001–2023). The classification dataset is the result of categorizing multi-year average GDI values, with the classification based on the provisions regarding the rate of grass yield loss in GB 19377—2003 to classify grassland degradation levels[26]. The spatial resolution of the

datasets is 500 m.

4.2 Data Results Analysis

4.2.1 Spatial Distribution of Grassland Natural Baseline

From a spatial distribution perspective (Figure 2), the natural baseline values of grassland productivity in the arid and semi-arid regions of Northwest China during 2001–2023 showed significant spatial differentiation, exhibiting a basic pattern of higher productivity on both eastern and western sides and lower productivity in the middle, with distinct latitudinal zonality. The regional natural baseline values of grassland productivity ranged between 0–363.5 $gC \cdot m^{-2} \cdot a^{-1}$, with high-value areas (>200 $gC \cdot m^{-2} \cdot a^{-1}$) appearing in the eastern part of the study area, specifically in the northeastern part of Hulunbuir City, the central part of Xing'an League and Chifeng City, and the southern part of Xilingol League, showing a belt-like distribution from northeast to southwest. Additionally, the natural baseline values were relatively high in the mountainous grasslands of the western Karamay and Tacheng regions in northern Xinjiang. Low-value areas (<50 $gC \cdot m^{-2} \cdot a^{-1}$) were found in the southern fringe of the Tarim Basin, with a more scattered distribution. This distribution pattern of grassland productivity natural baselines is primarily influenced by moisture distribution conditions, with relatively better moisture conditions on both eastern and western sides due to summer monsoon precipitation and westerly precipitation, respectively. Moisture decreases from the eastern and western sides toward the middle, resulting in a corresponding gradient in grassland productivity.

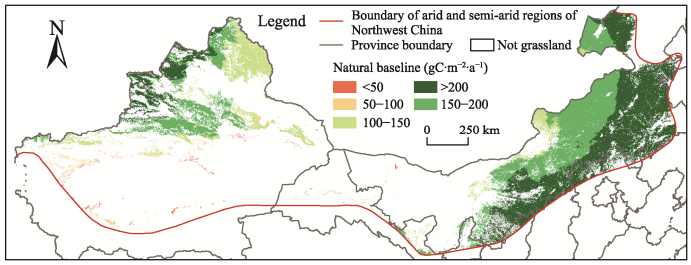


Figure 2 Spatial distribution map of natural baseline values for grassland (2001–2023)

4.2.2 Spatial-Temporal Characteristics of Grassland Degradation

Statistical analysis of the spatial distribution of degraded grasslands (Figure 3a, Table 2) indicates that during 2001–2023, undegraded grasslands dominated the region (54.4%), primarily distributed across the Hulunbuir and Xilingol plateaus in the east, and mountainous grasslands in western Xinjiang. Degraded grasslands covered 373,000 km^2 (45.6% of total area), with moderately degraded (28.7%) concentrated around the Horqin Sandy Land and from the Ordos to Ulanqab Plateaus. Severely degraded grassland accounted for only 5.8%, mainly in the western Junggar Basin. A slightly degraded grassland (11.1%) was found in the transitional zones between moderately degraded and undegraded areas.

Changes in degraded grassland areas (Table 2) reveal an overall improvement in regional grassland degradation. During 2001–2010, grassland degradation was particularly severe, with over 50% of grassland areas experiencing moderate to severe degradation. The area of degraded grassland slightly increased during this period. Spatial distribution patterns in eastern regions showed a progression from central to eastern and lateral areas, with light, moderate, and severe degradation occurring sequentially (Figure 3b, c). The western basin edges exhibited more severe degradation, while mountainous areas showed milder degradation. After 2011, the proportion of undegraded grassland increased significantly, with a single-stage maximum rise of nearly 14%. The area of undegraded grassland reached its

peak between 2016 and 2020 at 526,000 km^2. Both the area and severity of degraded grassland decreased substantially (Figure 3d–f), with proportions of light and moderate degradation declining. The area of slightly degraded grassland in 2021–2023 reached the lowest level in the last 23 years. Border zones between different grassland degradation levels became primary areas for grade transitions. In regions east of the Helan Mountains, grassland degradation gradually improved after 2001, with reduced degraded areas and enhanced vegetation, due to widespread implementation of ecological programs like grazing exclusion, rotational grazing, and desertification control. However, after 2021, the proportion of severely degraded grassland increased, and the western regions experienced a sharp deterioration, primarily due to the transition from moderate to severe degradation (Figure 3f).

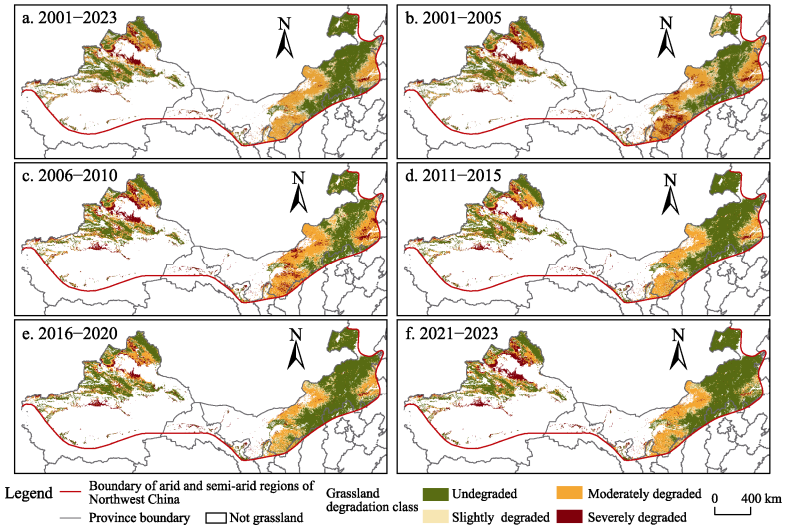


Figure 3 Spatial distribution maps of grassland degradation degree in different periods

Table 2 Statistics of grassland degradation area and its proportion in different periods

Periods	Undegraded		Slightly degraded		Moderately degraded		Severely degraded	
	Area (10^4 km^2)	Percent (%)	Area (10^4 km^2)	Percent (%)	Area (10^4 km^2)	Percent (%)	Area (10^4 km^2)	Percent (%)
2001–2023	44.5	54.4	9.1	11.1	23.5	28.7	4.7	5.8
2001–2005	37.4	45.7	9.7	11.9	26.4	32.3	8.2	10.1
2006–2010	37.6	46.1	9.3	11.4	27.3	33.5	7.4	9.1
2011–2015	49.1	60.1	7.6	9.3	20.6	25.2	4.3	5.3
2016–2020	52.6	64.4	8.7	10.7	16.9	20.7	3.4	4.2
2021–2023	51.8	63.3	6.7	8.3	17.6	21.6	5.6	6.8

The annual average GDI trend (Figure 4) shows the highest value in 2001, followed by a consistent downward trend with a rate of –0.514% per year (P<0.01), indicating sustained improvement in grassland productivity and overall ecological recovery in the study area. Between 2001 and 2010, the grassland degradation index experienced a significant decline. From 2011 to 2020, it showed a weak, fluctuating downward trend, but after 2020, the GDI began to rise again.

4.3 Dataset Validation

In 2012, the monitoring data from the Xinjiang Survey Team of the National Bureau of Statistics revealed that 85% of natural grasslands in Xinjiang have experienced varying degrees of degradation, with severely degraded areas accounting for approximately 40%[27], which closely matches the 36.5% of severely degraded area recorded in 2007–2012 in these datasets, demonstrating that the quantified grassland degradation degree derived from the dataset's methodology closely aligns with actual conditions.

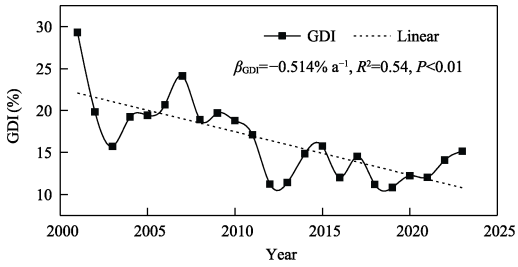


Figure 4 Interannual variation of grassland degradation index (GDI) in arid and semi-arid regions of Northwest China

5 Conclusion

Addressing the severe grassland degradation in the arid and semi-arid regions of Northwest China, the authors utilize remote sensing and meteorological data to establish a quantitative evaluation framework based on Climate Productive Potential (CPP) as a natural baseline. Covering the period from 2001 to 2023. The dataset comprises regional productivity baselines, annual quantitative degradation degrees, and long-term degradation classifications. By adopting a natural baseline as an objective reference, this approach offers distinct advantages in scientific rigor, dynamism, and comparability, effectively resolving long- standing issues such as inconsistent evaluation standards and the lack of interoperability between cross-studies. While this methodology provides a novel reference for grassland assessment and supports national ecological civilization and global climate adaptation strategies, its fundamental departure from traditional monitoring techniques necessitates long-term observational validation. However, direct comparisons with existing research remain a challenge; thus, subsequent research efforts should focus on addressing this critical issue.

Author Contributions

Cai, D. W. and Shang, Z. H. conducted the overall design of the dataset development. Cai, D. W. and Zhang, Y. Q. collected and processed the relevant data. Liang, J. H. and Dong, Z. J. developed the models and algorithms. Ai, Z. Y. and Luo, W. H. verified the data. Cai, D. W., Zhang, Y. Q. and Luo, W. H. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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