ISSN: 2688-8645

# Carbon Sink Effect of Plateau Grassland and Contribution of Carbon Cycle

Yuan Kuang

Shaanxi Dijian land comprehensive development Co., LTD, Xi'an 710075, China

## Abstract

**This paper reviews the research progress of plateau grassland carbon sink effect and its contribution and role to global carbon cycle. The paper also evaluates the size and change of plateau grassland carbon sink effect, and reveals its spatiotemporal distribution and dynamic characteristics. The paper discusses the relationship between plateau grassland carbon sink effect and global carbon cycle, and elucidates its role and significance in contributing to global carbon balance, mitigating global climate change, and protecting global biodiversity. The paper analyzes the positive and negative effects and interactions of climate change, human activities, grassland type and management on plateau grassland carbon sink effect, and proposes the influencing mechanism and mode of plateau grassland carbon sink effect. The paper points out the difficulties and shortcomings of the research on plateau grassland carbon sink effect, and puts forward some suggestions and prospects for future research. The paper aims to provide reference and inspiration for deepening the understanding of the internal mechanism and external influence of plateau grassland carbon sink effect, and for formulating effective grassland protection and management measures.**

## Keywords

**Plateau Grassland; Carbon Sink; Carbon Cycle; Climate.**

## 1. Introduction

Carbon cycle is one of the most important biogeochemical cycles in the Earth system, which determines the concentration and change of greenhouse gases in the atmosphere, and thus affects the trend and speed of global climate change[1]. The main components of the carbon cycle are carbon sources and sinks, carbon sources are the processes that release carbon dioxide ($CO_2$) to the atmosphere, and carbon sinks are the processes that absorb $CO_2$ from the atmosphere[2]. On a global scale, carbon sources mainly come from the combustion of fossil fuels and land use change, while carbon sinks mainly come from the absorption of terrestrial and marine ecosystems (Figure 1). Therefore, assessing and enhancing the capacity of carbon sinks is one of the important ways to mitigate global climate change[3].

Grassland is one of the most widely distributed terrestrial ecosystems in the world, accounting for 40% of the global land area, and storing 34% of the total carbon of the global terrestrial ecosystems[4]. Grassland carbon sink effect is the ability of grassland ecosystems to absorb and fix $CO_2$ from the atmosphere through processes such as plant photosynthesis and soil organic carbon storage. Grassland carbon sink effect has an important impact on the global carbon cycle and climate change, it can not only reduce the $CO_2$ concentration in the atmosphere, but also provide other ecosystem services, such as water conservation, soil conservation, biodiversity maintenance, etc. Therefore, studying the formation mechanism, influencing factors and evaluation methods of grassland carbon sink effect, is of great theoretical significance and practical value for understanding and predicting the response and feedback of grassland ecosystems to climate change, and for formulating reasonable grassland management and

ISSN: 2688-8645

protection measures. Alpine grassland carbon sink effect has a significant impact on global climate change. However, alpine grassland carbon sink effect also faces the dual threat of climate change and human activities, which may lead to the weakening or even reversal of its carbon sink effect, thus aggravating the deterioration of global climate change[5].

In recent years, domestic and foreign scholars have conducted a lot of research on alpine grassland carbon sink effect, mainly from the following aspects: (1) observing and simulating the net ecosystem carbon exchange of alpine grassland, evaluating the size and spatiotemporal variation of its carbon sink effect[6]; (2) analyzing the influencing factors of alpine grassland carbon sink effect, such as climate change, human activities, grassland type and management, etc., exploring their influence mechanism and degree[7]; (3) exploring the relationship between alpine grassland carbon sink effect and global carbon cycle, evaluating its contribution and role to global climate change, predicting its future change trend and potential impact[8]. These studies have provided valuable data and information for revealing the characteristics and laws of alpine grassland carbon sink effect, and for improving its potential and sustainability of carbon sink effect. This paper aims to review the research progress of alpine grassland carbon sink effect and its contribution and role to global carbon cycle, and to provide reference and inspiration for deepening the understanding of the internal mechanism and external influence of alpine grassland carbon sink effect, and for formulating effective grassland protection and management measures.

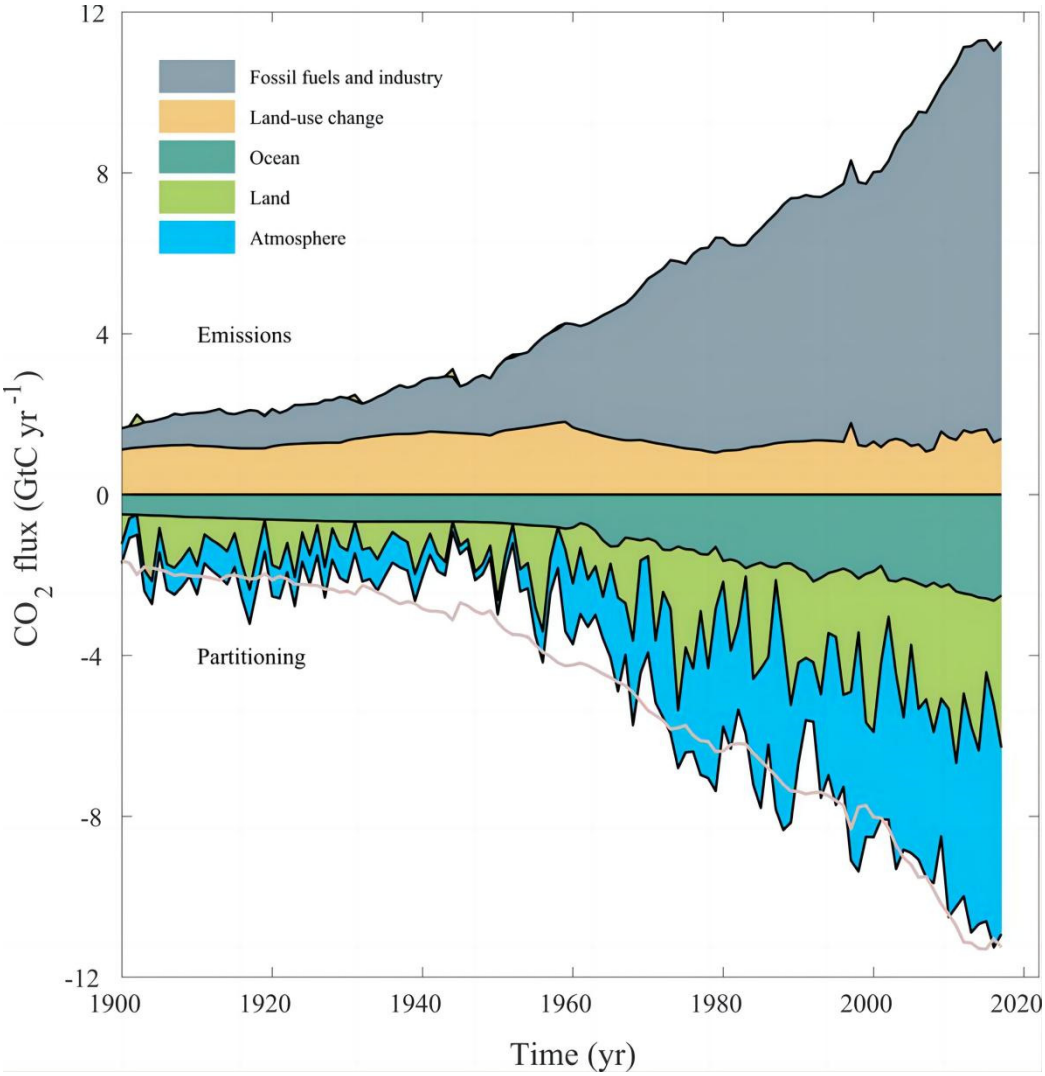


**Figure 1.** Combined components of the global carbon budget illustrated as a function of time[9]

ISSN: 2688-8645

## 2. Formation Mechanism of Alpine Grassland Carbon Sink Effect

The formation mechanism of alpine grassland carbon sink effect refers to the physical, chemical and biological processes that alpine grassland ecosystems absorb and fix $CO_2$ from the atmosphere through processes such as plant photosynthesis and soil organic carbon storage (Figure 2).

### 2.1. Plant Photosynthesis

Plant photosynthesis is the basis of alpine grassland carbon sink effect, which refers to the process that plants use light energy to convert $CO_2$ and water in the atmosphere into organic matter, while releasing oxygen. The intensity of plant photosynthesis depends on factors such as plant biomass, leaf area index, photosynthetic rate, photosynthetic efficiency, etc., which are affected by environmental factors such as climate, soil, nutrition, moisture, etc[10]. The characteristics of alpine grassland plant photosynthesis are that they have high photosynthetic rate and efficiency, as well as strong drought and cold tolerance, which enable alpine grassland to maintain high carbon fixation capacity under cold and dry conditions[11].

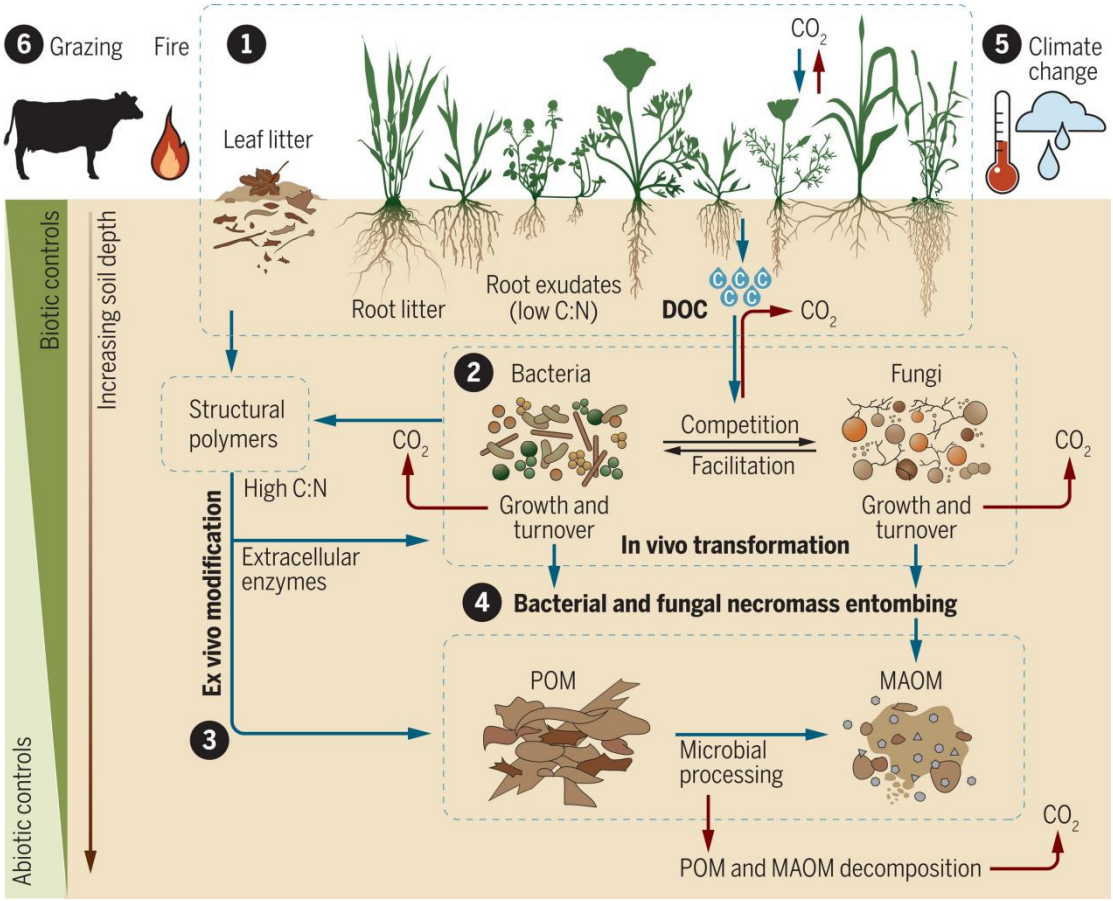


**Figure 2.** Conceptual framework for key factors and mechanisms controlling SOC sequestration in grassland ecosystems[10]

### 2.2. Soil Organic Carbon Storage

Soil organic carbon storage is an important component of alpine grassland carbon sink effect, which depends on the balance between soil organic carbon input and output. The input of soil organic carbon mainly comes from plant litter and root exudates, while the output of soil organic carbon mainly comes from soil microbial decomposition and respiration[12]. The characteristics of alpine grassland soil organic carbon storage are that they have high soil organic carbon content and density, as well as low soil organic carbon turnover rate and

ISSN: 2688-8645

decomposition rate, which enable alpine grassland to maintain high carbon storage capacity under low temperature and low moisture conditions.

### 2.3. Microbial Carbon Cycle

Microbial carbon cycle is the key link of alpine grassland carbon sink effect, which depends on factors such as microbial quantity, type, activity, function, etc., which are affected by environmental factors such as climate, soil, plant, nutrition, moisture, etc. The characteristics of alpine grassland microbial carbon cycle are that they have high microbial biomass and diversity, as well as strong microbial degradation and oxidation capacity, which enable alpine grassland to maintain high carbon transformation and flow capacity under cold and dry conditions.

## 3. Factors Affecting the Carbon Sink Effect of Alpine Grassland

The factors affecting the carbon sink effect of alpine grassland refer to the environmental factors that have an important role in the magnitude and variation of the carbon sink effect of alpine grassland, mainly including climate change, human activities, grassland type and management, etc.

### 3.1. Climate Change

Climate change is the most important natural factor affecting the carbon sink effect of alpine grassland, which mainly affects the formation mechanism of the carbon sink effect of alpine grassland through temperature, precipitation, light, wind speed and other meteorological elements. Temperature is the key factor affecting the carbon sink effect of alpine grassland, which directly affects the photosynthesis and respiration of plants, as well as the decomposition and respiration of soil microorganisms, thus affecting the input and output of carbon. Precipitation is another important factor affecting the carbon sink effect of alpine grassland, which mainly affects the water use efficiency of plants and the soil moisture content, thus affecting the growth of plants and the transformation of soil carbon. Light and wind speed also affect the carbon sink effect of alpine grassland, which mainly affect the photosynthetic efficiency and transpiration of plants, as well as the evaporation of soil. The impact of climate change on the carbon sink effect of alpine grassland is complex, which not only depends on the magnitude and direction of climate change, but also depends on the interaction and comprehensive effect of climate elements.

### 3.2. Human Activities

Land use change refers to the activities of human beings on alpine grassland, such as reclamation, planting, construction, etc., which cause the area, structure and function of alpine grassland to change, thus affecting the carbon sink effect of alpine grassland. Grazing management refers to the activities of human beings on alpine grassland, such as grazing, cutting, fertilizing, etc., which affect the vegetation composition, biomass and productivity of alpine grassland, thus affecting the carbon sink effect of alpine grassland. Grassland degradation refers to the decline of vegetation cover, species diversity and ecological function of alpine grassland due to natural or human factors, thus affecting the carbon sink effect of alpine grassland. The impact of human activities on the carbon sink effect of alpine grassland is bidirectional, which may increase or decrease the carbon sink effect of alpine grassland, depending on the type, intensity and duration of human activities.

### 3.3. Grassland Type and Management

Grassland type and management are another important factor affecting the carbon sink effect of alpine grassland, which mainly affect the carbon sink effect of alpine grassland by affecting the vegetation characteristics and soil properties of alpine grassland. Grassland type refers to

ISSN: 2688-8645

the vegetation type of alpine grassland, such as alpine meadow, alpine steppe, alpine sandy land, etc., different grassland types have different vegetation composition, biomass and productivity, thus affecting the carbon sink effect of alpine grassland. Grassland management refers to the artificial intervention measures on alpine grassland, such as enclosure, afforestation, irrigation, etc., different grassland management measures have different purposes and effects, thus affecting the carbon sink effect of alpine grassland. The impact of grassland type and management on the carbon sink effect of alpine grassland is diverse, which may increase or decrease the carbon sink effect of alpine grassland, depending on the choice and combination of grassland type and management measures.

## 4. Evaluation Indicators of Carbon Sink Effect of Alpine Grassland

The evaluation indicators of carbon sink effect of alpine grassland refer to the parameters or indices used to measure and reflect the magnitude and variation of carbon sink effect of alpine grassland, mainly including carbon storage, carbon flux and carbon balance, etc.

### 4.1. Carbon Storage

Carbon storage refers to the total amount of carbon stored in the alpine grassland ecosystem, mainly including vegetation carbon storage and soil carbon storage. Vegetation carbon storage includes aboveground and belowground carbon storage. Soil carbon storage includes organic carbon and inorganic carbon storage. Carbon storage is an important evaluation indicator of carbon sink effect of alpine grassland, which reflects the carbon storage capacity and carbon sink potential of alpine grassland ecosystem[13]. The measurement methods of carbon storage mainly include inventory method, remote sensing method and model method, etc.

### 4.2. Carbon Flux

Carbon flux refers to the rate of carbon exchange between alpine grassland ecosystem and atmosphere, mainly including net ecosystem carbon exchange (NEE), ecosystem respiration (RE) and net primary productivity (NPP), etc. NEE refers to the net $CO_2$ exchange between alpine grassland ecosystem and atmosphere, which is equal to the difference between plant photosynthesis (GPP) and RE. RE refers to the total amount of CO 2 released by alpine grassland ecosystem to the atmosphere, which includes plant respiration (RA) and soil respiration (RH) two parts. NPP refers to the net biomass increase of alpine grassland ecosystem, which is equal to the difference between GPP and RA. Carbon flux is another important evaluation indicator of carbon sink effect of alpine grassland, which reflects the carbon exchange dynamics and carbon balance status of alpine grassland ecosystem. The measurement methods of carbon flux mainly include eddy covariance method, ecosystem model method and carbon balance method, etc.

### 4.3. Carbon Balance

Carbon balance reflects the carbon income and expenditure of alpine grassland ecosystem. Carbon input mainly includes plant photosynthesis and exogenous carbon input, carbon output mainly includes plant respiration, soil respiration, litter decomposition, fire, erosion, harvest and emission, etc. Carbon balance is a comprehensive evaluation indicator of carbon sink effect of alpine grassland, which integrates the information of carbon storage and carbon flux, and reflects the degree and direction of carbon sink or source of alpine grassland ecosystem. The measurement methods of carbon balance mainly include carbon balance method, atmospheric inversion method and carbon isotope method, etc.

ISSN: 2688-8645

# 5. The Relationship between Plateau Grassland Carbon Sink Effect and Global Carbon Cycle

## 5.1. The Contribution of Carbon Sink Effect to Global Carbon Balance

Carbon balance reflects the stability and sensitivity of global carbon cycle. Carbon sink effect refers to the ability of ecosystems to absorb and fix CO 2 from the atmosphere, which is an important component of carbon input in global carbon cycle. Plateau grassland carbon sink effect refers to the ability of plateau grassland ecosystems to absorb and fix CO 2 from the atmosphere through processes such as plant photosynthesis and soil organic carbon storage, which is an important component of global terrestrial carbon sink. It is estimated that plateau grassland carbon sink effect can absorb and fix about 0.4 Pg C per year from the atmosphere, accounting for about 10% of global terrestrial carbon sink[14]. Plateau grassland carbon sink effect makes a significant contribution to global carbon balance, as it helps to reduce the concentration of CO 2 in the atmosphere, and maintain the stability and balance of global carbon cycle.

## 5.2. The Mitigation of Carbon Sink Effect on Global Climate Change

By reducing the concentration of CO 2 in the atmosphere, the carbon sink effect can lower the temperature rise in plateau areas, and alleviate the negative impacts of climate change in plateau areas. It is estimated that plateau grassland carbon sink effect can reduce the concentration of CO 2 in the atmosphere by about 0.2 ppm per year, equivalent to reducing the global temperature rise by about 0.01℃ . Plateau grassland carbon sink effect is effective in mitigating global climate change, as it helps to protect the ecological environment of plateau areas, and improve the climate adaptation capacity of plateau areas[15].

## 5.3. The Protection of Carbon Sink Effect on Global Biodiversity

By increasing the biomass and productivity of plateau grassland, the carbon sink effect can maintain the vegetation structure and function of plateau grassland, promote the evolution and adaptation of plants and animals in plateau grassland, and protect the genetic and species resources of plants and animals in plateau grassland. It is estimated that plateau grassland carbon sink effect can increase the biomass of plateau grassland by about 0.2 Pg C per year, equivalent to increasing the productivity of plateau grassland by about 10%[16]. Plateau grassland carbon sink effect is beneficial for the protection of global biodiversity, as it helps to maintain the ecological diversity and services of plateau grassland, and improve the ecological value and security of plateau grassland.

# 6. Research Prospects of Plateau Grassland Carbon Sink Effect

The research on plateau grassland carbon sink effect has achieved some important results, mainly including the following aspects:

(1)The concept and connotation of plateau grassland carbon sink effect have been defined, the formation mechanism and influencing factors of plateau grassland carbon sink effect have been clarified, and the evaluation indicators and measurement methods of plateau grassland carbon sink effect have been proposed.

(2)The size and change of plateau grassland carbon sink effect have been evaluated, the spatiotemporal distribution and dynamic characteristics of plateau grassland carbon sink effect have been revealed, and the regional and type differences of plateau grassland carbon sink effect have been analyzed.

(3)The relationship between plateau grassland carbon sink effect and global carbon cycle has been discussed, and the role and significance of plateau grassland carbon sink effect in

ISSN: 2688-8645

contributing to global carbon balance, mitigating global climate change, and protecting global biodiversity have been elucidated.

(4)The influencing factors of plateau grassland carbon sink effect have been studied, including climate change, human activities, grassland type and management, etc. The positive and negative effects and interactions of these factors on plateau grassland carbon sink effect have been revealed, and the influencing mechanism and mode of plateau grassland carbon sink effect have been proposed.

The research difficulties of plateau grassland carbon sink effect: The research on plateau grassland carbon sink effect still has some difficulties and shortcomings, mainly including the following aspects:

(1)The lack of long-term observation and monitoring data of plateau grassland carbon sink effect leads to the unclear spatiotemporal variation and dynamic characteristics of plateau grassland carbon sink effect, and the inaccurate regional estimation and simulation of plateau grassland carbon sink effect.

(2)The lack of comprehensive evaluation and comparative analysis of plateau grassland carbon sink effect leads to the unclear regional and type differences of plateau grassland carbon sink effect, and the unobvious advantages and potentials of plateau grassland carbon sink effect.

## References

[1] Philippe C, Christopher S, Govindasamy B, Bopp L, Victor B, Josep C, et al. Carbon and Other Biogeochemical Cycles. 2014. p. 465-570.

[2] Lyu X, Li X, Wang K, Zhang C, Dang D, Huashun D, et al. Strengthening grassland carbon source and sink management to enhance its contribution to regional carbon neutrality. Ecological Indicators. 2023; 152:110341.

[3] Pan Y, Birdsey R, Fang J, Houghton R, Kauppi P, Kurz W, et al. A Large and Persistent Carbon Sink in the World's Forests. Science (New York, NY). 2011; 333:988-93.

[4] Scurlock J, Hall D. The global carbon sink: A grassland perspective. Global Change Biology. 1998; 4:229-33.

[5] Xu R, Shi P, Gao M, Wang Y, Wang G, Buda S, et al. Projected land use changes in the Qinghai-Tibet Plateau at the carbon peak and carbon neutrality targets. Science China Earth Sciences. 2023;66.

[6] Liu Y, Fan J, Harris W, Shao Q, Zhou Y-C, Wang N, et al. Effects of plateau pika (Ochotona curzoniae) on net ecosystem carbon exchange of grassland in the Three Rivers Headwaters region, Qinghai-Tibet, China. Plant and Soil. 2012;366.

[7] Sun Y, Liu S, Liu C, Sun J, Liu Y, Wang F. Interactive response and spatial heterogeneity of alpine grassland biodiversity to soil, topography, climate, and human factors on the Qinghai-Tibet Plateau. Land Degradation & Development. 2023;34.

[8] Cao Z-y, Wang Y, Li J, Zhang J-j, He N. Soil organic carbon contents, aggregate stability, and humic acid composition in different alpine grasslands in Qinghai-Tibet Plateau. Journal of Mountain Science. 2016; 13:2015-27.

[9] Le Quéré C, Andrew R, Friedlingstein P, Sitch S, Hauck J, Pongratz J, et al. Global carbon budget 2018 [Data Paper]. 2018.

[10] Bai Y, Cotrufo MF. Grassland soil carbon sequestration: Current understanding, challenges, and solutions. Science. 2022;377(6606):603-8.

[11] Yang Y, Dou Y, Wang B, Wang Y, Liang C, An S, et al. Increasing contribution of microbial residues to soil organic carbon in grassland restoration chronosequence. Soil Biology and Biochemistry. 2022; 170:108688.

[12] Bai X, Huang Y, Wang B, Kuzyakov Y, An S. Belowground allocation and fate of tree assimilates in plant–soil–microorganisms system: 13C labeling and tracing under field conditions. Geoderma. 2021; 404:115296.

ISSN: 2688-8645

[13] Nan Y, Guangquan L, Shunbo Y, Lei J, Ying L, Yuanjie D, et al. Analysis of carbon sequestration effect of sloping land conversion program in Loess Plateau from the perspective of slope. Journal of Nanjing Forestry University (Natural Science Edition). 2023;47(1):180-8.

[14] Liu F, N ZY. Analysis of the spatio-temporal variation of vegetation carbon source/sink in Qinghai Plateau from 2000—2015. Acta Ecologica Sinica. 2021;41(14): 5792-803.

[15] Shao-jie M, Ke-xin Z, Cheng-ming CY-z, Jian-long L. Research Progress on the Carbon Cycle and Impact Factors of Grassland Ecosystem. Acta Agrestia Sinica. 2014;22(3):439-47.

[16] Huang Y, Zhongbao X, Liu J, Liu Q. Divergences of soil carbon turnover and regulation in alpine steppes and meadows on the Tibetan Plateau. Science of The Total Environment. 2021; 814:152687.