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Field crop residue estimate and availability for biofuel production in China

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ABSTRACT

Exploitation of crop residue biomass resources will improve soil quality, future energy security, global carbon balance, and sustainable crop production. The present study was performed in order to evaluate residue quantities and distribution of field crops in the 31 provinces of China mainland with the latest residue indices, based on a province or a region. The annual average total residue in China (750.36 Mt) was composed of 660.76 Mt field residues (88.1%) and 89.60 Mt process residues (11.9%) on an air dried basis, in 2008 and 2009. Grain cereals of rice (200.56 Mt, 30.35%), wheat (145.91 Mt, 19.45%), and maize (153.85 Mt, 23.28%) were the major crops which produced 500.32 Mt field residue, accounting for 73.08% of the total field residue. The annual field residues produced in the 31 provinces varied between 1.26 Mt (Beijing) and 71.59 Mt (Henan). The field residue was distributed in regions according to the order: Northwest China (54.23 Mt, 8.21%) < North China (75.66 Mt, 11.45%) < Southwest China (80.67 Mt, 12.21%) < Northeast China (89.61 Mt, 13.56%) < Central-South China (179.11 Mt, 27.11%) < East China (181.47 Mt, 27.46%). The SCE of the total crop residue was distributed in the top three regions: Central-South China (112.04 Mt)>East China (104.36 Mt)>Northeast China (55.02 Mt). The average residue yield was between 4.14 t ha^{-1} and 8.65 t ha^{-1} and the residue density was between 17.82 t km^{-2} and 224.45 t km^{-2} in these six regions. The total residue quantity for biofuel production could potentially reach 314 Mt (42%), which is composed of the unused (196 Mt) and the directly combusted fuel (118 Mt).

Contents

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1. Introduction

Crop residue has broad traditional usage as a soil amendment, as cooking and heating fuels in farm households, and as animal feed [1]. Concerns about the security and sustainability of fossil fuel use, coupled with advances in biomass conversion technology, have recently raised the possibility of using crop residues as a potential feedstock for bio-fuels and bio-based chemical production [2–5]. China is one of the biggest crop production countries, producing large quantities of crop residue on the one hand, while its energy consumption is increasing rapidly and is comparable to that of the United States as the world's leading emitters of greenhouse gases, on the other hand. As a result, China announced that by 2020, the country would cut its carbon emissions by 40–45% of the 2005 levels. More than 100 biomass power generation plants have been established, which use only crop and forest residues feedstock. Efficient utilization of an equivalent of 300 million tons of crop residue for bioelectricity generation could add renewable energy to China's energy production [6]. The installed capacity of biomass power generation reached 550 MW in 2010 [7]. Furthermore, commercial scale cellulosic ethanol production is ready to be matured by 2014 [8], indicating a greater need for biomass feedstock in the country. Once technology and subsidy for producing ethanol from cellulosic materials are in place, it may be more efficient and the resultant fuel may have lower emissions than grain ethanol [9]. Assessment of crop residue production is important for maintaining carbon sequestration and soil quality and for developing sustainable biomass energy.

The mean field crop production area was 93.92 M ha, which was 77.16% of the total crop harvest area in China in 2008 and 2009, according to the National Bureau of Statistics of China [10,11]. According to a review by Xie et al. [12], previous studies did not enable reaching proper conclusions on the quantity and distribution of the residues produced in the country, although attention has been paid to field crop residue assessment during the last two decades. The main reason for this is that previous researchers used inappropriate crop residue definition and residue index values, since residue weight was calculated from the product of total crop production and residue index. All previous researchers used the same residue index for the same crop across the 31 provinces. This is not appropriate, because China is very large and has temperate, sub-tropic, and tropic regions from the agro-climatic perspective, and humid, semi-humid, semiarid, and arid zones in terms of precipitation. The residue index of a crop should be different between regions where harvest indices are different, resulting from different varieties, soil fertility levels, management, etc. [13]. Furthermore, the values of the residue index used for assessing residues varied to a large extent and were inconsistent for the same crop between researchers [12]. As a result, the field residue indices used in different studies [14,15] evaluated the total accumulated residues of rice, maize, and wheat, as 63.13% of the total field crops harvest area [10,11]. It is also not clear whether the crop process residue was included or separated from the field residue, because the Field Residue Index (*FRI*) and the Process Residue Index (*PRI*) are not well-defined for each crop (see Wang et al. [16]). Lastly, although some of the previous studies addressed the source of the residue index values, we found that the original source was published some 20 years ago [17,18], after comparing the values among the previous studies [12].

Crop residue is consisted of field residue and process residue. Field residue was defined as material left in an agricultural field after the crop was harvested, including stalks and stubble (stems), and leaves. Process residue was defined as material produced in the primary manufacturing process, including rice hull, maize cob, cotton seed hull, peanut husk, sugarcane bagasse, and sugarbeet bagasse. Field crop residue (total residue) consists of field residue and process residue. The Field Residue Index (*FRI*) was the field residue weight to crop production ratio. The Process Residue Index (*PRI*) was the process residue weight to crop production ratio. It is therefore important to determine crop *FRI* and *PRI* values under current production conditions for crop residue assessment. Our group collected the data of harvest indices of field crops in China mainly from the original papers published between 2006 and 2011. We then determined the *FRI* [14–16] and *PRI* [19] from a total of 212 and 126 sample sites, respectively, based on province for rice, wheat, and maize and based on region for the other field crops, after properly defining the *FRI* and *PRI* (Table 1A and Table 1B). The objective of the present paper is to evaluate field crop residue quantity, diversity, and distribution in the 31 provinces of the China mainland, based on the latest *FRI* and *PRI* values of each province or region and crop production data from 2008 to 2009.

2. Methodology

2.1. Regions and provinces of China Mainland

According to the National Bureau of Statistics of China [10,11], the 31 provinces were divided into six regions (Fig. 1), i.e. North China (NC) including Beijing, Hebei, Inner Mongolia, Shanxi, and Tianjin; Northeast China (NEC) including Heilongjiang, Liaoning, and Jilin; East China (EC) including Anhui, Fujian, Jiangsu, Jiangxi, Shandong, Shanghai, and Zhejiang; Central-South China (CSC) including Guangdong, Guangxi, Hainan, Henan, Hubei, and Hunan; Southwest China (SWC) including Guizhou, Sichuan, Tibet, Yunnan, and Chongqing; and Northwest China (NWC) including Gansu, Ningxia, Qinghai, Shaanxi, and Xinjiang provinces.

2.2. Data collection

The field crops covered in this study were exactly matched to those listed in the China Statistical Yearbook [10,11]. Cereal crops were composed of rice (*Oryza sativa* L.), wheat (*Triticum* spp.), maize (*Zea mays* L.), and 'other cereals'. Fibrous crops included