Study on Methane Emission Factor of Paddy Fields in Hubei Province

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Abstract. Methane is one of the most important greenhouse gases, contributing about 15% of global warming, and agricultural activity is the largest source of methane, accounting for 50.15% of the country's total emissions. Accurate estimation of methane emission factors in paddy fields is of great significance to the statistics of agricultural greenhouse gas emissions and the implementation of relevant emission reduction measures. According to the method recommended by IPCC, the average methane emission factor of single season rice is 470 kg / hm², the average emission factor of fresh rice is 330 kg / hm², the average methane emission from late rice is Factor of 220 kg / hm². The factors that affect the methane emission in paddy fields in Hubei Province are mainly water management measures and soil environment.

Keywords: Methane, Emission Factors, Paddy fields, Hubei Province.

1. Introduction

Greenhouse effect caused by climate warming and other environmental issues have attracted worldwide attention [1]. Since the signing of the "Kyoto Protocol" in 2009, people of all countries have made unremitting efforts to protect mankind from the threat of climate warming [2]. The main cause of Greenhouse Effect is the increasing of greenhouse gases, such as the large use of fossil fuels, the sharp increase of population, the destruction of vegetation and so on. The IPCC assessment survey data shows that agricultural production activities are the main source of greenhouse gases, which means that the most important driver of climate change is agriculture. Many scholars have conducted in-depth research on agricultural greenhouse gas emissions. Greenhouse gases such as methane from agricultural production are also an important cause of climate warming. According to data released by the Food and Agriculture Organization of the United Nations, greenhouse gas emissions from the global agricultural production process account for more than 10% of the total emissions, and greenhouse gas emissions from the agricultural sector have been increasing at a certain rate since 1990. Greenhouse gases in the agricultural sector mainly come from three sources, one is the emission of nitrous oxide from agricultural land, the other is methane emission from rice fields, and the third is the
emission of animal husbandry industry [3]. Among them, carbon dioxide and methane are important greenhouse gases in the agricultural field. The greenhouse effect of each single molecular weight of methane is 15-30 times that of carbon dioxide [4]. As a country with the largest rice output in the world, China needs to solve the problem of reducing methane emissions from rice fields while ensuring that rice output can meet the needs of people's production activities [5].

The Food and Agriculture Organization of the United Nations pointed out that the huge potential of agricultural production activities can be fully utilized to deal with global warming [6]. According to statistics, the proportion of greenhouse gas emissions caused by the application of chemical fertilizers is relatively large but the growth rate is relatively fast. At the same time, the weight of greenhouse gas emissions from animals, feces and urine emissions, and intestinal fermentation caused by livestock breeding is also increasing. Emissions caused by rice cultivation have been increasing since 2008. Many experts and scholars are dedicated to studying the potential of agricultural greenhouse gas emission reduction [7]. By studying the external human factors in agricultural production activities and comparing the relationship between agricultural output value and greenhouse effect. Such as rational planning of agricultural machinery use, soil testing formula fertilization, irrigation water-saving technology, new crop breeding technology can effectively reduce greenhouse gas emissions. This is of great help to the specific research on agricultural emission reduction.

There are still many shortcomings in the accounting and statistics of greenhouse gas emissions [8]. First, there is a lack of statistical indicators that are in line with local actual conditions. Local agricultural departments have not conducted timely and effective statistics and measurements and the reporting statistics system is not complete. Second, statistics on greenhouse gas emissions are weak. China does not have a department that specializes in agricultural carbon emission statistics, and the agricultural department has not set up a statistical agency, and there is no full-time staff to perform statistics. Third, it lacks the support of a complete statistical system. Therefore, we use the CH4MOD model to estimate the methane emission factor from rice fields in Hubei Province, so as to improve the greenhouse gas emission inventory of Hubei Province and provide data support for the research on reasonable emission reduction measures.

2. Research methodology

2.1. Characteristics of rice production in the surveyed area
Field investigation results show that the irrigation patterns of paddy fields in Hubei Province are intermittent irrigation. Since 2011, 100% of straw has been returned to the field gradually and soil-measuring formula fertilization has been carried out. The rice cultivation in Yichang, Huanggang and Xiangyang is dominated by single-season rice, only in Huanggang. The basic situation of rice production is shown in Table 1.

2.2. Research on methane emissions from rice fields

2.2.1. Data collection. Collected from the "Statistical Yearbook of Hubei Province" in 2016 the daily average temperature data, soil sand content, and soil nutrient content of three places including Huanggang, Yichang, and Xiangyang in 2016; other auxiliary materials include journal articles, reports from the Ministry of Agriculture, and news newspaper A variety of materials provide the relevant basis for this study.

2.2.2. Household survey. This study used a field questionnaire survey (Annex 1) to conduct household surveys in 8 villages in three regions of Yichang City, Huanggang City and Xiangyang City. The survey content included basic information of farmers in the surveyed area and input parameters (rice yield, Field growth period, paddy field organic matter addition data, paddy field water management status) to obtain basic data.
2.3. Data processing method
In this study, the CH4MOD model was used to process data to obtain methane emission factors from rice fields in Hubei Province. The model needs to input various parameters such as rice planting area, rice yield, rice growth period, soil sand content and temperature, water management mode and rice variety parameters, and then obtain methane emission factors for each field after operation. Because methane emission in rice field is closely related to organic matter addition, the rotation mode in rice field should be distinguished, that is, the rice field type should be further divided according to the rotation type of rice field and other crops (winter wheat, winter oil vegetable, green manure, etc.), and the sowing area of rice should be sorted out separately. Water management data for paddy fields need to separately explain the water management methods for different rice growth periods (transplanting-tillering period, tillering-flowering period, flowering period-harvesting). In practical applications, the variety coefficient is "1" to calculate methane emissions.

3. Results and analysis

3.1. Survey of regional rice production characteristics
Field investigation results show that the irrigation patterns of paddy fields in Hubei Province are intermittent irrigation. Since 2011, 100% of straw has been returned to the field gradually and soil-measuring formula fertilization has been carried out. The rice cultivation in Yichang, Huanggang and Xiangyang is dominated by single-season rice, only in Huanggang. The basic situation of rice production is shown in Table 1.

Table 1. Basic situation of farmers' rice production

| Num ber | Place   | Population (man) | Rice field area (acre) | Rice field yield per unit (catty / acre) | Fertilization ratio (N:P:K) | Irrigation model | Rate of straw returning (%) |
|---------|---------|------------------|------------------------|----------------------------------------|-----------------------------|------------------|----------------------------|
| 1       | Yichang | 1-2              | 1-5                    | 1000-1200                              | /                           | 15:10:10         | 100                        |
| 2       | Huanggang | 1-4            | 1-20                   | 1100-1300                              | 600-700                    | 300-400          | 15:10:5                    | 100                        |
| 3       | Xiangyang | 1-2             | 1-10                   | 1100-1500                              | /                           | 20:10:10         | 100                        |

3.2. Methane emissions from rice fields in Hubei Province
A total of 36 data from Yichang, Huanggang and Xiangyang were processed by CH4MOD model. The input parameters of the model were rice planting area, rice yield per unit yield, rice growth period, soil sand content and temperature, water management model and rice variety. The data of methane emission factors from rice paddies are shown in Table 2.
Table 2. Three regional statistics on methane emission factors

| Place | Yichang | Huanggang | Xiangyang |
|-------|---------|-----------|-----------|
| Rice Field Category | Single-crop Rice | Single-crop Rice | Retooning rice | Single-crop Rice |
| Early Season | Late Season | Early Season | Late Season |
| Samples (n) | 30 | 30 | 15 | 15 | 30 |
| Emission factors (t/hm²) | 0.45-0.50 | 0.47-0.53 | 0.30-0.37 | 0.21-0.23 | 0.39-0.49 |
| Mean (t/hm²) | 0.47 | 0.49 | 0.33 | 0.22 | 0.47 |

Comparing with the emission factors of the IPCC provincial greenhouse gas emission inventory, it is found that the methane emission factor of 470 kg/hm² in the rice fields of seasonal rice and winter rape in Yichang area obtained in this survey is higher than the range of 170.2-320.1 kg/hm² in the table. According to the information obtained from reading the materials, we can see that since 2011, we have gradually implemented the full return of straw to the field in various regions, and the burning of straw has been prohibited [9]. Studies have shown that straw contains a large amount of potassium. After returning to the field, most of the potassium can be returned to the soil, reducing the amount of potassium fertilizer for the next crop, which can be used as a supplementary resource for potassium fertilizer, so the rice yield will be higher than before. The application of straw will increase CH₄ emissions, mainly because it reduces emission factor and provides more carbon sources, which increases the methane-producing substrate. In the same way, the single-season rice methane emission factor in Huanggang and Xiangyang areas will also increase. Since 2010, Huanggang City has conducted comprehensive research, demonstration and promotion of the "one two harvest" high-efficiency production model of ratooning rice. The so-called ratooning rice refers to the one-season rice that utilizes the regrowth characteristics of rice and adopts appropriate cultivation and management measures after the first season rice is harvested to make the dormant buds that survive on the harvested rice stubs germinate regeneration tillers, and then heading mature rice. Ratooning rice has now developed into "a two-ton grain field." The higher the yield, that is, the more plants above the ground, the more methane-producing substrate produced by the root system, and the more methane emissions [10]. The methane emission of 330 kg/hm² of double-cropping early rice and 220 kg/hm² of late rice were both within the normal range. According to data analysis, the field growth period of double-cropping early rice and late rice is 80-90 days, which is shorter than the field growth period of single-cropping rice of 110-135 days.

3.3. Influencing factors of methane emission in rice field

3.3.1. Natural conditions. In this survey, the difference in soil texture among the villages in Yichang, Huanggang and Xiangyang is one of the reasons for the different methane emission factors in rice fields. Soil texture can affect soil permeability and decomposition rate of soil organic matter, so it can affect soil and substrate supply of residual microorganisms, thus affecting methane emission in rice field significantly. The methane emission from clay paddy fields is significantly lower than that of loam and sandy paddy fields. The stickier the soil texture, the less methane emission. The reason is that clay soil has a strong retention of organic matter. Even if the organic matter content of clay soil is higher than that of light soil, the organic matter supplied to methanogenic bacteria may be less. Secondly, the buffer effect of clay soil is stronger, and the soil is higher after flooding, which limits the activity of methanogenic bacteria. Methane emissions from paddy fields are positively correlated with soil sand content. Soil temperature has a great influence on the quantity and activity of methane bacteria in soil. Most methane microbes are thermophilic [11]. The activity of methanogenic microorganisms requires suitable temperature. When the temperature is lower than the optimum temperature, the activity of methanogenic microorganisms increases with the increase of soil
temperature. The temperature increased, the microbial activity increased, the organic matter decomposition accelerated, the oxygen consumption accelerated, the respiration and transpiration of rice plants accelerated, and the methane emission efficiency was improved through two channels of bubble and liquid diffusion. Eventually, methane emissions increased. Therefore, rice methane emissions in Huanggang area are slightly higher than those in the other two places.

3.3.2. Field management measures. In this investigation, farmers generally dry the fields during the rice growth period to increase rice yield and ripen early. There are many important influences on drying fields. First, drying the field can control invalid tillers and consolidate effective tillers. In production, the method of drying the field can stop the growth of high-position young tiller buds without water and fertilizer supply, reduce nutrient consumption, so that the main stem and large tillers can obtain more nutrient supply, and lay a solid foundation for the growth of stalks and large ears. Second, improve the soil environment and enhance root vitality [12]. Through the field drying treatment, the atmosphere can directly enter the cultivated layer, enhance the permeability of the soil, improve the soil structure of the soil, and increase the oxygen content in the cultivated layer. After drying the field, the number of new roots increases, which promotes root extension, expands the range of root activity, and enhances absorption capacity. Third, coordinate vegetative growth and reproductive growth [13]. By drying the field, the level of nitrogen metabolism can be reduced, the growth rate of nutrients can be controlled, the capacity of carbon metabolism can be improved, and the accumulation of carbohydrates can be promoted. Fourth, lower the field temperature to suppress pest damage [14]. The occurrence and spread of many diseases and insect pests of rice are directly related to the temperature and humidity between rice plants. By drying the field, the air humidity between the plant clusters is reduced, the field microclimate environment is improved, the conditions for the propagation and propagation of germs and eggs are destroyed, and the occurrence and damage of diseases and insects are inhibited. The field water management methods often used in the sample areas are flooding-curing field-flooding-intermittent irrigation (mode ①) and flooding-curing field-intermittent irrigation (mode ②). Through data analysis, it can be seen that the methane emissions from rice fields in model ② are reduced by 20.51% on average compared to model ①. Water management in paddy fields affects soil permeability and redox status, which in turn affects CH4 emission and oxidation in paddy fields [15]. Choosing an appropriate paddy field water management model is of great significance to the reduction of methane emissions from paddy fields.

4. Conclusions
This paper conducts sampling surveys from three places in Hubei Province, and the rice sown area in Hubei Province obtained from remote sensing data has reached 2.045×10^7 hm^2 in 2009. The simulation results of the methane model show that the average methane emission factor of single-cropping rice in Hubei Province is 0.47 t/hm^2, the average emission factor of ratooning early rice is 0.33 t/hm^2, and the average methane emission factor of late rice is 0.22 t/hm^2. Simulation studies have shown that methane emissions from rice fields are different due to various environmental factors and human management measures. The paddy field water management mode has a greater impact on methane emissions from the paddy field. In addition, the input of organic materials in rice fields will also increase methane emissions. Therefore, it is very important to choose a reasonable rice field management method.

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