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Review of the Impact of Grassland Degradation on Ecosystem Service Value

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Abstract

In recent years, grassland degradation has become one of China's most critical environmental problems due to the interaction of natural environmental factors and human causes. Based on the systematic analysis of the spatial characteristics of grassland degradation and the current research status of environmental drivers, this paper summarizes and summarizes the research methods on the impact of grassland degradation on natural ecological service function and social and economic value to understand further the natural ecological service function of grassland degradation and its impact on social and economic benefits. The results show that since the function of grassland ecosystem service is much larger than the biomass value it provides, we should focus on the effective management of grassland from the design concept of ecological service function to achieve the sustainable development of grassland. We should do an excellent job in the comprehensive application of various ecosystems and service value evaluation methods in the future.

Keywords

Grassland Degradation, Remote Sensing Monitoring, Ecological Problems, Eco-Service Functions

1. Introduction

Vegetation, as an essential component of the earth's ecosystem, is also an essential component of surface coverage [1]. Vegetation plays a vital role in the biosphere, atmosphere and global carbon cycle, as well as in linking natural elements such as soil, water and energy [2]. Grassland vegetation is also the most significant renewable resource in the global terrestrial ecosystem [3], with essential ecological functions and economic values [4].

From an ecological point of view, grassland vegetation plays a vital role in cultivating soil fertility, preventing soil erosion and maintaining the ecological balance of the land. Economically, grassland vegetation can also feed herbivores and produce food, medicines and industrial raw materials for humans [1].

However, grassland habitats are not stable and are prone to degradation due to environmental disturbances [5]. Grassland degradation refers to the process of grassland productivity decline and environmental degradation due to unscientific management and unfavorable ecological and geographic conditions [6]. They are characterized by degradation of grasslands, including plants and soils, reduced yield and economic potential, reduced service functions, environmental degradation, reduced biodiversity or complexity, and reduced or even lost restoration functions [7].

In the traditional research on monitoring grassland degradation based on remote sensing, only the essential factors affecting grassland degradation were focused on. With the continuous development of remote sensing technology and the deepening of scholars' research on the whole aspects of grassland degradation, we began to explore the critical effects of grassland degradation on the economic aspects of ecological services and provide strong technical support for the prevention and management of grassland degradation.

However, such studies are fragmented and lack systematic organization and summary. Therefore, this paper further reviews the current research progress of grassland degradation from the aspects of the impact of grassland degradation on the economy of ecosystem services and shows the direction for future remote sensing monitoring of grassland degradation by analysis and summary.

In order to further elaborate on the related contents, readers can have a more comprehensive understanding of its research area. The article is divided into three parts: Part 1, the current status of grassland degradation, which mainly outlines the entry points and progress of most scholars' research on grassland degradation in two aspects: the influencing factors of grassland degradation and the socio-economic impacts on ecological service functions; Part 2, the research on the impacts of grassland degradation on grassland ecosystem service functions; and Part 3, the conclusion of the review.

2. Current Status of Research on the Impact of Grassland Degradation on the Economic Value of Natural Ecological Service Functions

Regarding the degradation of grasslands, scholars in China and abroad have conducted a large number of studies. In the study of the drivers of grassland degradation formation, domestic and international studies have shown that Kithsir Pereral *et al.* [8] combined MODIS NDVI data and Australian grassland climate data and found that NDVI can accurately reflect the relationship between grassland vegetation growth and extreme precipitation response in time and space. Ayako *et al.* [9] established the MODIS leaf area index as a function of field-measured sample plot data and found a high correlation between lightly grazed area and leaf area index (LAI). Dai Rui [10] selected grassland vegetation cover as the remote sensing monitoring index of grassland degradation and analyzed the spatial and temporal variation characteristics of grassland degradation in recent ten years, which provided an important reference basis for remote sensing monitoring of degraded, sandy and saline grassland in Tibet Autonomous Region. Wan Huawei [11] and Zhao Rubing [12] combined long time series remote sensing image data to analyze the driving forces of grassland change from various aspects such as land use, meteorological conditions, and human activities using geostatistical analysis methods such as geographic correlation analysis. Li Chongyang [13] synthesized the degradation grade of pastureland of pastoral households on the Qinghai-Tibet Plateau, the changing trend of each element and the main driving forces leading to the change of pastureland analysis determined that the degradation of pastureland of pastoral households in the study area was mainly mild since the 21st century, The change of pastureland vegetation cover was the result of the interaction of natural and socio-economic factors. Tian Jie [14] and others quantitatively assessed the relative roles of climate change and human activities on grassland changes, which is essential for exploring the mechanisms of grassland degradation and controlling grassland degradation.

Among the influencing factors of grassland degradation studied by most scholars above, climate and human factors are essential drivers of grassland degradation. Although there have been considerable achievements in the prevention and management of grassland degradation based on this type of research in recent years, human is the sum of all social relationships. Among the human factors of grassland degradation, economic interests drive human-related activities. Therefore, studying the impact of grassland degradation on the socio-economic value of natural ecological services can dig deeper to get sustainable development, the future development way of harmonious coexistence between human and natural environment.

Among the studies on the socio-economic impact of grassland degradation on ecosystem service functions, Camille *et al.* [15] showed in a remote sensing study of grassland that grassland resources play a pivotal role in developing the livestock economy. Xu Yao [16] conducted remote sensing monitoring of the degradation of grassland resources in Shenzha County and assessed and measured the loss of service function value in eight aspects of grassland ecosystems using an ecological economics assessment model. Lei Shengjian *et al.* [17] analyzed the differences in the loss of economic and ecological values due to grassland degradation based on remote sensing applications. By analyzing the grassland ecosystem in Hebei Province, Liu Zhiguo *et al.* [18] selected nine service functions as evaluation indexes and applied the ecological economics method to assess the value of grassland ecosystem services in 11 municipalities in Hebei Province. Han Peng *et al.* [19] quantified grassland ecosystem services such as grass production, soil conservation, water retention, and carbon storage using the remote sensing estimation model, RUSLE model, and InVEST model, analyzed the relationship between different ecosystem services, and explored the impact of grassland degradation status and dynamics on ecosystem services. In order to improve people's understanding of the indirect value of the service functions of the grassland ecosystem in the Liaohe River Reserve, Chen Ying *et al.* [20] used the shadow engineering method, the market value method and the opportunity cost method to evaluate the indirect value of the service functions of the grassland ecosystem in the Liaohe River Reserve, such as water conservation, air purification, carbon sequestration and oxygen release, nutrient cycling and storage, and soil conservation, for three consecutive years.

In summary, studying the driving forces of grassland degradation is an essential process for preventing and controlling grassland degradation. Studying the impact of grassland resources on the grassland ecosystem's service value and social economy is also of great guiding significance for preventing and controlling grassland degradation projects. However, most scholars have studied the impact of environmental and human factors on grassland degradation. In contrast, few have studied and summarized the critical impact of grassland resources on the value of grassland ecosystem services.

3. Effect of Grassland Degradation on the Socio-Economic Value of Grassland Ecosystem Services

A grassland ecosystem is a special ecosystem with both production and ecological functions. With the development of the social economy and the transitional development and utilization of grassland resources, the regional ecological problems have become increasingly prominent [21]. Based on evaluating the value of the grassland ecosystem service function, this paper further explores the critical impact of grassland degradation on the grassland ecosystem service function. It is essential to effectively bring the economic benefits of grassland resources into play, make scientific and rational decisions on regional ecological protection and economic development, and protect and restore the effective utilization of grassland resources [13]. This chapter mainly summarizes the value assessment methods of grassland ecosystem services used by most scholars. It uses them to study the impact of grassland degradation on its grassland ecosystem services.

3.1. Importance and Classification of Grassland Ecosystem Service Function

1) Importance of grassland ecosystem function

Ouyang Zhiyun combines ecology and economics and summarizes the connotation of ecosystem service function in many studies: ecosystem service function is the natural environmental conditions and utility for human survival formed and maintained by the ecosystem and its ecological process [22]. A grassland ecosystem is a complex ecosystem that integrates production life ecology. Its ecological services play an essential role in ensuring food security, maintaining herders' life and regulating ecological balance [23]. In 2001, Xie Gaodi *et* *al.* [24] evaluated the service value of natural grassland ecosystem in China and concluded that the service value of grassland ecosystem in China was 1497.9 per year × $108, which is 12.8 times of the service function of forest ecosystem, indicating the important role of China's natural grassland ecosystem in regional life support system.

2) Functional classification of terrestrial ecosystem

a) Classification by value

According to the research results of many scholars, it is concluded that [25] [26] [27], according to the value classification, there are three kinds of values respectively. The first kind of direct value is the commercialized function of providing human beings with meat, milk, skin, medicinal materials and other direct utilization; The second kind of indirect value is to support and maintain the environment on which human beings depend, such as soil and water conservation, climate regulation, nutrient circulation and other functions that are difficult to commercialize; The third category is selection value, future use or non-use value, such as biodiversity; The fourth category is existential value, which continues to exist, such as biological habitat, endangered species, etc.

b) Classified by its function

Grassland ecosystem service functions can be divided into four categories: product function, regulation function, cultural function and support function [22], as shown in **Table 1** [23].

3.2. Value Assessment Methods and Applications of Ecosystem Services

Ecosystem services is a large research area, which includes many classifications, such as the national assessment of grassland ecosystem services [25] [28], the regional assessment of grassland ecosystem services [29] [30], the spatial and temporal changes of the value of ecosystem services in recent decades, and the impact and mechanism of grassland degradation [5] [13] [27] [31]. However, within the scope of this study, we only need to discuss the impact of grassland degradation on grassland ecosystem services, that is, the impact of grassland degradation and its mechanism.

Reading through numerous literature has concluded that there are three main types of methods for assessing the functional value of grassland ecosystem services: the method of quantitative factor [24] [29] [32] [33], the method of functional value [13] [26] [27] [34] [35] and the method of model calculation [36] [37].

1) Measurement factor method

Based on the classification methods of the Millennium Eco-Assessment Classification System and Costanza *et al.*, this paper uses the table of equivalent factors of the value of ecological services per unit area of Xie Gao Di Study, which is called the equivalent factor method for short. It classifies the functions of ecosystem services, constructs the value equivalents of various service functions of

Table 1. Evaluation index system of grassland ecosystem service function.

Service type	Functional indicators	Evaluation content
Provide product functions	livestock products	Provide meat, milk, wool, leather and other animal husbandry products
	plant resources	Provide product value of primary edible plant resources and medicinal plant resources
Regulation function	Climate regulation	The functional value of grassland ecosystem in temperature, humidity and wind regulation
	Soil C accumulation	Impact of soil organic carbon accumulation on global climate and its eco-economic value
	Water resources regulation	Ecological benefits of water conservation function of grassland ecosystem
	Erosion control	Ecological benefits of preventing soil wind erosion and hydraulic erosion
	Air quality control	Role and value of purifying air pollutants and improving environmental quality
	Waste degradation	The ecological and economic value of livestock manure degradation, removal and nutrient return
	Nutrient cycle	Circulation of main nutrient elements and their ecological benefits
Cultural function	Ethnic and cultural diversity	Cultural diversity and its educational and aesthetic knowledge system and value
	Leisure tourism	Ecotourism benefits with grassland ecosystem as the theme
Support function	Sand fixation, soil improvement and fertility enhancement	Ecological functions and value of fixed sandy land, soil formation and soil improvement
	Habitat provision	The ecological and economic value of maintaining biodiversity function

different types of ecosystems according to quantifiable standards, and evaluates them in combination with the area of distribution of ecosystems [24] [32].

Xie Gaodi [38] *et al.* constructed a dynamic assessment method of terrestrial ecosystem service value in China based on the unit area value equivalent factor method. They realized the dynamic and comprehensive assessment on time (monthly scale) and space (provincial scale) of 14 ecosystem types and 11 types of ecosystem service function value in China. Based on the table of ecosystem service equivalents, Wang Liqun [39] and others discussed the landscape pattern and ecosystem service value changes of Niulanshan-Mapo town on the edge of Beijing from 1992 to 2015. The correlation between the landscape index and ecosystem service value was analyzed. The main functions of the grassland ecosystem in Xinjiang were investigated by using equivalent factors such as Yemao [40]. The ecological values of different service functions and types of grassland ecosystems in Xinjiang were mainly estimated.

Mulinsong [29] and other research based on the unit area ecosystem service value equivalent factor estimation method used the biomass estimated from 1982-2014 remote sensing data and annual precipitation data of spatial interpolation to adjust the unit area ecosystem service value equivalent factors of four categories and 11 subcategories and then estimated the service value and its spatial distribution characteristics of temperate grassland ecosystem in Inner Mongolia Autonomous Region. From 1982 to 2014, the results showed that 33 years: 1) The average value of total ecosystem services per unit area of temperate grassland in Inner Mongolia Autonomous Region was 29780.3 yuan/hm^2. Among them, the total ecosystem service value per unit area of desert grassland, typical grassland and meadow grassland were 2097.71 yuan/hm^2, 27110.7 yuan/hm^2 and 126,620 yuan/hm^2, respectively. 2) The service value of the temperate grassland ecosystem in the Inner Mongolia Autonomous Region is 1.6 trillion Yuan/year, among which the adjusted service value (1.07 trillion Yuan/year) > the support service value (0.31 trillion Yuan/year) > the supply service value (0.11 trillion Yuan/year) > the cultural service value (0.11 trillion Yuan/year). 3) Overall, the service value of the temperate grassland ecosystem in the Inner Mongolia Autonomous Region shows a gradually decreasing spatial distribution from northeast to southwest. The service value of grassland ecosystem (0.82 trillion yuan/year) > typical grassland (0.77 trillion yuan/year) > desert grassland (0.02 trillion yuan/year). Grassland ecological services are of great value and play an active role in constructing ecological civilization, which provides more reliable data support for formulating a reasonable path for the construction of regional ecological civilization.

2) Functional Value Method

Eco-economic methods are used to estimate the value of ecosystem services, referred to as functional value methods. The methods of ecological value assessment can be roughly classified into three categories: 1) Direct market methods, including market value method, cost expenditure method, asset value method and human capital method. 2) Alternative market methods, including alternative cost method, shadow engineering method, opportunity cost method and travel cost method; 3) Simulated Market Method (Conditional Value Method).

The main evaluation methods of grassland ecosystem service value include the market value method, opportunity cost method, production cost method, water balance method, shadow engineering method, alternative price method, etc. These methods in grassland ecosystems are illustrated in **Table 2** [21].

Table 2. Comparison of assessment methods for grassland ecosystem service function.

Service Function Type	Evaluation Index Factor	Evaluation methods	Advantage	shortcoming
Supply function	Animal husbandry plant resources	Market Value Method	Assessment is impressive and credible	The results are one-sided, and the data must be sufficient and comprehensive.
Adjustment function	Climate Regulation	Production Cost Method	Estimation from the production side is intuitive and accurate	Require adequate data to consider the causal effects of ecosystem services and products
	Soil C Accumulation	Carbon Tax, Opportunity Cost	Assessment is impressive and credible	Resources must be scarce
	Regulating the atmosphere	Forestry Cost, Carbon Tax, Industrial Oxygen Production	The loss of resource value is the investment cost of substitution projects	Large space-time differences
	Conserving water sources	Shadow Engineering, Water Balance	Represent difficult-to-estimate ecological values as alternative projects	Large space-time differences
	Erosion Control	Opportunity Cost Method	Assessment is impressive and credible	Resources must be scarce
	Soil consolidation and fertility preservation	Shadow Engineering, Market Value	Assessment is objective and reliable	Many of the functions of ecosystems cannot be replaced by technology.
	Nutrient Cycle Waste Degradation	Alternative Price Method	Comparing and Analyzing the Ecological Environment Value from the Side	Strong Subjectivity
Support Functions	Bio-diversity	Conditional Value Method, Opportunity Cost Method	Value assessment for commodities exchanged in the absence of actual and alternative markets.	Intense subjectivity, significant deviation and regional differences Cultural Functions
Cultural Functions	Travel	Expense Act, Travel Expense Act	Rough quantification of ecological environment value	Only calculating the total amount of money spent on expenses does not really reflect the actual recreational value.

Liu Lulu [35] *et al.* used the model simulation variable control method to determine the contribution rate of ecological engineering and climatic factors to the ecological effect. They conducted a cost-benefit analysis of the three rivers' source's ecological protection and construction projects. Min Qingwen [41] *et al.* estimated the economic value of its main service functions by market value method and alternative market method, respectively, based on organic matter production in typical grassland ecosystems in Inner Mongolia. Zhao Haizhen [34] and other methods used the market value method, alternative engineering method, and shadow price method to calculate the service functions of mountain shrub grassland ecosystem such as product production, fixed CO_2, and the release of O_2, water conservation, and maintenance of nutrient cycle. Through the analysis of the grassland ecosystem in Maqu County, Wang Jing [42] *et al.* established the evaluation index system of the impact of overgrazing on the value of grassland ecosystem services. They made a preliminary estimation of the economic losses caused by overgrazing using ecological economics.

Xu Yao *et al.* [16] used the eco-economic evaluation model to estimate the loss of service function value in eight aspects of the grassland ecosystem in Shenza County. The results showed that the grassland degradation area in Shenza County increased by 47.40 from 1990 to 2010. $\times 10^4$ hm^2, loss of ecosystem service function value as high as 5.20×10^8 yuan; In 1990-2000, grassland degradation was more serious, which was also when the value of ecosystem service function was more lost. The trend of grassland degradation slowed down from 2000 to 2010. The value of biomass provided by grasslands in northern Tibet only accounts for 7.0% of the total value of ecosystem services. The function of grassland ecological services is much larger than the value of biomass provided by grasslands. Therefore, grasslands must be managed from the concept of ecosystem services to achieve the sustainable development of grasslands.

3) Model calculation method

With the development of remote sensing technology, some model calculations are gradually used, referred to as the model calculation method. Ecosystem assessment models based on GIS technology and remote sensing data, such as InVEST model, ARIES, MIMES, etc. [36], especially InVEST model, have the advantages of dynamic, spatial, multi-level, multi-module, and can well assess and analyze complex ecosystem service functions [37]. Most scholars focus on applying In VEST model in ecological engineering, grassland water and soil conservation, carbon storage, biodiversity, water conservation, and soil and fertility conservation. In order to achieve the dynamic spatial assessment, some scholars used remote sensing images and models to assess grassland ecosystem service functions, which made up for the shortcomings of "point with the area," and realized the spatialization and dynamic assessment of grassland ecosystem service functions [43] [44].

The dynamic process of grassland ecosystem service function in the study area of the Qinghai-Tibet Plateau was effectively analyzed and evaluated by Yuge [45] *et al.* with the growing season as the time unit. Based on the water conservation function evaluation module of In VEST, Bao Yubin [46] *et al.* took the Loess Plateau in northern Shaanxi as the study area to quantitatively evaluate the impact of land use/cover change on Water Conservation in the study area under the background of the project of returning farmland to forest and grassland.

Han Peng *et al.* [27] quantified grassland ecosystem services such as grassland yield, soil conservation, water conservation, carbon storage, etc., by using the remote sensing yield estimation model, RUSLE model, InVEST model, etc. The relationship between different ecosystem services was analyzed, and the impact of grassland degradation status and dynamics on ecosystem services was discussed. The results showed that: 1) Grass yield, soil conservation, water conservation and carbon storage of pastoral grasslands in 2000 were all low, showing a decreasing trend from southeast to northwest. As of 2017, grassland yield, soil conservation, water conservation and carbon storage of pastoral grasslands in central and Midwest Xilinhot increased significantly, while ecosystem services described above in some pastoral grasslands in southern and Northern Xilinhot declined. 2) Grass yield, soil conservation, water conservation and carbon storage of pastoral grasslands in 2017 showed a synergistic relationship. Dynamically, there was a trade-off between carbon storage and soil conservation in 2000 and a synergistic relationship in 2017. The relationship between grass yield and soil conservation changed from an insignificant synergy in 2000 to a significant one in 2017 ($p < 0.01$). The relationship between other ecosystem services was also significantly synergistic in 2000 ($p < 0.01$) and did not change in 2017. 3) Correlation analysis showed that between 2000 and 2017, the change in grassland degradation index (GDI) had a negative correlation with the increment of ecosystem services such as grassland yield, soil conservation, water conservation and carbon storage, indicating that the grassland recovery/degradation process had an important impact on grassland ecosystem services.

3.3. Problems and Future Development in Value Assessment of Ecosystem Services

Among the above methods for assessing the value of ecosystem services, each has its own shortcomings:

1) Equivalent factor method

The equivalent factor method is based on the unit area value of ecosystem services. It has less data and is more intuitive and easy to use. It is suitable for assessing the value of ecosystem services at regional and global scales [47]. Because of the heterogeneity of ecosystems, specific ecosystem service value indicators are not sufficient to measure the actual value of ecosystem services in different regions [48]. Therefore, this method is not dynamic enough and it is difficult to express and analyze spatially.

2) Functional Value Method

This method has many input parameters, no uniform parameter standard and a complicated calculation process. Moreover, most of the ecosystem services have no market transaction price to refer to, and the estimated results deviate from the true value of the ecosystem services, which has a greater subjectivity [38].

3) Model calculation method

The model calculation can provide more information on the causes and influencing factors of changes in ecosystem services, and visually reflect the specific situation of the study area to promote people's understanding of changes in ecosystem services. However, the model calculation is mostly a large-scale ecological calculation service, such as the law of ecosystem evolution and change trend, which is not suitable for deeper mechanism research.

Moreover, due to the different spatial heterogeneity of grassland in different study areas, the economic development level of the study area is also very different, so the ecological functions of different study area grassland types are quite different [21]. These different grassland types are described quantitatively and uniformly, and the results of the study are bound to be erroneous. At present, the main trend of evaluation development is large-scale analysis, which does not have a deep understanding of the underlying mechanism. Therefore, in the future research process, we should do more in-depth research on the basis of current trend analysis. For specific study areas, we can further analyze the development of the grassland ecosystem by focusing on the process of grassland degradation and analyzing the particularity of grassland resource utilization.

At the same time, the existing assessment framework and system select roughly the same type of service function as the forest ecosystem, lacking specificity [49]. Some studies have over-added the number of indicators, making their results less practical. A grassland ecosystem is a grass-livestock-human symbiosis complex ecosystem [21]. Therefore, in future studies, we need to fully understand the relationship between various ecological services, and use the evaluation needs, spatial scales and grassland types to determine the evaluation indicators of the study, so as to make the evaluation process more scientific and objective.

4. Conclusions

1) Evaluation Indicators

Because the evaluation index of grassland ecosystem service value is similar to that of other vegetation and lacks pertinence, in future studies, it is necessary to fully understand the relationship between various ecological services, and to use the evaluation needs, spatial scales and grassland types to determine the evaluation index of the study so as to make the evaluation process more scientific and objective.

2) Evaluation methods

In the study of the impact of grassland degradation on grassland ecosystem service function, the function value method is most widely used. From the perspective of eco-economics, it can directly reflect the extent of loss of grassland degradation on its ecological service value. However, this method requires more parameters, a complicated calculation process and strong subjectivity. Model computing, as opposed to functional value, is based on GIS technology and remote sensing data, which can well assess and analyze complex ecosystem service functions and visually reflect the specific situation of the study area in order to promote people's understanding of ecosystem service changes. However, the model calculation is mostly the law of ecosystem evolution, which is not suitable for deeper mechanism research. If the data is small and the global scale of grassland resource change is studied, the quantity factor method is better.

3) Impact of grassland degradation on ecological services

In this paper, the service value of the grassland ecosystem and the impact of grassland degradation on it are reviewed in three different assessment methods. The results show that the process of grassland recovery/degradation has an important impact on grassland ecosystem services. Moreover, the function value method can be used to assess the ecological service function of grassland, which is much larger than the biomass value it provides. Therefore, the concept of ecological service function must be used to manage grassland in order to achieve the sustainable development of grassland. At the same time, the comprehensive application research of different methods of ecosystem service value evaluation will be strengthened to form an efficient and scientific ecosystem service value evaluation system in the future.

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Conflicts of Interest

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