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Original Research

Straw Biochar Production and Carbon Emission Reduction Potential in the Yangtze River Economic Belt Region

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Abstract

In order to comprehend the temporal and spatial variations in the quantity of crop straw resources in the Yangtze River Economic Belt over the past decade, as well as the estimated carbon emission reduction potential from straw biochar, the straw coefficient method was employed to scientifically estimate the crop straw resources in the region from 2011 to 2020. The study analyzed the spatiotemporal distribution characteristics of straw resource density and per capita resource quantity. Furthermore, it estimated the carbon emission reduction potential of preparing biochar from straw. The results indicate that the total amount of crop straw in the Yangtze River Economic Belt increased by 0.22×10^8 t from 2011 to 2020. In 2020, the theoretical total amount of crop straw resources in the region was approximately 3.04×10^8 t. The overall net potential for greenhouse gas mitigation was an emission reduction of approximately 2.18×10^8 t of CO_{2e}. It is evident that converting crop straw into biochar holds significant potential and serves as an effective means to achieve carbon emission reduction.

Keywords: crop straw, carbon emission, Yangtze River Economic Belt

Introduction

Crop straw, abundant in organic matter, represents the Earth's largest renewable resource. China, being a major agricultural producer, contributes approximately one-fifth of the global crop straw resources [1]. According to the 2021 grain production data released by the National Bureau of Statistics, China achieved an impressive 18 consecutive years of abundant harvests in grain production [2]. Consequently, the production of crop straw has been steadily increasing. However, crop straw have long been treated as waste and either abandoned or incinerated, leading to severe environmental pollution issues [3]. The environmental impact is evident, with China's agricultural and rural greenhouse gas emissions accounting for around 15% of the nation's total greenhouse gas emissions [4]. In response to these challenges, China has implemented a series of policies to address the responsible management of crop straw. In September 2020, President Xi Jinping, during the 75th session of the United Nations General Assembly, emphasized China's commitment to striving for a peak in carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060 [5]. This is the first time that China has proposed the goal of achieving peak carbon emissions and carbon neutrality,

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attracting significant international attention. As the world's largest carbon-emitting country, accounting for 28.8% of the total global energy-related carbon emissions, China plays a crucial role in global efforts toward peak carbon emissions and carbon neutrality. In this process, agriculture, which has significant potential for emission reduction and carbon sequestration, will also play an important role. The "Implementation Plan for Agricultural Emission Reduction and Carbon Sequestration" issued by the Ministry of Agriculture and Rural Affairs and the National Development and Reform Commission emphasizes the need to carry out agricultural production in a resource-saving and environmentally friendly manner, creating a spatial pattern that is energy-efficient and low-carbon. Consequently, to fulfill the dual objectives of peak carbon emissions and carbon neutrality, urgent measures are required in the agricultural sector. The comprehensive utilization of crop straw emerges as one specific measure contributing to pollution reduction, carbon mitigation, the advancement of modern agriculture, and the assurance of energy security [6]. To effectively plan the comprehensive utilization of crop straw, it is imperative to gain a thorough understanding of the current status of crop straw resources, utilization, and carbon reduction potential. This forms the basis and motivation for the present study. Current research in this field is predominantly focused on two aspects. Firstly, regarding the estimation of straw resources, the widely adopted method is the straw coefficient approach, where the key lies in determining the appropriate coefficient. Some studies utilize a nationally uniform coefficient to calculate the straw resource quantity for the same crop variety, neglecting regional variations in crop yields. This oversight makes it challenging to derive precise results. Secondly, there is a considerable body of research on estimating carbon reduction and sequestration in biomass resources. For instance, studies by Pan *et al*. employ a life cycle assessment to estimate that the production of biomass charcoal from straw and its subsequent field application can achieve a net carbon sink of 249 to 398 kg CO_{2e} /t [7]. However, variations in the yield and carbon content of biochar produced from different biomass materials, along with discrepancies in carbon balance systems and standards, contribute to divergent estimates of carbon sequestration outcomes.

The Yangtze River Economic Belt encompasses 11 provinces and municipalities, including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan, and Guizhou. Covering an area of approximately 2.05 million square kilometers, it constitutes 21.4% of the total national territory [8]. Notably, its population and gross domestic product (GDP) collectively surpass 40% of the national figures. The Yangtze River Economic Belt spans the eastern, central, and western regions of China and is a key focus of the "Three Major Strategies" implemented by the central government [9, 10]. It serves as a globally influential inland economic belt, a belt for coordinated development through interaction between the eastern, central, and western regions, and a belt for comprehensive internal and external openness along the coastal, riverside, and border areas. Additionally, it stands as a pioneering demonstration area for ecological civilization construction. In recent years, numerous scholars have conducted extensive economic and social research around the Yangtze River Economic Belt [11]. To elucidate the detailed potential of biochar preparation from crop straw in the Yangtze River Economic Belt region, this study initially employed the grass-to-grain ratio method to estimate the quantity of crop straw resources. Subsequently, it analyzed the spatiotemporal variation characteristics of straw resource quantities. By utilizing a literature analysis approach, the study delineated rational standards for carbonization and carbon fixation rates for different crop straws. Applying a life cycle assessment method, the research estimated the collectible quantity of crop straw and its potential for biochar preparation in the Yangtze River Economic Belt region. The aim is to clarify the current status of crop straw resources, the potential for biochar preparation, and carbon reduction potential, and to provide valuable data and policy references for promoting the rational utilization of crop straw resources and achieving the "dual carbon" goal in the region.

Research Methods and Data Sources

Data Sources

Crop yield data were sourced from the China Statistical Yearbook, encompassing the years 2011 to 2020. Data collection focused on the Yangtze River Economic Belt region, comprising a total of 11 provinces, municipalities, and autonomous regions. The crops considered in the dataset include corn, rice, wheat, legumes, cotton, rapeseed, peanuts, potatoes, sesame, hemp, sugarcane, sugar beets, and tobacco. Additionally, records of arable land area and population figures for the same period were compiled for the 11 regions.

Evaluation Indicators

The assessment of crop straw resources, biochar production potential, and carbon reduction potential is conducted through the integration of the Life Cycle Assessment (LCA) method. This study primarily focuses on five evaluation indicators: total resource quantity, resource density, biochar production potential, and carbon emission reduction potential.

Straw Coefficient

The straw coefficient refers to the ratio of the aboveground straw yield to the grain yield per unit

Table 1. Straw coefficients of major crops in the Yangtze River Economic Belt region.

Species	National average	Upper Yangtze River	Middle Yangtze River	Lower Yangtze River
Rice	1.00	1.02	1.07	1.10
Wheat	1.22	0.91	0.97	0.95
Corn	1.01	0.85	1.04	1.09
Potato	0.16	0.20	0.16	0.13
Peanut	1.26	1.27	1.25	1.61
Oilseed rape	1.86	1.86	1.86	2.32
Bean	1.19	0.93	1.46	1.45
Cotton	2.95	2.75	-	-
Sugar cane	0.06	-	-	0.06
Beetroot	0.43	-	-	-
Sesame	2.01	-	-	-
Hemp	1.90	-	-	-
Tobacco	0.71	-	-	-

Note: The symbol "-" denotes the absence of relevant data in the reference literature. In instances where specific straw coefficients are unavailable for a given region, referencing the national average is recommended.

area of crops, representing the yield ratio between the by-product with continued utility value (straw) and the primary product (grain) of the main utilization method (Table 1). The straw coefficient method is commonly employed for estimating straw resource quantities due to its intuitive and explicit nature. Owing to the varied growth conditions of different crops in distinct regions influenced by factors such as natural climate and geographical environment, we have established the following regional crop straw coefficient settings based on the Ministry of Agriculture and Rural Development of China.

Calculation of Total Straw Resources

The economic yield assessment of agricultural products is primarily based on the weight of crop grains. The total straw resource quantity can be calculated based on crop yield and the ratio of straw to grain. The calculation formula is as follows:

$$Y_1 = \sum_{i=1}^{n} P_i \times R_i$$

In the equation, Y_1 represents the total straw resource in the Yangtze River Economic Belt region, P represents the crop yield in that region, R represents the straw coefficient for crops, and i represents different types of crops, where i = 1, 2, 3,···, n. P_i denotes the annual yield of the i-th crop in a specific region, and R_i represents the straw coefficient for the i-th crop in that region.

Calculation of Straw Production Per Unit of Arable Land

$$Y_2 = \frac{Y_1}{h}$$

In the equation, Y_2 represents the straw resource density in a specific region, and h denotes the arable land area in that particular region.

Calculation of Biochar Production

$$Y_3 = \sum_{i=1}^{n} K_i \times W_i$$

In the equation, Y_3 represents the production of biochar, K_i denotes the yield of the i-th type of crop residue, and W_i corresponds to the carbonization efficiency of the i-th type of crop residue.

Carbon Fixation by Soil Sequestered Biochar

$$Y_4 = \sum_{i=1}^{n} C_i \times t_i$$

In the equation, Y_4 represents the total amount of carbon sequestered in the soil, C_i denotes the production of biochar for the i-th crop, and t_i signifies the carbon content of the i-th biochar.

Assumption Values and Potential Calculation of Greenhouse Gas Mitigation Through the Preparation of Biochar from Straw Resources

Production Process Generates Heat That Can Be Burned Instead of Fossil Fuels

A1: Total straw resources/t = Y_1
A2: Biogas production rate/% = 35 [12, 13]
A3: Biogas calorific value/MJ·kg^{-1} = 6 [14]
A4: Electricity conversion factor/% = 35 [14]
A5: CO_2 emissions from coal power generation/kg·(KW·h)$^{-1}$ = 1.07 [15]
A6: Preparation process power output/kW·h = A1×A2×A3×A4/3.6×1000
A7: Reduces CO_2 emissions by replacing coal combustion/t = A6×A5/1000

Biochar Preparation, Production and Sequestration Calculations

A8: Biochar production rate/% = 2.14(a); 37.71(b); 30.34(c); 29.91(d) [16]
A9: Biochar carbon content/% = 57.19(a); 62.89(b); 59.76(c); 72.84(d) [16]
A10: Biochar carbon rate = 18.38%(a); 19.94%(b); 18.13%(c); 18.53%(d) [16]
A11: Biochar stabilization component ratio = 80% [17]
A12: C-CO_2 conversion factor = 3.67
A13: Total biochar production/t = Y_3
A14: Biochar Soil Sequestration Fixed Carbon/t = Y_4
A15: Biochar Soil Sequestration Fixed CO_2/t = A14×A12

Biochar for Crop Growth and Carbon Sequestration

A16: Biochar addition increases yield/% = 12.5(a); 13.40(b); 17.40(c)
A17: Carbon content of crops/% = 41.97(a); 45.61(b); 45.67(c)(A17)
A18: Crop yield per unit area without biochar addition/t·hm^{-2} = 7.04(a); 5.42(b); 6.10(c)
A19: Biochar addition increases yield/t·hm^{-2} = A16×A18 = 0.88(a); 0.73(b); 1.06(c)
A20: Percentage of biochar returned to fields/t·hm^{-2} = 38.13
A21: Area of biochar that can be returned to the field/hm^2 = A13/A20/3
A22: Crop C-fixation/t = A17(a) × A19(a) ×A21(a) + A17(b)×A19(b)×A21(b) + A17(c)×A19(c)×A21(c)
A23: Increased crop yield fixed CO_2/t = A22×A12

Inhibition of N_2O Release by Biochar

A24: N_2O emission/kg·hm^{-2} = 3.34(a); 1.75(b); 2.53© [18]
A25: N_2O emission suppression rate/% = 94.59 [19]
A26: N_2O to CO_2 conversion factor = 298 [17]
A27: N_2O emission reductions/t = A21×A24 ×A25/1000
A28: Conversion to (CO_{2e})/t = A26×A27

Fertilizer Reduction from Biochar Application (in CO_{2e})

A29: Fertilizer application(N;P;K)/kg·hm^{-2} = 273.1(N); 238.5(P); 223.6(K)
A30: Reduction in agricultural fertilizers(N; P; K)/% = 10((N); 20(P); 20(K)
A31: CO_{2e} emissions from fertilizer production/kg = 3(N/kg); 0.7(P/kg); 1(K/kg) [17]
A32: Fertilizer application reduces CO_{2e} emissions/t = A29(N)×A30(N)×A31(N) + A29(P)×A30(P)×A31(P)+A29(K)×A30(K) ×A31(K)

Greenhouse Gas Emissions During Transport

A33: Greenhouse gas emission factors for straw collection, storage, and transport (CO_{2e}) kg·t^{-1} = 27.53[20]
A34: CO_{2e} emissions per ton of biochar dispersed/kg = 45.32 [21]
A35: CO_{2e} emissions from straw feedstock and biochar transport/t = (A1+A13)×A33
A36: CO_{2e} emissions from biochar dispersal/t = A13×A34
A37: Total emissions (CO_{2e})/t = A35 + A36
A38: Net potential for greenhouse effect mitigation (CO_{2e})/t = A7 + A15 + A23 + A28 + A32-A37

Where a, b, c, and d denote rice, wheat, maize, and beans, respectively, and "-" denotes that the relevant data need to be obtained by calculation.

Results and Discussion

Trends in Total Crop Straw Resources

As depicted in Fig. 1, over the past decade, the total quantity of crop straw resources in the Yangtze River Economic Belt has exhibited a steady upward trajectory. From 2011 to 2020, the overall volume of straw resources in this region increased from 2.82 × 10^8 t to 3.04 × 10^8 t. Throughout this ten-year period, an overall increasing trend characterized the total volume of crop straw resources in the area. However, there were intermittent instances of decline in certain years, such as in 2016, when the total straw resources decreased by 5.02 × 10^6 t compared to 2015. Additionally, from 2017 to 2019, there was a consecutive three-year decline in the total straw resources, although it remained higher than the quantity recorded in 2011.

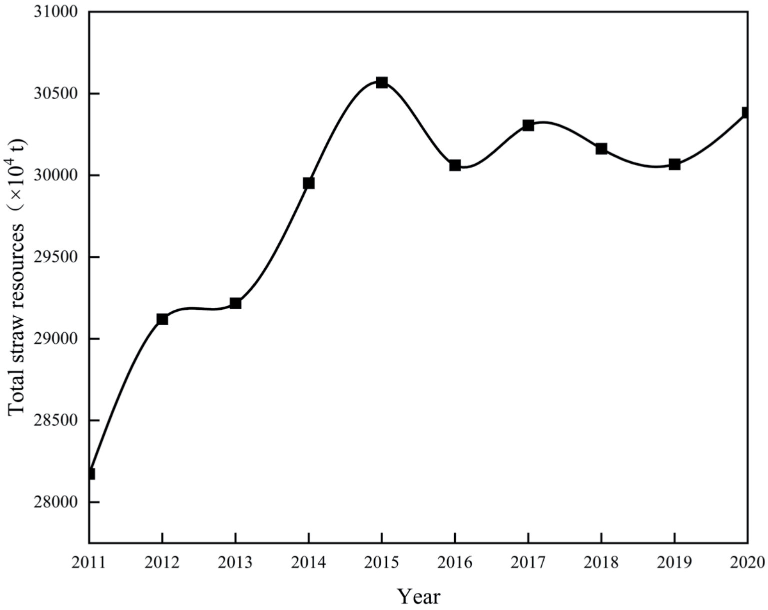

Fig. 1. Changes in total straw resources in the Yangtze River Economic Belt region from 2011 to 2020.

Changes in the Structure of Crop Straw

As depicted in Fig. 2a), the net increase in rice, wheat, and maize straw resources collectively amounted to 0.19×10^8 t during the period from 2011 to 2020, representing a growth rate of approximately 9.41%. The proportional contribution of these three crop residues to the total agricultural straw remained relatively stable, around 73.67%, consistently maintaining their dominant position in the straw resources of the Yangtze River Economic Belt region. Over the years 2011 to 2020, the resource quantities of these three types of straw exhibited a fluctuating pattern. The substantial presence of rice, wheat, and maize straw in the overall straw resources can be attributed to several factors. Firstly, these crops are major staple foods in China, and the high proportion of their straw resources is a reflection of the country's large population and significant demand for grains. Secondly, in order to enhance the global competitiveness of Chinese agricultural products in the world trade market, there is a continuous effort to increase the production of key staple crops while meeting domestic consumption needs. Additionally, the impact of factors such as adjustments in economic growth, accelerated urbanization, and the upgrading of consumption patterns for major agricultural products also plays a significant role.

Spatial Distribution of Crop Straw

As indicated in Table 2, two provinces (municipalities) within the Yangtze Economic Belt region experienced a decline in total straw resources from 2011 to 2020, namely Shanghai and Zhejiang. In comparison to the year 2020, the total straw resources in Shanghai and Zhejiang decreased by 0.05×10^7 t and 0.09×10^7 t, respectively. Shanghai and Zhejiang, not traditionally recognized as agricultural production areas, have predominantly shifted towards the development of the tertiary industry in recent years. Hence, the decrease in total straw resources in these regions is considered a normal phenomenon. On the contrary, the total straw resources in the remaining provinces (municipalities) exhibited an upward trend. Among them, Sichuan and Anhui provinces demonstrated relatively higher total straw resources, with a significant growth rate. Over the period from 2011 to 2020, both Sichuan and Anhui provinces witnessed an increase of 0.55×10^7 t in their total straw resources. From the perspective of production per unit of arable land area (Fig. 2a), Sichuan, Anhui, and Jiangsu provinces ranked as the top three in the Yangtze Economic Belt region. Notably, Guizhou province had the lowest straw resource density, standing at only 21.82 t/hm^{-2}.

According to geographical location, the Yangtze River Economic Belt can be divided into three regions: the Upper Reaches, the Middle Reaches, and the Lower Reaches. The Upper Reaches include Chongqing, Sichuan, Guizhou, and Yunnan; the Middle Reaches comprise Jiangxi, Hunan, and Hubei; and the Lower Reaches consist of Shanghai, Jiangsu, Zhejiang, and Anhui. As depicted in Table 3, during the period from 2011 to 2020, the straw resources in these three regions generally exhibited the trend of Upper Reaches>Middle Reaches>Lower Reaches, with only the Lower Reaches surpassing the Middle Reaches in 2019. In 2020, the straw resources in the Upper, Middle, and Lower Reaches were 108.1 million tons, 98.6 million tons, and 97.1 million tons, respectively. Compared to 2011, these figures represent an increase of 9.63%, 5.23%, and 8.49%, respectively. Examining the straw yield per unit

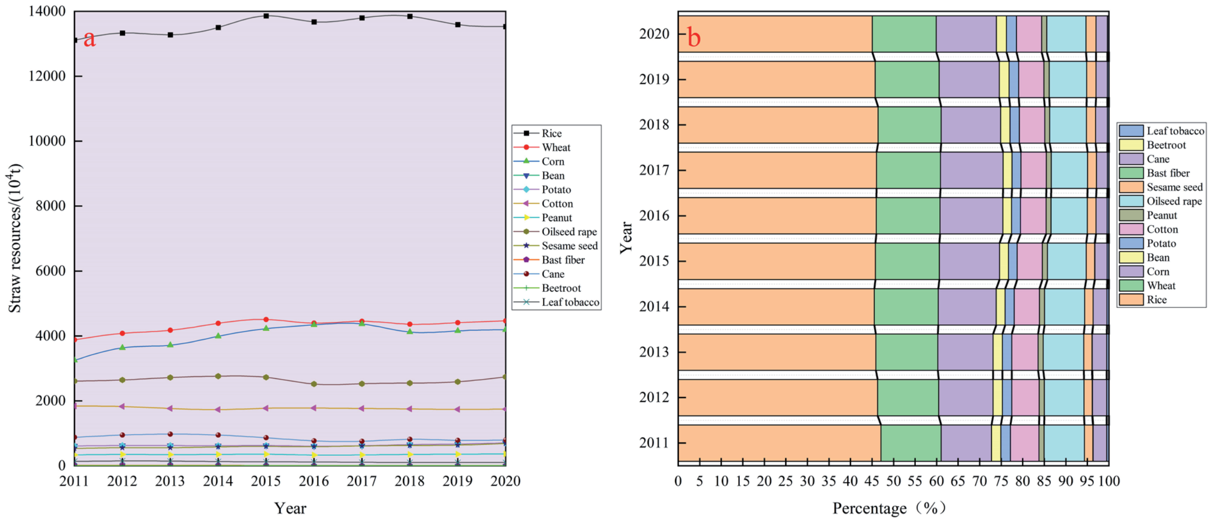

Fig. 2. Production and share of various types of crop straw from 2011 to 2020.

of cultivated land (Fig. 2b) in 2020, the Upper Reaches exhibited a production of 4.21 t·hm^{-2}, the Middle Reaches recorded 4.48 t·hm^{-2}, and the Lower Reaches reached 5.23 t·hm^{-2}.

Straw Biochar Preparation Potential and Carbon Emission Reduction Potential

China possesses abundant crop straw resources characterized by large quantities, diverse types, and high carbon content. Biochar, as a significant renewable resource, is primarily derived from agricultural waste such as crop straw and animal manure. Produced under

Table 2. Spatial distribution of crop straw (×10^7 t) in the Yangtze River Economic Belt region from 2011 to 2020.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Shanghai	0.14	0.14	0.13	0.13	0.13	0.11	0.10	0.11	0.10	0.09
Jiangsu	0.38	0.39	0.39	3.98	4.04	3.96	4.04	4.08	4.15	4.18
Zhejiang	0.80	0.77	0.71	0.70	0.68	0.65	0.67	0.70	0.70	0.71
Anhui	4.17	4.43	4.42	4.74	5.00	4.67	4.72	4.71	4.77	4.72
Jiangxi	2.42	2.47	2.51	2.56	2.58	2.55	2.55	2.50	2.46	2.46
Hubei	3.33	3.44	3.561	3.62	3.84	3.65	3.71	3.67	3.57	3.65
Hunan	3.61	3.67	3.62	3.70	3.73	3.69	3.72	3.68	3.65	3.74
Chongqing	1.11	1.11	1.11	1.11	1.12	1.15	1.15	1.15	1.15	1.16
Sichuan	5.01	5.06	5.14	5.17	5.31	5.45	5.51	5.53	5.55	5.66
Guizhou	1.13	1.40	1.31	1.40	1.42	1.50	1.46	1.25	1.20	1.19
Yunnan	2.61	2.72	2.80	2.85	2.73	2.68	2.70	2.78	2.76	2.80

Table 3. Total Straw Resources (×10^7 t) in the Upper, Middle, and Lower Reaches of the Yangtze River Economic Belt from 2011 to 2020.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Upper	9.86	10.29	10.36	10.52	10.57	10.77	10.81	10.71	10.67	10.81
Middle	9.37	9.59	9.69	9.89	10.15	9.89	9.97	9.85	9.68	9.86
Lower	8.95	9.24	9.16	9.55	9.84	9.39	9.52	9.60	9.72	9.71

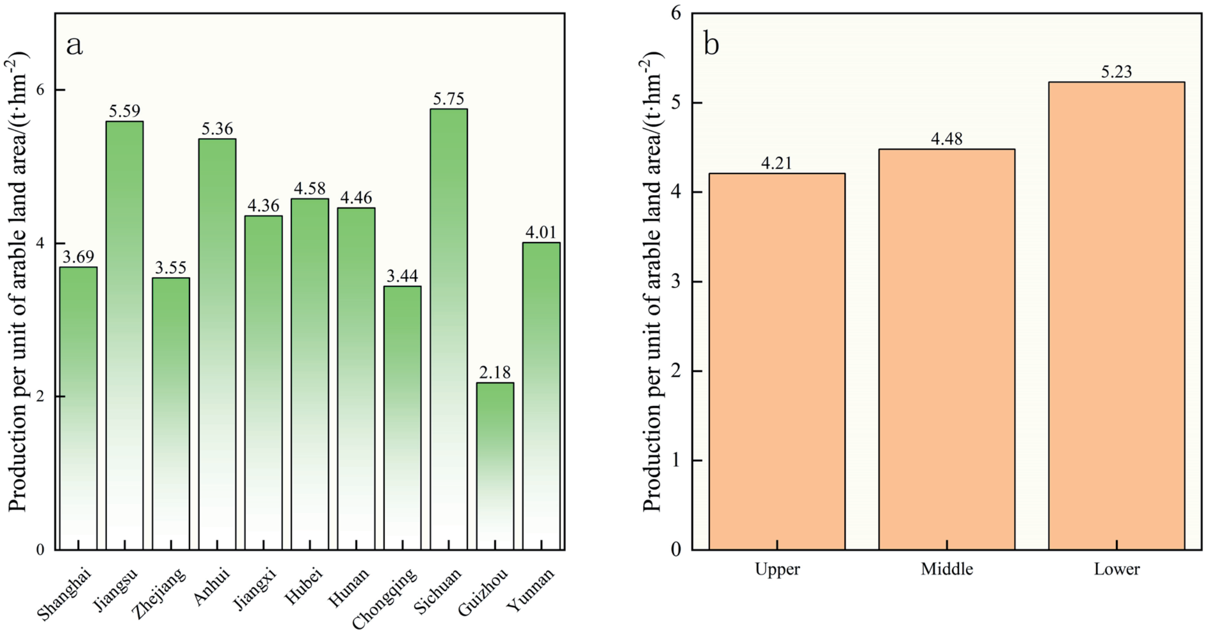

Fig. 3. Straw Resources Per Unit of Arable Land Area in the Yangtze River Economic Belt Region in 2020.

anaerobic or oxygen-deprived conditions at temperatures below 700°C, biochar is a carbon-rich, solid substance with a substantial surface area and stability. In addition to carbon, it contains hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), and trace amounts of various elements. Biochar, when integrated into the soil, exhibits a remarkable capacity to sequester carbon for extended periods, ranging from centuries to millennia. This property contributes to carbon fixation and the reduction of carbon dioxide emissions. Annually, biochar facilitates the mitigation of greenhouse gas emissions by an amount equivalent to 12% of the current total human emissions [22-24].

Accounting Boundary

The estimation of carbon sequestration potential in biomass char is typically conducted through a life cycle assessment (LCA) [25], encompassing the entire process from raw material collection and biomass char production to field application. This comprehensive approach considers intermediate stages such as the transportation of raw materials and biomass char to estimate greenhouse gas emission balances. Therefore, the accounting boundaries for this study are delineated as follows:

1. The energy released during the preparation of crop residues for biomass char production, substituting for fossil fuels, results in a reduction in greenhouse gas emissions.

2. The biomass char prepared remains stably sequestered in the soil over the long term, contributing to the carbon sequestration potential of the soil.

3. The carbon sequestration achieved through the burial of biomass char derived from crop residue preparation in the soil enhances crop growth.

4. The application of biomass char reduces the need for synthetic fertilizers, thereby mitigating the greenhouse gas emissions associated with fertilizer production.

5. Biomass char suppresses N_2O emissions from the soil.

6. Greenhouse gas emissions and energy consumption during the transportation of raw materials and the final biomass char product are considered in the overall assessment.

Carbon Reduction Potential

Renewable energy is replacing fossil fuel combustion in terms of carbon sequestration potential. In the preparation process of biochar, three main products are generated: biochar, bio-oil, and syngas. The primary products vary depending on the pyrolysis method employed, including slow pyrolysis, fast pyrolysis, and gasification. Under slow pyrolysis conditions, the yields of biochar, bio-oil, and syngas are 35%, 30%, and 35%, respectively. Although both bio-oil and syngas possess certain calorific values during pyrolysis, current technological limitations prevent the direct utilization of bio-oil for electricity generation. However, the quantity of bio-oil produced can contribute to the energy requirements of the pyrolysis process. In 2020, China's collectible crop straw amounted to 3.04×10^8 t (Fig. 1), and the syngas produced during biochar preparation could generate approximately 0.62×10^{11} kWh of electricity, equivalent to around 0.66×10^8 t of CO_{2e} (Table 4). Regarding biochar production and carbon sequestration, variations exist in the carbon content of different crop straws, leading to differences in biochar yield and carbon content. This study primarily considers the biochar yields of rice, wheat, corn, and soybean, using their average values as a calculation standard for other crop varieties. The estimated biochar production potential from crop straw in 2020 is 7.16×10^7 t (Table 4). Accounting for unstable components in biochar, assumed to be 20%, and taking the median carbon content of 57.19%-72.84%, the total sequestered carbon is estimated to be 4.46×10^7 t, equivalent to 1.64×10^8 t of CO_{2e}. Regarding the carbon sequestration potential of biochar application to enhance crop yield, biochar incorporation into soil can improve acidity, raise pH levels, enhance soil water retention capacity, promote crop growth, and increase crop yields. Considering variations in the yield-enhancing effects of biochar on different crop varieties, this study focuses on rice, wheat, and corn, with an average application rate of 38.13 t per hectare. The estimated area suitable for biochar application is 1.79×10^6 hectares, resulting in a carbon sequestration potential of 2.42×10^4 t, equivalent to 8.88×10^4 t of CO_{2e}. In terms of reducing CO_{2e} emissions from fertilizer production, biochar contains trace elements that can enhance soil microbial diversity, improve soil fertility, and increase fertilizer use efficiency. Applying biochar at a certain ratio can reduce the application of conventional fertilizers and increase nitrogen fertilizer recovery. This study focuses on grain crops, with N, P, and K fertilizer application rates of 273.1, 238.5, and 223.6 kg/ha, respectively. Compared to conventional fertilization, a 10% reduction in nitrogen and a 20% reduction in phosphorus and potassium fertilizers could result in an estimated reduction of 8.58×10^5 t of CO_{2e} emissions. Concerning the inhibition of N_2O emissions by biochar, N_2O is a major greenhouse gas, with a global warming potential (GWP) 298 times that of CO_2. Agricultural soils are a significant source of N_2O emissions, accounting for 66.2% of the total emissions. Biochar incorporation into soil significantly mitigates N_2O emissions, with an estimated reduction of 1.71×10^3 t of N_2O emissions, equivalent to a reduction of 5.09×10^5 t of CO_{2e} emissions. Regarding greenhouse gas emissions during raw material collection, biochar production, and spreading processes, calculations based on the energy consumption of the entire process estimate greenhouse gas emissions during straw collection and transportation at 2.39×10^7 t. Additionally, greenhouse gas emissions during biochar spreading, along with other fertilizers, are approximately 3.24×10^6 t. The total greenhouse gas emissions during raw material and biochar transportation, as well as biochar spreading, amount to 1.03×10^7 t (Table 5).

Table 4. Biochar Production and Electricity Consumption During Its Preparation.

Items	Results
Biochar production	7.16×10^7 t
Preparation process power output	0.62×10^{11} kg·(KW·h)$^{-1}$

Conclusions

The Yangtze River Economic Belt region possesses 39.38% of China's total straw resources. If these straws could be transformed into biochar, the overall potential for mitigating greenhouse gas emissions from straw in the region would amount to 2.18×10^8 t. In support of achieving China's "dual carbon" goals, this study provides data support for the accurate and rational assessment of the carbon sequestration capacity of crop straw biochar in the Yangtze River Economic Belt region. The research suggests that the utilization of crop straw for biochar production holds significant potential and is deemed an effective approach for carbon emission reduction in the agricultural sector. To advance these efforts, it is recommended that government authorities focus on biochar production from agricultural straw. Support through policies and funding should be directed towards field trials assessing the application effectiveness

Table 5. Calculation of Greenhouse Effect Mitigation Potential of Biochar Prepared by Straw.

Accounting Items	Accounting Results/t
Reduces CO_2 emissions by replacing coal combustion	0.66×10^8
Biochar soil sequestration fixed CO_2	1.64×10^8
Crop C-fixation	2.42×10^4
Increased crop yield fixed CO_2	8.88×1^04
N_2O emission reductions (CO2e)	5.09×1^05
Fertilizer application reduces CO_{2e} emissions	8.58×10^5
CO_{2e} emissions from straw feedstock, and biochar transport	1.03×10^7
CO_{2e} emissions from biochar dispersal	3.24×1^06
Total emissions (CO_{2e})	1.35×10^7
Net potential for greenhouse effect mitigation (CO_{2e})	2.18×1^08

of biochar in soil. Subsequently, the formulation of biochar-related standards is encouraged to ensure the judicious and scientifically tailored application of crop straw-derived biochar, achieving the dual benefits of carbon emission reduction and soil restoration with increased yields.

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Conflict of Interest

The authors declare no conflict of interest.

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