The Spatial and Temporal Variation Characteristics of CH₄ and CO₂ 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 CH₄ and CO₂ 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 CO₂ and CH₄, showed distinctly spatial and temporal variation under different land use types in the wetland. In the spring, the emission flux of CO₂ was higher than that of CH₄ in the autumn, and appeared negative in HW3 and HW4 in the autumn. CH₄ 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 CO₂ emission flux of HW4 discharged the largest emission flux reaching 29.3 mg·m⁻²·h⁻¹, but the CH₄ emission flux of HW2 discharged the largest emission flux reaching 0.15 mg·m⁻²·h⁻¹. From the estuary to the inland, the emission flux of CO₂ was decreased at first and then appeared increasing trend, but the emission flux of CH₄ was contrary to CO₂.

Keywords

Wetland, CH₄ and CO₂, 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 CO₂ and CH₄ are considered as the most important greenhouse gases, accounting for 70% and 23% of the contribution to the temperature rising efficiency respectively [1].

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 km² and is composed of large wetland areas, where the total area of the wetlands amounts to 4167 km² [7]. Among the total wetlands, natural wetlands cover 3131 km² (or 75.1% of the whole delta), and artificial wetlands cover 1036 km² (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 CH₄ and CO₂ emission flux under different land use types in the Yellow River Delta Wetland were investigated, including: 1) The variation characteristics of CH₄ and CO₂ emission flux under different seasons; 2) The variation characteristics of CH₄ and CO₂ emission flux under different years; 3) The variation characteristics of CH₄ and CO₂ 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 land use characteristics of the Yellow River Delta Wetland were shown in Figure 2, 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, *Tamarix 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.](image-url)
Table 1. Soil sampling sites and description of ecosystem situation.

<table>
<thead>
<tr>
<th>Number</th>
<th>Sampling site</th>
<th>Longitude and latitude</th>
<th>Description of ecosystem situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Woodland</td>
<td>E118°55'32&quot;N37°45'96&quot;</td>
<td>Woodland ecosystem, the vegetation types are mainly poplars.</td>
</tr>
<tr>
<td>C2</td>
<td>Cotton field</td>
<td>E118°55'39&quot;N37°46'11&quot;</td>
<td>Farmland ecosystem, the vegetation types are mainly cotton.</td>
</tr>
<tr>
<td>C3</td>
<td><em>Imperata cylindrica</em> community</td>
<td>E118°58'21&quot;N37°46'9&quot;</td>
<td>The vegetation types are mainly <em>Imperata cylindrica</em> and <em>Phragmites australis</em>, with 0.5 - 1.2 m of plant height and about 80% of cover degree.</td>
</tr>
<tr>
<td>C4</td>
<td><em>Tamnrix chinesi</em> community</td>
<td>E119°1'1&quot;N37°45'51&quot;</td>
<td>The vegetation type is <em>Phragmites australis</em>, with 0.5 - 1.5 m of plant height and about 40% of cover degree.</td>
</tr>
<tr>
<td>C5</td>
<td><em>Phragmites australis</em> community</td>
<td>E119°04'07&quot;N37°45'90&quot;</td>
<td>The vegetation type is <em>Phragmites australis</em>, with 0.5 - 1.8 m of plant height and about 85% of cover degree.</td>
</tr>
<tr>
<td>C6</td>
<td><em>Suaeda salsa</em> community</td>
<td>E119°920&quot;N37°44'48&quot;</td>
<td>The vegetation types are mainly <em>Phragmites australis</em> and <em>Suaeda salsa</em>, with 0.5 - 1.0 m of plant height and about 65% of cover degree.</td>
</tr>
<tr>
<td>C7</td>
<td>Beaches bare land</td>
<td>E119°11'22&quot;N37°45'68&quot;</td>
<td>The vegetation types are mainly <em>Suaeda salsa</em> and <em>Phragmites australis</em>, with 0.5 - 1.2 m of plant height and about 45% of cover degree.</td>
</tr>
<tr>
<td>C8</td>
<td>Beaches bare land</td>
<td>E119°13'44&quot;N37°45'30&quot;</td>
<td>The vegetation types are mainly <em>Suaeda salsa</em>, with 0.2 - 0.6 m of plant height and about 15% of cover degree.</td>
</tr>
<tr>
<td>C9</td>
<td><em>Suaeda salsa</em> community</td>
<td>E119°12'76&quot;N37°43'46&quot;</td>
<td>The vegetation types are mainly <em>Suaeda</em>, with 0.2 - 0.5 m of plant height and about 25% of cover degree.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Community type</th>
<th>Longitude and latitude</th>
<th>Description of ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW1</td>
<td>Beaches bare land</td>
<td>N37°43'4&quot;E119°13'45&quot;</td>
<td>The major land use is tidal flats, and scattered vegetation such as <em>Phragmites australis</em> and willow, height of 0.5 - 1 m.</td>
</tr>
<tr>
<td>HW2</td>
<td><em>Suaeda salsa</em> community</td>
<td>N37°45'55&quot;E119°08'50&quot;</td>
<td>The vegetation types are <em>Suaeda salsa</em> and <em>Phragmites australis</em>.</td>
</tr>
<tr>
<td>HW3</td>
<td><em>Phragmites australis</em> community</td>
<td>N37°45'22&quot;E119°7'43&quot;</td>
<td>The vegetation type is <em>phragmites australis</em> community, mainly including <em>Phragmites australis</em>, <em>Suaeda salsa</em>, <em>Tamnrix chinesi</em> and <em>wild chrysanthemum</em>, with 2 cm layer of litter at the surface.</td>
</tr>
<tr>
<td>HW4</td>
<td><em>Tamnrix chinesi</em></td>
<td>N37°46'04.6&quot;E119°09'27.1&quot;</td>
<td>The vegetation type is community of <em>Tamnrix chinesi-Phragmites australis</em>, and 80% of cover degree. There are oilfield pipelines and vehicles and other human activities around.</td>
</tr>
<tr>
<td>HW5</td>
<td>Farmland</td>
<td>N37°46'2&quot;E118°55'38&quot;</td>
<td>The vegetation type is cotton.</td>
</tr>
</tbody>
</table>

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 CH4 and CO2 flux. The concentrations of CH4 and CO2 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 CO2 were measured in the static opaque chamber. CH4 and CO2 flux was calculated by using the following formula [15]:

\[
J = \frac{dc}{dt} \cdot \frac{M}{V_0} \cdot \frac{P}{P_0} \cdot \frac{T}{T_0} \cdot H
\]

where \( J \) represents the gas flux (mg m\(^{-2}\) h\(^{-1}\)); \( dc/dt \) is the straight slope 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:
\[ L = J \cdot S \cdot 24 \cdot h \cdot 365 \cdot d \cdot 10^{-6} \]

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.
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·m$^{-2}$·h$^{-1}$, but 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 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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References