

Collectable Amounts of Straw Resources and Their Distribution in China

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Keywords: straw resources; Straw-grain ratio; collectable coefficient; collectable amount; distribution

Abstract. Crop straw is a valuable renewable resource, which holds great potential to be developed further. The estimation of the yield and collectable amount of crop straw is a foundation for its comprehensive utilization. Based on the output of major farm products, the collectable amounts of different kinds of crop straw in China and their distribution were estimated in this study. China holds enormous crop straw resources, and more than 60986.1×10^4 t of straw resources could be collected in 2014. Corn stalk, rice straw and wheat straw were the three most abundant crop straws, whose collectable amounts in 2013 reached 21481.0×10^4 , 15420.1×10^4 and 11519.4×10^4 t, accounting for 35.2%, 25.3% and 18.9% of the total collectable crop straw, respectively. Henan, Heilongjiang and Shandong were the richest provinces in straw resources, where the collectable amounts of the three crop straws reached 6142.1×10^4 , 5901.0×10^4 and 4894.5×10^4 t, accounting for 10.6%, 10.2% and 8.4% of total collectable amount of those in China, respectively.

1. Introduction

The product of crop photosynthesis includes both the seeds and the straw from harvested crops. As inevitable by-product in agricultural production, crop straw is produced in huge quantity every year. Crop straw is a valuable renewable resource, and its comprehensive utilization plays an important role in the sustainable development of agriculture. The estimation of the yield and collectable amounts of straw resources is one of the foundations of the utilization of crop straw. Many studies on estimation of straw resources have been performed using different methods, however, with large-scale differences in those calculation results [1-3]. In this study, based on the outputs of major farm products from authoritative data sources, the reserves and collectable amounts of different kinds of straw resources in China were estimated. In addition, the distribution of the three major crop straws, corn stalk, rice straw and wheat straw, was analyzed.

2. Methods

All the outputs data of major farm products comes from *China Statistical Yearbook 2014* and the web site of *National Bureau of Statistics of China* [4].

Straw-grain ratio (S_G) refers to the ratio of yield of crop straw to output of main product of the crops. The straw-grain ratios used in this paper are referenced from a previous study [5]. The reserve of crop straw (W_S) is calculated from Eq.1.

$$W_S = W_P \times S_G, \quad (1)$$

where W_P is the output of main product of the crop and S_G the straw-grain ratio.

The collectable amounts

The collectable amount of straw resource refers to the maximum quantity of crop straw that can be collected from the field for further utilization in the actual operations of farming and harvesting management. The collectable amount of crop straw (W_{GS}) is calculated from Eq.2.

$$W_{GS} = W_S \times I_G, \quad (2)$$

where W_S is the yield of crop straw and I_G the collectable coefficient referring to the proportion of collectable and utilizable crop straw in total yield of crop straw. The collectable coefficients used in this paper are referenced from a previous study [6].

3. Results

3.1. Estimation results of crop straw resources in China

As a major country of grain production, China has enormous crop straw resources. Based on the output data of major farm products from *China Statistical Yearbook 2014* and the relevant data from the *National Bureau of Statistics of China*, and referencing the straw-grain ratios described in a previous study [5], the yields of crop straw in China in the last three years were calculated (Table 1). Taking straw resources produced in 2014 as an example, the output of main crop straw in China reached 72836.9×10^4 t, and the yields of corn stalk, rice straw and wheat straw were 25880.8×10^4 , 18578.4×10^4 and 13878.8×10^4 t, accounting for 35.4%, 25.5% and 18.7% of the total quantity of crop straw, respectively. As the three major straw resources, the reserve of corn stalk, rice straw and wheat straw contributed nearly 80% to the total output of the agricultural crop straw, which holds great potential to be developed further.

Table 1 National estimated amounts of crop straw resources in 2012-2014

Crops	Grain-straw ratios	Output of farm products ($\times 10^4$ t)			Straw yield ($\times 10^4$ t)			Percent in total straw (%)
		2012	2013	2014	2012	2013	2014	
Rice	0.9	20423.6	20361.2	20642.7	18381.2	18325.1	18578.4	25.5
Wheat	1.1	12102.3	12192.6	12617.1	13312.5	13411.9	13878.8	18.7
Corn	1.2	20561.4	21848.9	21567.3	24673.7	26218.7	25880.8	35.4
Beans	1.6	1730.5	1595.3	1625.7	2768.8	2552.5	2601.1	3.7
Tubers	0.5	3292.8	3329.3	3357.3	1646.4	1664.7	1678.7	2.3
Peanuts	0.8	1669.2	1697.2	1648.2	1335.4	1357.8	1318.6	1.9
Rapeseeds	1.5	1400.7	1445.8	1477.2	2101.1	2168.7	2215.8	3.0
Sesame	2.2	63.9	62.3	63.0	140.6	137.2	138.6	0.2
Cotton	3.4	683.6	629.9	616.1	2324.2	2141.7	2094.7	3.0
Fiber crops	1.9	26.1	22.9	23.1	49.6	43.6	43.9	0.1
Sugarcane	0.3	12311.4	12820.1	12561.1	3693.4	3846.0	3768.3	5.2
Beetroots	0.2	1174.0	926.0	800.0	234.8	185.2	160.0	0.3
Tobacco	1.6	340.7	337.4	299.5	545.1	539.8	479.2	0.7
Total	-	75780.2	77269.0	77298.3	71206.8	72592.7	72836.9	100

3.2. Estimation results of collectable amounts of straw resources in China

Based on the estimated amount of straw resources (Table 1), and according to the collectable coefficients confirmed by the previous study [6], the collectable amounts of various types of crop straw were calculated and presented in Table 2. The estimation results showed that the total amount of straw resources can be collected in China in 2014 was about 60986.1×10^4 t, and about 16% of crop straw was remained in the field or wasted in the collection process. Corn stalk, rice straw and wheat straw were the three most abundant crop straw resources which contributed nearly 80% to the total collectable reserves. The collectable corn stalk, rice straw and wheat straw were 21481.0×10^4 , 15420.1×10^4 and 11519.4×10^4 t, accounting for 35.2%, 25.3% and 18.9% of the total collectable crop straw, respectively.

Table 2 Total yield and collectable amounts of straw resource in 2014

Straw types	Straw yield ($\times 10^4$ t)	Collectable coefficient	Collectable amount ($\times 10^4$ t)	Percent in total collectable amount (%)
Rice straw	18578.4	0.83	15420.1	25.3
Wheat straw	13878.8	0.83	11519.4	18.9
Corn stalk	25880.8	0.83	21481.0	35.2
Beans straw	2601.1	0.88	2289.0	3.8
Tubers vine	1678.7	0.80	1342.9	2.2

Continued from Table 2

Straw types	Straw yield ($\times 10^4$ t)	Collectable coefficient	Collectable amount ($\times 10^4$ t)	Percent in total collectable amount (%)
Peanuts vine	1318.6	0.85	1120.8	1.8
Rapeseeds stalk	2215.8	0.85	1883.4	3.1
Sesame stalk	138.6	0.85	117.8	0.2
Cotton stalk	2094.7	0.90	1885.3	3.1
Fiber crops stalk	43.9	0.87	38.2	0.1
Sugarcane bagasse	3768.3	0.88	3316.1	5.4
Beetroots pulp	160.0	0.88	140.8	0.2
Tobacco stalk	479.2	0.90	431.3	0.7
Total			60986.1	100.0

3.3. Distribution of main straw resources in China

In recent years, the yield of crop straw in China is increasing. Due to the different geographical position and climatic condition, the distribution and collectable amounts of different crop straws are also different. Table 3 presents the provincial data of collectable amounts of corn stalk, rice straw and wheat straw in recent three years. In 2013, for example, corn stalk is the most abundant straw resources, whose output accounted for 35% of main crop straw production. The collectable corn stalk mainly distributed in north-eastern provinces, such as Heilongjiang, Jilin and Liaoning, and north China, such as Henan, Hebei, Shandong, Inner Mongolia and Shanxi. Rice straw is the second most abundant straw resources, accounting for 25% of main crop straw production, which is mainly distributed in south China and east China, such as Hunan, Hubei, Sichuan, Jiangxi, Jiangsu, Anhui, Guangxi and Guangdong, and Heilongjiang province in northeastern China. As the third largest straw resources, wheat straw accounted for about 19% of the main crop straw production, mainly distributing in Henan, Hebei, Shandong, Anhui and Jiangsu provinces. Henan province, Heilongjiang province and Shandong province had the largest quantities of straw resources, in which the yields of those three crop straws were 6142.1×10^4 , 5901.0×10^4 and 4894.5×10^4 t, accounting for 10.6%, 10.2% and 8.4% of total collectable amount of those three crop straws in China, respectively.

Table 3 Provincial estimated amounts of corn stalk, rice straw and wheat straw in 2011-2013

Provinces	Corn stalk ($\times 10^4$ t)			Rice straw ($\times 10^4$ t)			Wheat straw ($\times 10^4$ t)		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Beijing	90.0	83.2	74.9	0.1	0.1	0.1	25.9	25.1	17.1
Tianjin	94.0	92.0	101.8	8.0	8.4	9.6	49.5	50.9	52.3
Hebei	1633.1	1642.9	1697.1	45.0	37.2	43.9	1165.1	1221.3	1266.5
Shanxi	851.2	900.2	951.7	0.4	0.4	0.5	219.4	236.6	210.7
Inner Mongolia	1625.6	1777.3	2061.5	58.2	54.7	41.8	156.0	172.1	164.7
Liaoning	1354.9	1417.8	1556.9	377.3	379.3	378.6	3.4	2.9	2.5
Jilin	2329.6	2568.4	2764.6	465.8	390.7	420.7	1.2	1.2	0.0
Heilongjiang	2665.0	2876.4	3203.6	1540.4	1621.9	1658.8	94.8	63.9	35.5
Shanghai	2.7	2.5	2.5	66.4	66.6	64.8	22.0	20.6	16.1
Jiangsu	225.3	229.2	215.6	1392.5	1419.4	1435.9	934.2	957.5	1005.5
Zhejiang	14.5	29.1	26.6	484.8	454.3	433.4	24.7	24.7	25.4
Anhui	361.1	425.8	424.3	1036.2	1041.0	1017.7	1110.0	1181.4	1216.1
Fujian	16.5	17.9	19.2	384.0	376.3	375.0	0.7	0.7	0.6
Jiangxi	10.5	12.5	12.0	1456.7	1476.1	1497.0	2.0	2.1	2.2
Shandong	1970.8	1986.5	1959.3	77.7	77.2	77.4	1920.9	1989.9	2025.8
Henan	1689.7	1740.8	1789.3	354.5	367.9	362.9	2851.3	2900.9	2945.8
Hubei	275.1	281.5	269.7	1207.8	1233.5	1252.5	314.8	281.0	380.6
Hunan	187.7	196.5	184.3	1923.9	1965.9	1913.5	9.3	7.8	10.0

Continued from Table 3

Provinces	Corn stalk ($\times 10^4$ t)			Rice straw ($\times 10^4$ t)			Wheat straw ($\times 10^4$ t)		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Guangdong	78.6	79.3	81.3	819.4	841.5	780.6	0.2	0.2	0.3
Guangxi	243.8	249.6	264.9	809.8	853.1	863.7	0.2	0.2	0.2
Hainan	10.3	11.3	12.0	108.4	116.4	112.0	0.0	0.0	0.0
Chongqing	256.0	255.2	257.1	368.7	372.0	375.8	38.7	35.1	30.8
Sichuan	698.8	698.5	759.4	1140.8	1147.5	1157.5	398.1	399.0	384.6
Guizhou	242.8	340.9	296.8	227.0	300.6	269.9	46.0	47.8	47.1
Yunnan	595.9	697.2	731.2	499.5	481.5	498.9	90.3	80.6	73.5
Tibet	2.7	2.6	2.5	0.4	0.4	0.4	22.7	22.4	22.0
Shaanxi	548.5	564.6	584.4	63.2	65.2	68.0	375.2	397.7	355.9
Gansu	423.9	502.1	569.2	0.0	2.9	2.8	226.0	254.5	215.4
Qinghai	15.1	16.9	16.4	0.0	0.0	0.0	32.3	32.1	32.9
Ningxia	171.7	190.4	205.4	52.9	53.3	51.5	57.5	56.6	42.2
Xinjiang	515.6	589.7	666.3	45.3	42.1	44.7	526.5	526.4	549.7
China	19201.0	20479.2	21761.5	15014.8	15247.4	15232.2	10718.7	10993.1	11131.9

4. Conclusions

China holds enormous crop straw resources. Estimated from the outputs data of major farm products from *National Bureau of Statistics of China*, more than 60986.1×10^4 t of straw resources can be collected in China in 2014. The collectable corn stalk, rice straw and wheat straw were 21481.0×10^4 , 15420.1×10^4 and 11519.4×10^4 t, accounting for 35.2%, 25.3% and 18.9% of total amount of collectable straw, respectively. Henan, Heilongjiang and Shandong were the richest provinces in straw resources, where the collectable quantities of the three crop straws reached 6142.1×10^4 , 5901.0×10^4 and 4894.5×10^4 t, respectively.

Acknowledgements

This work was financially supported by the Natural Science Foundation of Hainan Province (Grant No. 20154194) and the Fundamental Scientific Research Funds for Chinese Academy of Tropical Agricultural Sciences (Project No. 1630052015044).

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