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The Spatial and Temporal Variation Characteristics of CH_4 and CO_2 Emission Flux under Different Land Use Types in the Yellow River Delta Wetland

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Abstract

The Yellow River Delta Wetland is one of the youngest wetlands, and also the most complete, extensive wetlands in China. The wetland in this delta is ecologically important due to their hydrologic attributes and their roles as ecotones between terrestrial and aquatic ecosystems. In the study, the spatial and temporal variation characteristics of CH_4 and CO_2 emission flux under five kinds of land use types in the wetland were investigated. The results indicated that the greenhouse gas emission flux, especially the CO_2 and CH_4, showed distinctly spatial and temporal variation under different land use types in the wetland. In the spring, the emission flux of CO_2 was higher than that of CO_2 in the autumn, and appeared negative in HW3 and HW4 in the autumn. CH_4 emission flux of HW4 and HW5 was negative in the spring and autumn, which indicated that the CH4 emission process was net absorption. Among the five kinds of land use types, the CO_2 emission flux of HW4 discharged the largest emission flux reaching 29.3 $mg \cdot m^{-2} \cdot h^{-1}$, but the CH_4 emission flux of HW2 discharged the largest emission flux reaching 0.15 $mg \cdot m^{-2} \cdot h^{-1}$. From the estuary to the inland, the emission flux of CO_2 was decreased at first and then appeared increasing trend, but the emission flux of CH_4 was contrary to CO_2.

Keywords

Wetland, CH_4 and CO_2, Emission Flux, Land Use, Spatial and Temporal Variation

1. Introduction

Global warming has attracted wide attention and advanced research hotspot of global environmental problems, which is caused by increased greenhouse gas (GHG) emissions and the change of land use. Both CO_2 and CH_4 are considered as the most important greenhouse gases, accounting for 70% and 23% of the contribution to the temperature rising efficiency respectively [1].

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Wetlands account for 6% of the world's land surface [2] and play an important role in the global carbon cycle by acting as natural carbon sinks [3]. Wetlands contain about 12% of the global carbon pool, and are very close related to climate change [4]. Wetlands provide a productive ecosystem and favorable habitat for a wide variety of plants and animal species in the world. However, wetlands ecological systems are also ecologically sensitive and adaptive systems, and show enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant species, and soil and sediment characteristics [5].

The Yellow River Delta, one of the largest deltas in China, is situated in the northeast of Shandong Province on the southern bank of the Bohai Sea [6]. The delta covers an area of 7870 km^2 and is composed of large wetland areas, where the total area of the wetlands amounts to 4167 km^2 [7]. Among the total wetlands, natural wetlands cover 3131 km^2 (or 75.1% of the whole delta), and artificial wetlands cover 1036 km^2 (or 24.9% of the study area) [8]. The Yellow River Delta Wetland is one of the youngest wetlands, and also the most complete, extensive wetlands in warm temperate area in China. The wetlands in this delta are ecologically important due to their hydrologic attributes and their role as ecotones between terrestrial and marine ecosystems [9].

In this study, the spatial and temporal variation characteristics of CH_4 and CO_2 emission flux under different land use types in the Yellow River Delta Wetland were investigated, including: 1) The variation characteristics of CH_4 and CO_2 emission flux under different seasons; 2) The variation characteristics of CH_4 and CO_2 emission flux under different years; 3) The variation characteristics of CH_4 and CO_2 emission flux under different land use types. This study may have a large contribution to the protection of new-born frangibility, typical habitat and biodiversity in the wetland ecological system. It will also be beneficial for investigating the influence of the wetland carbon storage change on the terrestrial ecosystem carbon cycle and the global climate change.

2. Materials and Methods

2.1. Site Description

The study was conducted at the Yellow River Delta Wetland (N36˚55' - N38°16', E117˚31' - E119˚18'), which is located in the southern bank of the Bohai bay and western bank of the Bohai Sea (**Figure 1**). It belongs to the warm temperate and semi-humid monsoon climate zone, with 594.3 mm of mean annual precipitation, 2049.4 mm of average annual evaporation, 12.4˚C of mean annual temperature and 217.8 days of mean annual frost-free period. The soil types of this zone have high salinity, including tidal soil, saline tidal soil and coastal tidal soil. Tidal soil is neutral or alkalescence, and is mainly distributed along the river and south central plains. Salt soil distributes in the coastal areas, with a small amount of salt cultivated [10].

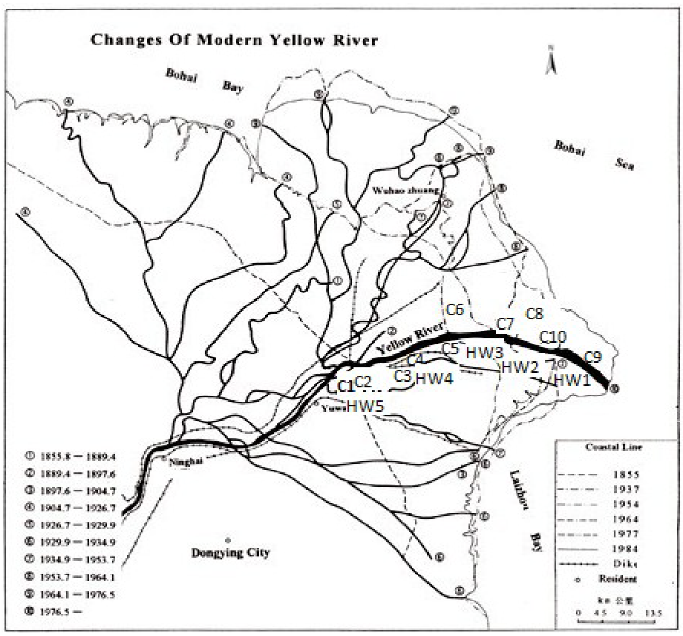

Figure 1. Location of the Yellow River Delta Wetland and sampling.

2.2. Sampling Sites Selection

The monitoring sites and Lland use characteristics of the Yellow River Delta Wetland were shown in **Figure2**, **Table 1** and **Table 2** [10]. There were 10 sites of soil samples and 5 kinds of typical salt marsh plant communities as carbon emissions monitoring site, including beaches bare land, *Suaeda salsa* community, mixed community of *Phragmites australis* and *Suaeda salsa*, *Phragmites australis* community, *Tamnrix chinesi* community and farmland community. The five types of vegetation communities in Yellow River Delta Wetland are the most typical and representative, and have a zonal distributing phenomenon from the coastal to the inland [11] [12].

2.3. Experimental Methods

The emissions concentration and fluxes of CH_4 and CO_2 were measured by using the static opaque chamber-GC technique, an eddy covariance technique. Five sampling sites were selected to collect 0 - 20 cm of soil samples in every typical salt marsh plant community. The samples of soil, plants and water were stored at 4˚C and analyzed in 48 h after sampling. The other parameters, such as TN, TP, pH, and OM, were measured according to the Standard Methods of APHA [13] [14].

The frequency of samples was taken every quarter of one year. The method of vegetation coverage degree is quadrat sampling method. The size of quadrat is 100 cm × 100 cm. In the quadrat, every vegetation coverage degree can be obtained.

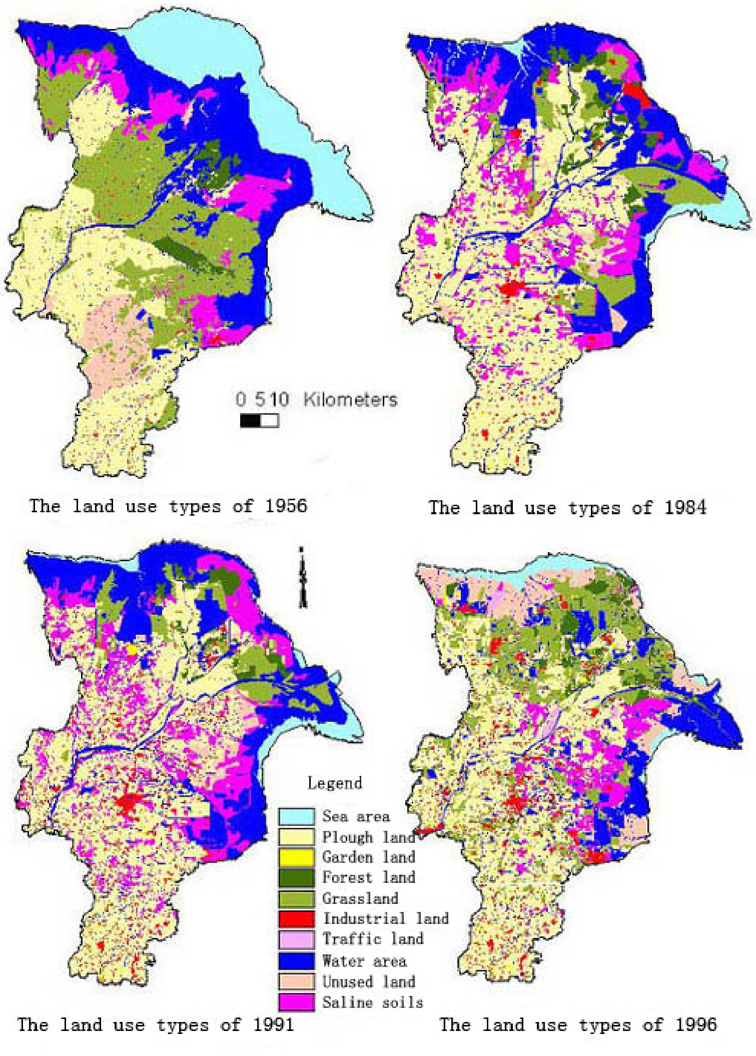

Figure 2. Land use characteristics of the Yellow River Delta Wetland.

Table 1. Soil sampling sites and description of ecosystem situation.

Number	Sampling site	Longitude and latitude	Description of ecosystem situation
C1	Woodland	E118˚55'32" N37˚45'96"	Woodland ecosystem, the vegetation types are mainly poplars.
C2	Cotton field	E118˚55'39" N37˚46'11"	Farmland ecosystem, the vegetation types are mainly cotton.
C3	*Imperata cylindrica* community	E118˚58'21" N37˚46'4"	The vegetation types are mainly *Imperata cylindrical* and *Phragmites australis*, with 0.5 - 1.2 m of plant height and about 80% of cover degree.
C4	*Tamnrix chinesi* community	E118˚58'21" N37˚46'9"	The vegetation types are mainly *Tamnrix chinesi*, with 0.5 - 2.5 m of plant height and about 60% of cover degree.
C5	*Tamnrix chinesi* community	E119˚1'1" N37˚45'51"	The vegetation type is *Phragmites australis*, with 0.5 - 1.5 m of plant height and about 40% of cover degree.
C6	*Phragmites australi* community	E119˚04'07" N37˚45'90"	The vegetation type is *Phragmites australis*, with 0.5 - 1.8 m of plant height and about 85% of cover degree.
C7	Mixed community of *Phragmites australi* and *Suaeda salsa*	E119˚9'20" N37˚44'48"	The vegetation types are mainly *Phragmites australis* and *Suaeda salsa*, with 0.5 - 1.2 m of plant height and about 65% of cover degree.
C8	*Suaeda salsa* community	E119˚11'22" N37˚44'68"	The vegetation types are mainly *Suaeda salsa*, with 0.5 - 1.0 m of plant height and about 45% of cover degree.
C9	Beaches bare land	E119˚13'44" N37˚43'04"	The vegetation types are mainly *Suaeda salsa*, with 0.2 - 0.6 m of plant height and about 15% of cover degree.
C10	*Suaeda salsa* community	E119˚12'76" N37˚43'46"	The vegetation types are mainly *Suaeda*, with 0.2 - 0.5 m of plant height and about 25% of cover degree.

Table 2. Typical salt marsh plant community and description of ecosystem situation.

Number	Community type	Longitude and latitude	Description of ecosystem
HW1	Beaches bare land	N37˚43'4" E119˚13'45"	The major land use is tidal flats, and scattered vegetation such as *Phragmites australi* and willow, height of 0.5 - 1 m.
HW2	*Suaeda salsa*	N37˚45'55" E119˚08'50"	The vegetation types are *Suaeda salsa* and *Phragmites australi*.
HW3	*Phragmites australis*	N37˚45'2" E119˚7'43"	The vegetation type is *phragmites australis* community, mainly including *Phragmites australis*, *Suaeda salsa*, *Tamnrix chinesi* and *wild chrysanthemum*, with 2 cm layer of litter at the surface.
HW4	*Tamnrix chinesi*	N37˚46'04.6" E119˚09'27.1"	The vegetation type is community of *Tamnrix chinesi-Phragmites australi*, and 80% of cover degree. There are oilfield pipelines and vehicles and other human activities around.
HW5	Farmland	N37˚46'2" E118˚55'38"	The vegetation type is cotton.

2.4. Date Analysis

The size of the static opaque chamber is 100 cm × 100 cm × 60 cm. The static opaque chamber method was used to measure CH_4 and CO_2 flux. The concentrations of CH_4 and CO_2 were determined with infrared carbon dioxide analyzer or G-C. The sampling time was 0, 20, 40, 60, 90, 120 min in 120 min sample period. At the same time, the temperature, air pressure and the concentration of CO_2 were measured in the static opaque chamber. CH_4 and CO_2 flux was calculated by using the following formula [15].

$$J = \frac{\mathrm{d}c}{\mathrm{d}t} \cdot \frac{M}{V_0} \cdot \frac{P}{P_0} \cdot \frac{T_0}{T} \cdot H$$

where J represents the gas flux ($\mathrm{mg \cdot m^{-2} \cdot h^{-1}}$); $\mathrm{d}c/\mathrm{d}t$ is the straightslope for the gas concentration at the time change of sampling; M is molar mass of gas to be measured; P is the pressure in sampling site; T is the absolute temperature; V_0, P_0, T_0 are molar volume of gas, air pressure and absolute temperature under the standard state condition; H is the height of sampling box above the water surface.

The load of annual emissions was calculated by using the following estimation formulas:

$$L = J \cdot S \cdot 24\,\text{h} \cdot 365\,\text{d} \cdot 10^{-6}$$

where L represents the load of annual emissions ($t \cdot a^{-1}$); J is the mean gas flux ($mg \cdot m^{-2} \cdot h^{-1}$); S is the zone area (m^2).

3. Results and Discussion

3.1. The Variation Characteristics of CH_4 and CO_2 Emission Flux under Different Seasons

Five different plant communities were selected to monitor the carbon emissions on-site under different seasons. The emissions flux of CH_4 and CO_2 in different kinds of salt marsh plant communities was calculated. The results were shown in **Figure 3.**

The results of CH_4 and CO_2 emission flux presented distinct season diversity in the spring and autumn. In the spring, CO_2 emission flux was higher than that in the autumn, and appeared negative in HW3 and HW4 in the autumn. CH_4 emission flux of HW4 and HW5 was negative in the spring and autumn, which indicated that the CH_4 emission process was net absorption.

3.2. The Variation Characteristics of CH_4 and CO_2 Emission Flux under Different Years

The emissions flux of CH_4 and CO_2 in different kinds of salt marsh plant communities was calculated under different years. The results were shown in **Figure 4**.

From the **Figure 4**, emission fluxes of CO_2 were all positive in 2011, performance for carbon emissions. But emission flux of CH_4 was all negative in 2011, showing the net carbon absorption. Except for HW2 and HW5, the emission flux of CH_4 was contrary to that of CO_2 in 2012. The emission flux of CH_4 was contrary to that of CO_2 for HW4 and HW5 in 2013.

3.3. The Variation Characteristics of CH_4 and CO_2 Emission Flux under Different Land Use Types

CO_2 emission flux of HW3 and HW4 was opposite in the spring and autumn (**Figure 5**). The performance of HW3 and HW4 for CO_2 emission was released in the spring, and performance for carbon sequestration in the autumn. While other land use types, the CO_2 emission flux was characterized by carbon emissions.

CH_4 emission flux of HW4 and HW5 was all negative in the spring and autumn. While for other land use types, emission flux of CH_4 was characterized by net carbon emissions.

From the **Figure 6**, the results of CH_4 and CO_2 annual emission flux presented distinct space diversity under different land use types. Among the 5 kinds of land use types, the HW4 discharged the largest emission flux of CO_2 reaching 29.3 $mg \cdot m^{-2} \cdot h^{-1}$. It can be concluded that the emission flux of CO_2 was increased by the human activities. The emission flux of CO_2 was distinct because of the large hydrological change of Yellow River's water level, which made the soil condition of oxidation and reduction alternately changed frequently. The order of CO_2 emission flux: HW4 > HW5 > HW1 > HW2 > HW3. Except for CO_2 emission flux of HW1 and HW3 was

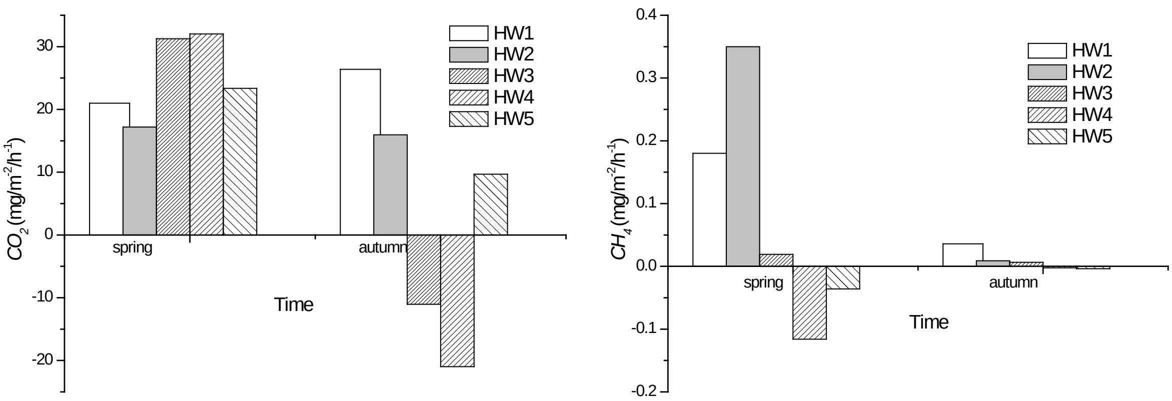

Figure 3. The variation characteristics of CH_4 and CO_2 emission flux under different seasons.

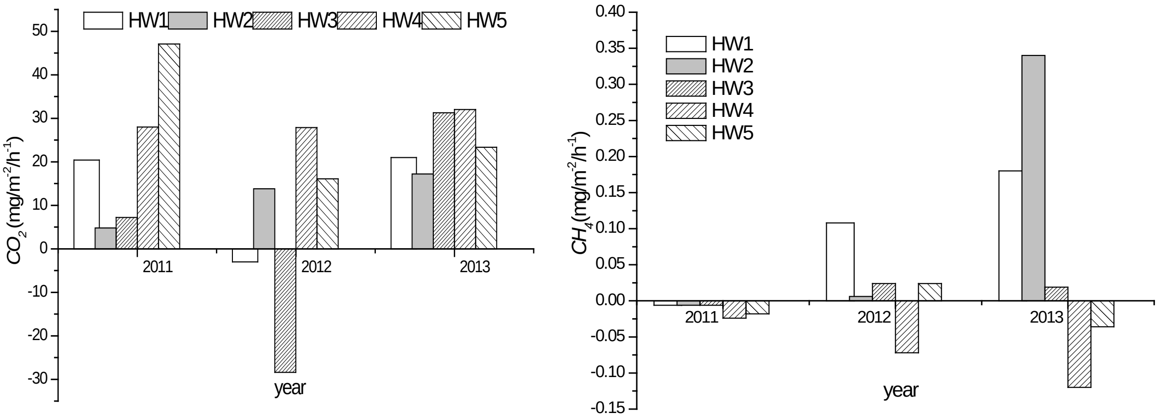

Figure 4. The variation characteristics of CH_4 and CO_2 emission flux under different years.

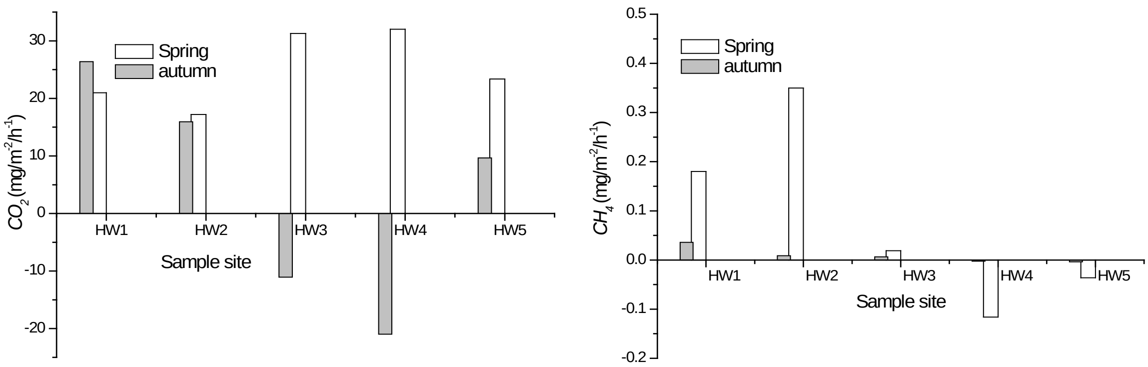

Figure 5. The seasonal variation characteristics of CH_4 and CO_2 emission flux under different land use types.

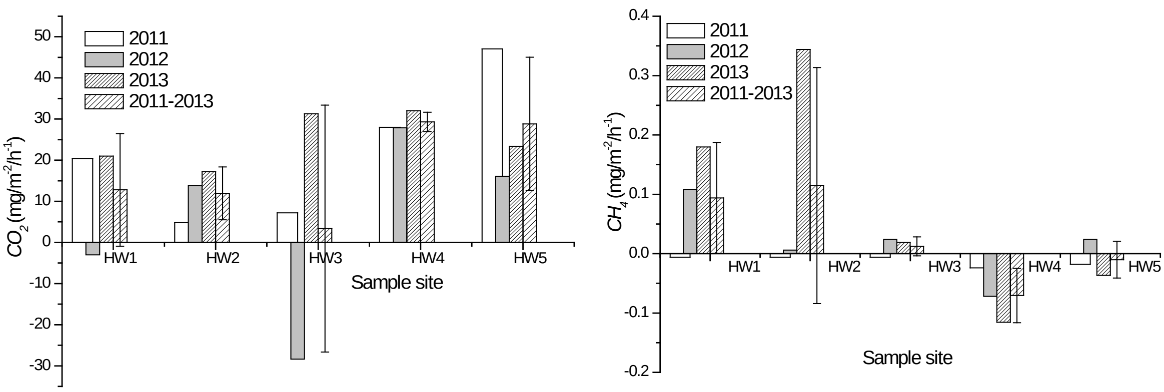

Figure 6. The annual variation characteristics of CH_4 and CO_2 emission flux under different land use types.

negative in 2012, the others were all positive.

Among the 5 kinds of land use types, the HW2 discharged the largest emission flux of CH_4, reaching 0.15 mg·m^{-2}·h^{-1}. From the estuary to the inland, the emission flux of CH_4 was increased at first and then showed decreasing trend. The order of CH_4 emission flux: HW2 > HW1 > HW3 > HW4 > HW5. CH_4 emission flux of HW4 and HW5 was negative, and showed the net carbon absorption.

4. Conclusions

The greenhouse gas emission flux, especially the CO_2 and CH_4, showed distinctly spatial and temporal variation under different land use types in the Yellow River Delta Wetland. In the spring, the emission flux of CO_2 was higher than that of CO_2 in the autumn, and appeared negative in HW3 and HW4 in the autumn. CH_4 emission flux of HW4 and HW5 was negative in the spring and autumn, which indicated that the CH_4 emission process was net absorption.

Among the 5 kinds of land use types, the HW4 discharged the largest emission flux of CO_2, reaching 29.3 $mg \cdot m^{-2} \cdot h^{-1}$, but the HW2 discharged the largest emission flux of CH_4, reaching 0.15 $mg \cdot m^{-2} \cdot h^{-1}$. From the estuary to the inland, the emission flux of CO_2 was decreased at first and then showed decreasing trend, but the emission flux of CH_4 was contrary to CO_2. Among the 5 kinds of land use types, the order of CO_2 emission flux: HW4 > HW5 > HW1 > HW2 > HW3. Except for CO_2 emission flux of HW1 and HW3 was negative in 2012, the others were all positive. The order of CH_4 emission flux: HW2 > HW1 > HW3 > HW4 > HW5. CH_4 emission flux of HW4 and HW5 was negative and showed the net carbon absorption.

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