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Distribution characteristics, resource utilization and popularizing demonstration of crop straw in southwest China: A comprehensive evaluation

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ABSTRACT

The resource utilization of crop straw, as a part of energy development strategy, is important in term of economy and environmental protection. Based on statistics for agriculture and data, the distribution characteristics, resource utilization, and popularizing demonstration of crop straw in southwest China were comprehensively evaluated. Occurrence of the straw during the last ten years in the Socio-economic Development Region (SEDR) was estimated. On the basis of it, the critical problems during the utilization processes and the multipurpose utilization technologies of crop straw were discussed. Results showed that theoretical straw yield in southwest China in 2015 was 8.2×10^7 t, and corn straw accounted for 54.28% of the total. The order of the straw yield was corn > rice > bean in the three southwest provinces. At present, crop straw is mainly used as soil amendment, fertilizer, fodder, industrial materials, biogas, and power generation. Moreover, the straw fermentation should be also promoted for ecological agriculture. Current progress in straw resource utilization in the innovative demonstration area, namely Liupanshui Agricultural District (LAD), was illuminated. Resource and utilization of crop straw, via biogas production, feedstuff, and returning to field, was about 82% of the total. At the strategic level, regional SEDR system planning should be overall planed in agricultural field, and it is a critical part of the coordinated development of straw utilization. Through the master plan practice of the demonstration area, the suggestions on state modern construction system of agricultural waste were raised.

1. Introduction

China is a large agricultural country, where agricultural residues are available in large quantities with potential biomass energy (Zhou et al., 2011). Straw, as an important component of agricultural residue, is usually disposed of by incineration, discard, and landfill. Due to the pollution brought by straw and the potential energy it contains, the utilization of straw has been drawn more and more international attention in recent years. The crop straw yield of China, including rice, wheat, corn, bean and potato straw, was about 750 million tons in 2016 (China Statistical Yearbook, 2017), which is a huge amount of easily accessible and renewable resource. Mehmood et al. (2018) reported that the contributions of crop straw burnings for PM2.5 in the atmosphere had increased significantly in North and Northeast China in 2016. Furthermore, more than 30% of straw is left on the field or directly burned outdoors in the eastern and southern provinces of China (Hong et al., 2016). During the harvesting season, straw burning might bring about a regional environmental pollution (Li et al., 2017). Straw burning could release a lot of air pollutants such as soot, nitrogen oxides, sulfur dioxide and polycyclic aromatic hydrocarbons (PAHs), causing serious deterioration of atmospheric quality and affecting the health of people (Hong et al., 2016). Currently, Chinese government has paid much attention to dispose straw for preventing and controlling the atmospheric pollution. The prohibition of straw burning has been strictly implemented in 2014 (State council of China, 2014). The policy has made some achievements so far, but several problems also cannot be ignored. For example, the way to deal with crop straw in Guizhou province was either open burning or discard at will, which led to resource waste and environment pollution in the last decades (Zhang et al., 2017). Therefore, there is still a lot of work to do to develop the

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Table 1
Straw yield in three southwest provinces of China in 2015.

Crop types	RPR coefficient	China		Sichuan		Yunnan		Guizhou	
		Grain output ($\times 10^7$ t)	Straw yield ($\times 10^7$ t)	Grain output ($\times 10^7$ t)	Straw yield ($\times 10^7$ t)	Grain output ($\times 10^7$ t)	Straw yield ($\times 10^7$ t)	Grain output ($\times 10^7$ t)	Straw yield ($\times 10^7$ t)
Rice	0.623	20.82	12.97	1.55	0.97	0.66	0.41	0.42	0.26
Wheat	1.336	13.02	17.39	0.43	0.57	0.09	0.12	0.06	0.08
Corn	2	22.46	44.93	1.53	3.06	0.37	0.75	0.32	0.65
Bean	1.5	1.59	2.38	0.15	0.22	0.09	0.14	0.03	0.05
Potato	0.5	3.33	1.66	0.26	0.13	0.39	0.19	1.22	0.61
Total		61.22	79.33	3.92	4.95	1.60	1.61	2.05	1.65

straw utilization.

At present, the studies on the straw resource solely focused on the occurrence, straw burning, utilization, collection and storage. Li et al. (2017) reported that food crop straw is considered an ideal candidate for clean energy production, and approximately 59.3% of the straw was produced from central and eastern China. Yang et al. (2010) analyzed the potential for energy utilization of biomass resource such as crop straw, forest biomass livestock manure and municipal solid waste in China. It is noticed that a large difference existed between the highly populated East and the sparsely inhabited West regions in China. Therefore, to address environmental challenges posed by proper handling of straw, several sustainable strategies should be developed in China (Qu et al., 2012). Zeng et al. (2007) reviewed the technologies utilized to extract energy in biomass in China, including improved furnace, biogas production, straw gasification and straw briquette. Zhang and Ma (2015) assessed five types of straw-reuse technologies (straw-biogas production, -briquetting, -based power generation, -gasification, and -bioethanol production) in northeast China, using emergy analysis. Zhou et al. (2011) estimated the sustainable biomass as a resource for energy in China, using agricultural residues, forest residues and municipal solid waste. According to the Emergetic Ecological Footprint method, the circulation modes of straw utilization were investigated (Liu et al., 2017). Wang et al. (2010) calculated the collectable and reusable coefficients of straw in the Huang-Huai-Hai area (the area along the Yellow River, Huai River, and Hai River) of China, and discussed the collectable and reusable volume of straw during 2005. Meanwhile, the logistics cost analysis of rice straw pellets for feasible production capacity and spatial scale in Nanporo town of Japan were presented (Ishii et al., 2016). Soam et al. (2017) estimated the potential utilization practice of straw from an environmental perspective in India. Silalertruksa and Gheewala (2013) compared and assessed the life cycle of rice straw utilization for fuels and fertilizer in Thailand. Sasaki et al (2016) discussed the utilization of straw in methane fermentation and lignin recovery by a combinational process involving mechanical milling, supporting material and nanofiltration. Despite these previous work, little has been done on the utilization of straw resource regard to its distribution characteristics in certain areas. Grain output accounted for more than 80% of crop yield in China. The straw resource in southwest China, such as Yunnan, Guizhou and Sichuan province, is featured by its multiple variety, huge quantity and wide distribution. For those reasons, it deserves to have a careful evaluation on its distribution characteristics, resource utilization and popularizing demonstration in this region.

The objectives of this work are: 1) to illuminate the current situation of crop straw in southwest China; 2) to investigate the straw treatment and utilization technologies; 3) to assess the existing demonstration projects; 4) to provide new evidence and more comprehensive fundamental data for the energy conservation and emission reduction; 5) to raise some suggests for future development in agricultural waste recycling and treatment.

2. Research status on crop straw in southwest China

2.1. Data analysis

The original data information was mainly collected from (1) “China Statistical Yearbook”, (2) “Yunnan Statistical Yearbook”, (3) “Guizhou Statistical Yearbook”, (4) “Sichuan Statistical Yearbook”, etc.

The theoretical straw yield can be estimated by following equation (Wang et al., 2010; Zeng et al., 2007):

$$M = \varepsilon \times F \quad (1)$$

Where M (t) is the theoretical straw yield, ε is the coefficient of Residue-to-Production Ratios (RPR), F (t) is the grain output.

2.2. Quantity and composition of crop straw

Straw is residues or by-products of harvesting crops. However, the straw yield has not been listed by any related statistic departments, rather it is often estimated based on the crop output and the corresponding Residue-to-Production Ratios (RPR) (Singh, 2016). There are the abundant crop straw resource in the predominantly agricultural provinces (Yunnan, Guizhou and Sichuan), located in southwest China.

The grain output, RPR coefficient (Zhang et al., 2013) and straw yield were showed in Table 1. The total output of crop straw was 8.2×10^7 t in the three southwest provinces in 2015, which accounted for 13.42% in China. The difference of straw yield among Yunnan, Guizhou and Sichuan province was observed ubiquitously. The total straw yield was the highest in Sichuan province, which accounted for 60.31% of the three provinces. The following was Guizhou and Yunnan province, which accounted for 20.09% and 19.60%, respectively. For the types of crop straw, the corn straw was the major crop straw, which was accounted for 54.28% of total crop straw, followed by rice (19.95%), potato (11.33%), wheat (9.41%), and bean (5.02%) straws. In China, they took for 56.64%, 16.35%, 2.09%, 21.92% and 3.00% of the amount of crop straw, respectively.

Percentage of the five crop straws in three southwest provinces of China were shown in Fig. 1. The corn straw was the most dominant type of the five straws in Guizhou, Sichuan and Yunnan provinces and it was accounted for 39.28%, 61.83% and 46.42% of the total straw respectively. The order of the straw yield was corn > rice > bean in the three southwest provinces. However, there were several differences in the composition of straw resource in these provinces. For example, the potato straw took for 36.83% of the total in Guizhou, while that is 12.06% in Yunnan and 2.61% in Sichuan respectively.

2.3. Variation trend of crop straw

As shown in Table 2, the straw yield has gradually increased with an average rate of 2.54% from 2006 to 2015. However, there was the highest value (6.73%) in 2008 and the slowest value (0.01%) in 2009. The straw yield increased from 6.6×10^7 t to 8.2×10^7 t with the rate of 2.46% in the three southwest provinces. The annual growth rate of straw in Guizhou, Yunnan and Sichuan province was 3.07%, 2.56% and