Quantity and Utilization of Crop Straw Resources in China

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Abstract. China is one of the major agricultural countries in the world, which is rich of crop straw resources. However, the types, quantities and changes of straw resources of major crops have not been known for a long time. This paper tries to estimating the quantities of straw resources of major food crops, which uses the output data of five major food crops such as rice, corn, wheat, beans, and potatoes in China in 2019. On the basis of scientifically determining the Residue to Product Ratio(RPR), this paper uses the grass-to-valley ratio method to measure the quantities of straw resources of major food crops, in order to provides reference and decision support for the development of comprehensive straw utilization policies and plans in China. At last, this paper points out the problems existing in the comprehensive utilization of straw resources in China and proposes countermeasures based on the actual situation.

Keywords: Quantity of Crop Straw, The Residue to Product Ratio, Utilization Problem

1. Introduction
Energy resources are one of the important forces to promote the progress of human society. Since the beginning of the 20th century, with the rapid development of society and economy, the population has exploded and resulting in a substantial increase in the consumption of fossil energy, such as coal, oil, natural gas and so on. This situation has directly led to the decrease of traditional non-renewable energy sources, and caused a series of problems such as the world energy crisis and environmental pollution and ecological damage. Biomass energy represented by crop straw resources is a kind of recyclable, clean and pollution-free renewable energy [1]. The exploitation and utilization of crop straw resources can effectively alleviate the contradiction of energy supply shortage and reduce the damage to the ecology and environment caused by the use of fossil energy.

China is a large country of agricultural production, which crop straw resources are very rich. Under the great attention of the government and after years of cultivation by the majority of scientific research institutions and related enterprises, comprehensive utilization of crop straw resources have developed a lot in China [2]. However, the type, quantity and changes of straw resources of major crops have not been known for a long time, which has restricted the development of comprehensive utilization of crop straw resources. In this context, this paper combines the output data of China's major food crops such as rice, corn, wheat, beans, and potatoes in 2019, scientifically determines the RPR, and estimates the quantities of straw resource of the main food crop, in order to provides
reference and decision support for the development of comprehensive straw utilization policies and plans in China.

2. Quantity Estimation of Crop Straw Resources

2.1. The output of Grain crops
Before the comprehensive utilization of crop straw resources, we must first understand the types and quantities of crop straw resources, which is prerequisites for large-scale industrial using. China is an important agricultural country in the world whose output of major food crops and other agricultural and sideline products has maintained world-leading levels[3]. Since the beginning of the new century, the government attaches great importance to the national food security work and China's output of grain continues to grow rapidly, except the year of 2018 which output was slight reduced in due to natural disasters and adjustment of planting structure. In the rest years, China's grain output continued to increase and made a great historic achievement of “fifteen-year increase” in grain output which has a clear leading edge globally[4]. The data are shown in Table 1 which come from China Statistical Yearbook 2019.

| Year | Total | Rice  | wheat | corn   | Beans crops | Potato crops |
|------|-------|-------|-------|--------|-------------|--------------|
| 2013 | 63048 | 20629 | 12371 | 24845  | 1542        | 2855         |
| 2014 | 63965 | 20961 | 12832 | 24976  | 1565        | 2799         |
| 2015 | 66060 | 21214 | 13264 | 26499  | 1513        | 2729         |
| 2016 | 66044 | 21109 | 13327 | 26361  | 1650        | 2726         |
| 2017 | 66161 | 21268 | 13433 | 25907  | 1842        | 2799         |
| 2018 | 65789 | 21213 | 13144 | 25717  | 1920        | 2865         |
| 2019 | 66385 | 20960 | 13360 | 26075  | 2130        | 2885         |

As shown in table 1, China's grain output continues to grow in terms of totals who increased from 63.048 million tons in 2013 to 66.385 million tons in 2019, with a net increase of 33.37 million tons and a growth rate of 5.3%, achieving the great historic achievement of “fifteen-year increase”. Data released by the National Bureau of Statistics shows that the country's total grain output was about 65.789 million tons in 2018 which get a decrease of 3.71 million tons and a 0.6% decrease over the same period in 2017. This is mainly because local governments have conscientiously implemented the spirit of the No. 1 Document of the CPC Central Committee, further promoted structural reforms on the supply side of agriculture, actively reduced rice and corn plantations with large stocks, expanded soybean planting and developed economic crops in accordance with local conditions which under the strong leadership of the Party Central Committee and the State Council[5]. Although the annual grain output declined, but the decrease was not significant and was still at a high level, which is still a year of bumper harvest in 2018.

Look separately, The output of rice has not changed much in 7 years which is stable at about 21 million tons, and it has experienced a process of first growth and then decline. In 2017, the output of rice reached a peak of 21268 million tons; the output of wheat is gradually increasing, but the growth rate is slow. The current output is maintained at about 130 million tons, and the output in 2017 reached a peak of 13.433 million tons; output changes of corn are more obvious, showing a marked rapid increase and a gradual decline. In the year of 2015, China's corn production reached 264.99 million tons, reaching a historical high. Since then, the corn planting area has begun to decline due to the adjustment of the planting structure, and the corn production has also started to decrease. Output of corn are now maintained at about 250 million tons; due to China's soybean revitalization plan, the output of legume crops has shown a slow decline and has gradually started to pick up in recent years. While ensuring national food security and food production capacity is not reduced, various regions of China actively promote structural reforms on the supply side of agriculture, reduce the cultivation of low-quality and inefficient crops and expand the planting scale of crops such as soybean and...
miscellaneous grain in 2019. This is resulting in the planting area of legume crops in China reached 166 million mu, an increase of 13.32 million mu over the previous year and reached a growth rate of 8.7%. Among them, the soybean planting area was 140 million mu, an increase of 13.82 million mu over the previous year and an increase of 10.9%. Therefore, the comprehensive utilization of legume crop straw is the focus in the future[6].

2.2. Establishment of the Residue to Product Ratio
Because the complication of the reality, there have been some research about the quantities of straw resources across the country which shows that there are large differences about quantities between the same straw resources in different years or in different periods in the same year, which are caused by four main reasons[7]. The first is the difference in measurement methods. There are two main methods for measuring the quantities of crop straw resources at this stage, one is estimating crop straw quantities directly through field research and another is by the Residue to Product Ratio method. Then the difference in the value of the Residue to Product Ratio will affect the results of the measurement of straw resources. The second is the difference in crop biological output and estimated accuracy, such as the impact of high and poor years, which will cause inter-annual differences in estimated straw resources. The third is the difference in statistics of crop types. Some scholars have ignored crop straws such as hemp, sugar, melons and vegetables. The estimated straw resources only counted crops such as grain, cotton and oil crops. The fourth is the difference in the definition of straw. In some studies, straw only includes “field straw” and does not include shell residues such as peanut shells. As shown in Table 2, in order to measure the total quantities of crop straw resources in China as accurately as possible, this paper summarizes the RPR of different crops based on previous literature and get our own result.

Table 2. Residue to Product Ratio(RPR).

| Crop category     | RPR | Crop category     | RPR |
|-------------------|-----|-------------------|-----|
| Rice              | 0.93| Potato crops      | 0.48|
| Wheat             | 1.38| Oil crops         | 1.84|
| Corn              | 1.17| Cotton            | 5.09|
| Millet            | 1.40| Hemp crops        | 4.28|
| Sorghum           | 1.49| Sugar crops       | 0.2 |
| Other cereals     | 1.47| Tobacco crops     | 0.63|
| Legumes           | 1.62|                   |     |

2.3. Quantity of crop straw resources
The calculation of the quantities of crop straw resources is based on the original economic output of the crops which can be found on the websites of China Statistical Yearbook, China Agricultural Statistical Yearbook, National Bureau of Statistics and provincial and municipal statistical bureaus. Therefore, we can use the RPR method to estimate the theoretical resource of the main crop straw resources in China. The calculation formula is:

\[ P_i = \sum_{i=1}^{n} \lambda_i * G_i \]  

(1)

In the type: \( P_i \) is the total crop straw resources in theoretical; \( i \) is the number of straw species; \( G_i \) is the economic output of type \( i \) crops; \( \lambda_i \) is the RPR of \( i \) crop. As shown in Table 3, we can get the theoretical output data of crop straw resources in China through calculation.
Table 3. Theoretical quantities of crop straw resources/10^4 t.

| Year | Total | Rice | wheat | corn | Beans crops | Potato crops |
|------|-------|------|-------|------|-------------|--------------|
| 2013 | 69192 | 19185| 17072 | 29067| 2498        | 1370         |
| 2014 | 70303 | 19494| 17708 | 29222| 2535        | 1344         |
| 2015 | 72798 | 19729| 18304 | 31004| 2451        | 1310         |
| 2016 | 72845 | 19631| 18391 | 30842| 2673        | 1308         |
| 2017 | 72954 | 19779| 18536 | 30311| 2984        | 1344         |
| 2018 | 72441 | 19728| 18139 | 30089| 3110        | 1375         |
| 2019 | 73274 | 19493| 18437 | 30508| 3451        | 1385         |

As shown in table 3, the theoretical total number of straw resources of the five major food crops of rice, wheat, corn, beans and potatoes in China has jumped to more than 700 million tons since 2014 and it has maintained a rapid growth trend, which is consistent with China's successive years of bumper grain production and output growth. In 2018, due to the adjustment of the national planting structure and natural disasters in some areas, grain and straw production both declined.

In terms of items, the theoretical output changes of straw resources of the five main crops of rice, wheat, corn, beans, and potatoes are consistent with the changes in the economic output of the aforementioned five main crops.

When collecting crop straw resources, excessive straw collection can adversely affect soil, environment, and crop output and many crops need to be harvested with stubble, and some branches and leaves fall off during the collection process [8]. The quantities of collectable crop straw resources will also be affected by factors such as collection methods and climate, so this article considered that some waste biomass during the straw collection process needs to be left in the land to meet the requirements of environmental and farming sustainability when calculating the total theoretical resources of crop straws[9]. The formula for the quantities of straw collectible resources is:

\[ p_c = \sum_{i=1}^{n} \eta_i (\lambda_i * G_i) \]  \hspace{1cm} (2)

In the type, \( p_c \) stands for total crop straw resources that can be collected, \( \eta_i \) is Collectible utilization rate of type \( i \) crop straw. Some Studies have shown that when the Collectable ratio rate of crops is between 30% to 70%, the sustainability of cultivated land can be guaranteed. Thus, in this paper the collectable ratio rate of crops selected is 70%, and the collectable and utilizable amount of straw of the main crops is calculated as shown as Table 4.

Table 4. Collection quantities of crop straw resources/10^4 t.

| Year | Total | Rice | wheat | corn | Beans crops | Potato crops |
|------|-------|------|-------|------|-------------|--------------|
| 2013 | 69192 | 19185| 17072 | 29067| 2498        | 1370         |
| 2014 | 70303 | 19494| 17708 | 29222| 2535        | 1344         |
| 2015 | 72798 | 19729| 18304 | 31004| 2451        | 1310         |
| 2016 | 72845 | 19631| 18391 | 30842| 2673        | 1308         |
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| 2018 | 72441 | 19728| 18139 | 30089| 3110        | 1375         |
| 2019 | 73274 | 19493| 18437 | 30508| 3451        | 1385         |

From the total point of view, the total amount of straw resources that can be collected and used in China's major food crops keeps increasing, and the rate of increase is getting faster and faster. The amount of straw resources that can be collected and used increased from 480 million tons in 2013 to 510 million tons in 2019, which get an increase of 30 million tons, and a growth rate of more than 6%.
With the continuous increase of China's grain output and the advancement of mechanized harvesting equipment year by year, the amount of straw resources that can be collected and used will continue to grow rapidly. The abundant supply of straw resources constitutes the industrialization basis for comprehensive utilization of straw in China.

In terms of items, the quantities of collection and utilization of rice straw resources showed a trend of rapid growth, and then gradually decreased in 7 years. The peak collection and utilization amount of the rice straw resource appeared in 2017 which was 138.45468 million tons, and is now stable at more than 130 million tons, which is very suitable for large-scale industrial use. The collectable and usable quantities of wheat straw resources showed a rapid growth trend and then a gradual decline in 7 years. The peak of the collectable and usable amount of wheat straw resources was 127.78678 million tons, which also appeared in 2017. The current collectable and usable amount remains at an industrialized utilization level of over 120 million tons. The collection and utilization of corn straw resources is the largest among the five main food crops, which is maintained at more than 200 million tons, and the utilization space is huge. The culmination of the collection of corn straw resources was 217.03 million tons, which appeared in 2015. And in recent years, there has been a gradual decline which mainly because of China's initiative to adjust the agricultural planting structure. The collection and utilization of legume straw resources has shown a marked rapid growth in recent years, from 17.48 million tons in 2013 to 24.15 million tons in 2019, which made an increase of 6.31 million tons and a growth rate of 36%. Furthermore, stimulated by the national soybean revitalization plan, soybean planting area will further expand and the collection and utilization of legume straw resources will increase significantly in the foreseeable future. Legume crop straw is a key area for comprehensive straw utilization in China in the future. The collection and utilization of potato crop straw resources is relatively small, maintaining a low level of 9.5 million tons.

3. Problems in Comprehensive Utilization of Straw Resources in China
Guided by national favorable policies, comprehensive utilization of straw resources has developed rapidly, but some problems have also emerged such as the comprehensive utilization cost of straw is too high, the utilization rate is not so high, the comprehensive utilization structure is unreasonable and the industrial chain about comprehensive utilization of straw resources is short[10]. According to the calculation by the Ministry of Agriculture and Rural Affairs, in 2017, the comprehensive utilization rate of straw resources in China was less than 80%, and a large amount of straw resources was burned or discarded at random compared with more than 90% are comprehensive used in developed countries. The current level of mechanization of straw collection and transportation in China is not high, manual collection methods can only be used in most case which leads to high labor intensity and high labor costs for farmers. The cost of collecting straw resources is much higher than its selling price, and the comprehensive benefit is very low, which has led to a low enthusiasm for farmers to collect and use straw resources [11]. In China, most of the straw is mainly used for low value-added utilization methods such as feed, returning fields, and cooking fuel for farmers. Only a small part is applied to industrial raw materials and new energy sources (Converse straw resources into gas, Burning straw to generate electricity) which are high value-added.

4. Solution
For better comprehensive using of straw resources, we should start to solve existing problems by raising farmers' awareness of comprehensive straw utilization, formulating comprehensive straw utilization planning, reducing utilization costs of straw resources, and strengthening research and development of straw utilization technologies. Government should actively publicize the knowledge of comprehensive utilization of straw resources among farmers, increase the awareness of comprehensive utilization of straw by farmers and fully mobilize their enthusiasm. Also, each region should formulate a long-term plan for comprehensive utilization of crop straws in accordance with the actual situation of agriculture and economy in accordance with the relevant national overall planning and policy guidance. In order to reduce the cost of utilization, each region should formulate and improve the
corresponding tax incentives and fiscal subsidies for different links and different ways of comprehensive utilization of straw resources. At last, the innovation and application of technology is the fundamental way out for the comprehensive utilization of straw industry. Therefore, it is necessary to strengthen technical research on comprehensive utilization of straw, accelerate the introduction and development of new technologies, and continuously open up new ways for comprehensive utilization of straw resources.

5. Conclusion
Quantities of crop straw resources such as rice, wheat, corn, beans, and potato straw resources are abundant in China which calculated by the RPR method. Making full use of China's crop straw resources can not only alleviate China's energy crisis, but also reduce ecological damage and environmental pollution. Facing various problems in the comprehensive utilization of straw resources in China, we need to solve the problems from increasing publicity, formulating comprehensive straw utilization plans, increasing capital investment, strengthening technology research and introducing market mechanisms and so on.

References
[1] Kaiwei Z , Zhen L , Xianchun T , et al. Study on the ecological potential of Chinese straw resources available for bioenergy producing based on soil protection functions[J]. Biomass and Bioenergy, 2018, 116:26-38.
[2] Liu X , Li, Shutian*. Temporal and spatial distribution characteristics of crop straw nutrient resources and returning to farmland in China[J]. Transactions of the Chinese Society of Agricultural Engineering, 2017, 33(21):1-19.
[3] Ru-Qin F , Jia L , Shao-Hua Y , et al. Progresses in Study on Utilization of Crop Straw in Soilless Culture[J]. Journal of Ecology & Rural Environment, 2016, 32(3):410-416.
[4] Wang H , Wang F , Sun R , et al. Policies and regulations of crop straw utilization of foreign countries and its experience and inspiration for China[J]. Transactions of the Chinese Society of Agricultural Engineering, 2016.
[5] Bao J C , Yu J H , Feng Z , et al. [Situation of distribution and utilization of crop straw resources in seven western provinces, China][J]. Ying yong sheng tai xue bao = The journal of applied ecology / Zhongguo sheng tai xue xue hui , Zhongguo ke xue yuan Shenyang ying yong sheng tai yan jiu suo zhu ban, 2014, 25(1):181-187.
[6] WANG Ya-jing B I , Gao Y Y , Chun-yu. The Assessment and Utilization of Straw Resources in China[J]. Chinese Agricultural Sciences, 2010(12):1807-1815.
[7] M. Cui, L. Zhao, Y. Tian. Analysis and evaluation on energy utilization of main crop straw resources in China[J]. Nongye Gongcheng Xuebao/transactions of the Chinese Society of Agricultural Engineering, 2008, 24(12):291-296.
[8] Gao, Liwei, Ma L , Zhang W , et al. Estimation of nutrient resource quantity of crop straw and its utilization situation in China[J]. Transactions of the Chinese Society of Agricultural Engineering, 2009, 25(7):173-179.
[9] Wei Hongjian, Yang Qing.Spatial and Temporal Distribution and Yield of Crop Straw Resources in China[J]. Renewable Energy,2019.9.
[10] Lin Chengxian. Research on the status and development strategy of comprehensive utilization of straw [J]. China Agricultural Information, 2014,05: 29-30.
[11] Liang Wenjun, Liu Jia, Liu Chunjing, et al.Treatment and Recycling of Crop Straws [D]. Chemical Industry Press, 2018.01.