Research article

Effects of Burning Crop Residues on Soil Quality in Wenshui, Shanxi of China

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Abstract Large amount of crop residues are produced every year in China. Although crop residues are rich in organic matter, nitrogen, phosphorus, potassium, calcium and magnesium, local farmers tend to burn residues in the fields in order to simplify preparation for following cultivations and to enhance the development of economic conditions. Thus, attention has been paid to the effects of crop residues burning on soil environment. The objectives of this study are to observe changes in burning density and to evaluate changes in soil quality caused by burning practices in Wenshui, Shanxi of China. Burning density was analyzed based on the Fire Information for Resource Management System (FIRMS). In addition, onsite experiment on residue burning was conducted in Wenshui and soil samples were collected for evaluating the change of soil quality and soil fauna. It was observed that the burning density in Wenshui of Shanxi in 2009 was much larger at 0.0467 events/km^2/year than that in 2001 at 0.00141 events/km^2/year. Also, the results of onsite experiment on residue burning conducted in Wenshui indicated that soil surface temperature rose to 415 degrees Celsius resulting in the sudden decrease of microorganism population. In addition, values of electrical conductivity (EC) and pH increased to 219 mS/m and 9.04, respectively. However, there was a slight decrease in soil permeability. Burning crop residues on farmland may accelerate nitrogen loss. Besides, concentration of phosphorous in soil tended to increase with the burning process. Therefore, it was concluded that the burning of residues significantly affects soil ecosystem and its quality.

Keywords burning crop residues, soil quality, microorganism

INTRODUCTION

In China, the yield of crop residues is 79,454.4×10^4 tons per year and increases steadily at a rate of 1,251.2×10^4 tons every year (Zhong et al., 2003). Crop residues were important sources of energy in many parts of China, where crop residues were mainly utilized as domestic fuel. However, crop residues utilized as domestic fuel has been disregarded due to the adaptation of other fuel sources (Yan et al., 2005). This situation causes a significant increase of crop residues in fields as Song et al. (1995) breported that crop residues used as domestic fuel decreased about 50%. Therefore, local farmers tended to burn residues in the field in order to simplify the preparation for the following cultivation. Although there were many reports on the effects of crop residue burning on soil quality, few studies have been conducted in China, especially in Shanxi. Therefore, this study has been proposed. The objectives of this study are to observe changes in burning density and to evaluate changes in soil quality caused by burning practices in Wenshui, Shanxi of China. On the other hand, Srimuang et al. (2004) reported that the burning process affects soil physical and chemical properties up to 15 cm deep from soil surface. In addition, high soil temperatures may kill soil microbes and plant roots, destroy soil organic matter, and degrade soil nutrients as well as water holding capacity (Srimuang, 2006).

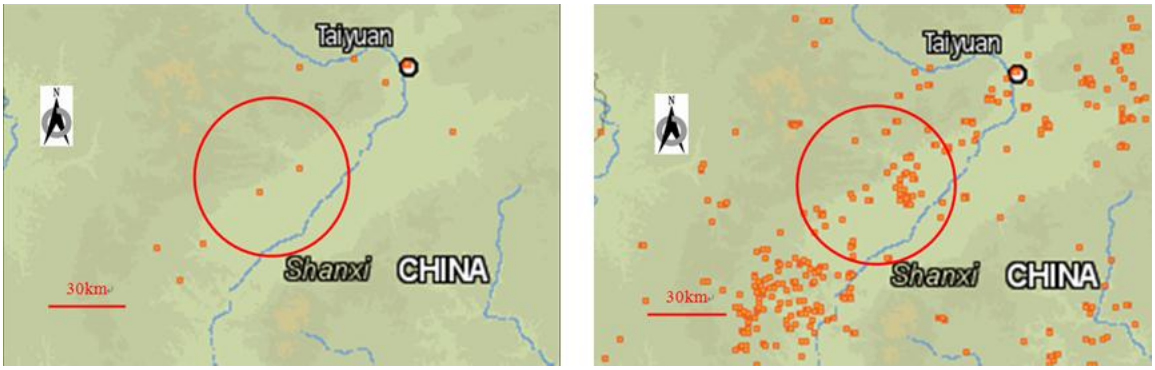
METHODOLOGY

The research site is located in Xiaqu Village, Wenshui of Shanxi Province, in the central part of China (37°26'N, 112°01'E, 767 m above sea level). The region has a continental monsoon climate and is rather arid having an average annual precipitation around 350-700 mm. Upland field farming is the main agricultural activity in Shanxi Province. The total area in Wenshui is 1,064 km^2 in which upland field occupies about 400 km^2 or about 40% of the total area. The dominant soil type in the study is SL as shown in Table 1.

Table 1 Soil texture of Wenshui, Shanxi, China

Depth (cm)	Specific gravity	Particle size distribution (%)					Soil texture
		Gravel	Coarse sand	Fine sand	Silt	Clay	
0-20	2.77	0	0.38	66.54	23.80	9.28	SL

The burning density was analyzed based on the Fire Information for Resource Management System (FIRMS). FIRMS integrates remote sensing and GIS technologies to deliver global MODIS hotspot/fire locations and burned area information to natural resource managers and other stakeholders around the world (Web Fire Mapper, 2010). The area monitored was comprised in a 30 km radius from the center of Wenshui, Shanxi of China. Data were gathered in a yearly basis from 2001 to 2009.



2001 2009

Fig. 1 Changes in burning density around Shanxi of China

For the field burning experiment, an observation pit of 1 m wide, 1 m long and 1 m deep was excavated in the corn field, near a burned pile of crop residues for observing soil temperature and volumetric water content. Dried corn residues were burned within 30 minutes right beside the pit as shown in Fig. 2-a. Soil temperature and moisture were measured by using a thermocouple and a water content reflect meter inserted into the wall of the pit (Fig. 2-b) at different depths of 1, 5, 10, 20, 30 and 40 cm from soil surface. Measurements were done at 5, 10, 30, 60, 120, 180, 240, 300, 320, 360 and 420 minutes passed after burning.

For laboratory analysis, two different types of soil were collected from field site: unburned soil and burned soil. Both soils were collected from the same field. However, burned soil was collected from a burning experimental plot. To observe the effects of burning on general microorganisms, some amounts of unburned soils were burned by oven at 415 degrees Celsius within 30 minutes to correspond to the condition of soil during the burning at the field site. For burned soil as well as unburned soil, analysis of general microorganisms was carried out with an agar plate.

(a) (b) (c) (d)

Fig. 2 Field burning experiment conducted in Wenshui Shanxi of China

In addition, saturated permeability test was conducted by falling head method. Both unburned and burned soils were undergone for soil general bacteria, electrical conductivity (EC) and pH, to make out the effects of residue burning on soil chemical and physical properties. Also, changes in total nitrogen and total phosphorous in soil were analyzed under different temperatures.

RESULTS AND DISCUSSION

Burning density was analyzed on the basis of the Fire Information for Resource Management System (FIRMS). Results from the analysis on changes in burning density showed that burning density in Wenshui of Shanxi in 2009 at 0.0467 events/km^2/year was much larger than that in 2001 at 0.00141 events/km^2/year. It was observed that burning density in 2009 was 33 times higher than that in 2001 as shown in Fig. 3.

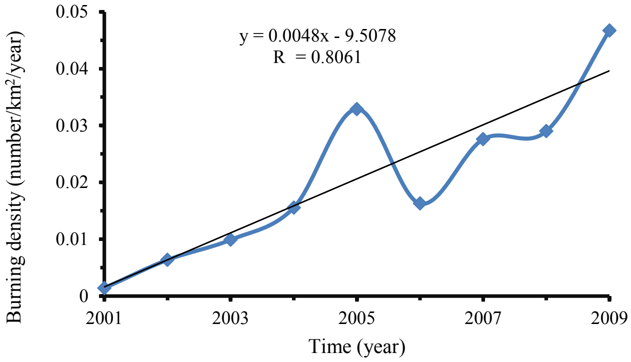


Fig. 3 Burning density occurred from the year 2001 to 2009

On site burning was conducted to measure soil volumetric water content (VWC) and soil temperature in a corn field located at Wenshui, Shanxi of China. Experimental results indicated that temperature of surface soil rose to 415 degrees Celsius (Fig. 4) immediately after starting the burning, and then it decreased gradually with time after ceasing the burning. Also, it was observed that soil volumetric water content at depths of 1 cm to 40 cm decreased with burning. However, this decreasing tendency of soil volumetric water content at 1 cm deep lasted until the end of the observation. In addition, at other depths, there was some fluctuation of soil volumetric water content as shown in Fig. 5.

For evaluating changes in soil quality with the burning, values of EC and pH were analyzed. The changes in EC and pH values were measured by glass electrode method. The values of pH increased from 8.23 to 9.04 with the burning and there was a significant difference between pH values of unburned and burned soils at 99% confidence interval (Fig. 6). Also, values of electrical conductivity (EC) increased to 219 mS/m from 128 mS/m with the burning (Fig. 7).

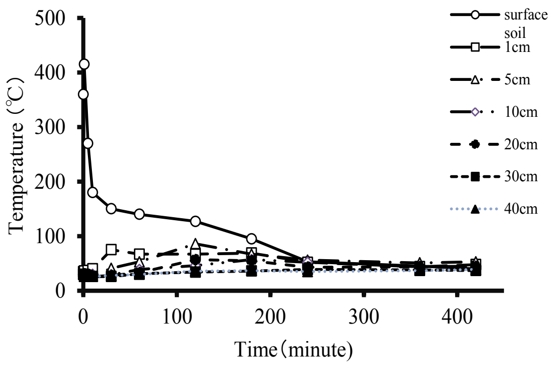


Fig. 4 Changes in temperature with burning

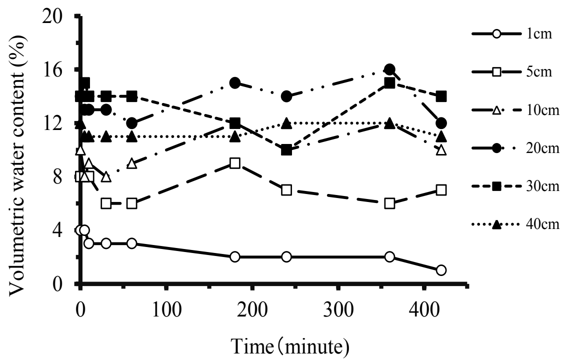


Fig. 5 Changes in VWC with burning

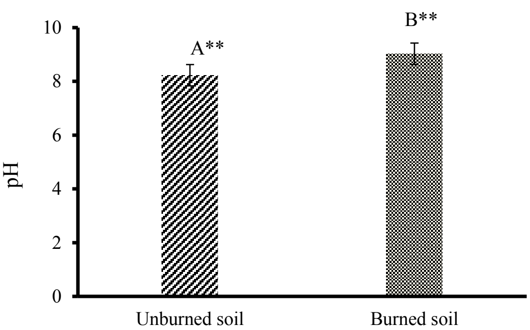


Fig. 6 Changes in pH with burning

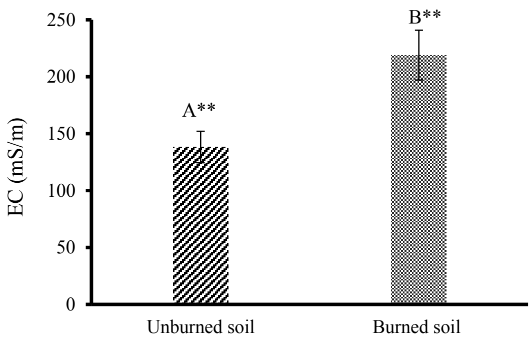


Fig. 7 Changes in EC with burning

The population of general microorganisms in unburned and burned soils was measured employing an agar plate. Results indicated that general microorganisms existing in unburned soil were 3.0×10^7 cfu/g while there was no general bacteria found in the burned soil (Fig. 8). Results indicated that general bacteria cannot live at 415 degrees Celsius that was observed in the field burning experiment in Wenshui, Shanxi of China. Thus, the effect on the destruction of soil microorganisms is a big concern for soil environment researchers.

However, no significant change was observed in permeability between unburned and burned soils. Also, a significant difference was not observed as shown in Fig. 9.

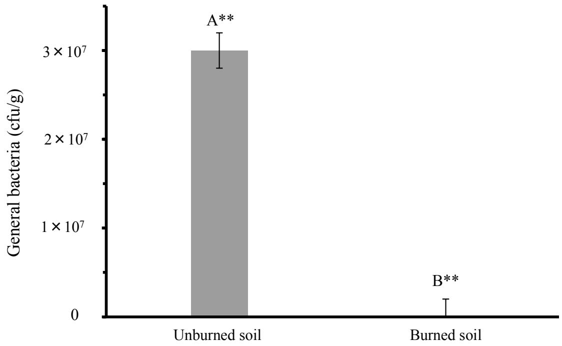


Fig. 8 Changes in general bacteria with burning

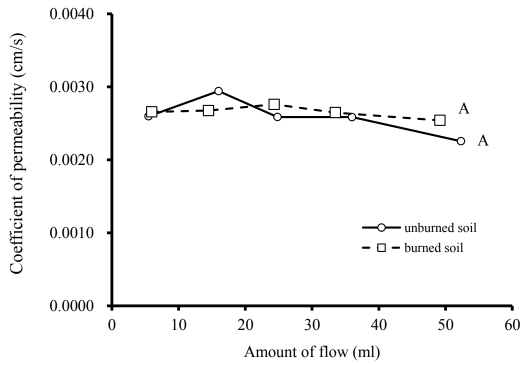


Fig. 9 Changes in water permeability with burning

The changes in total nitrogen and total phosphorous concentration with the burning are shown in Fig. 10 and Fig. 11. A tendency for total nitrogen to decrease with the burning temperature was observed. This tendency may be caused by the release of nitrogen components into the air with the burning (Fig.10). However, total phosphorous tended to increase with the burning temperature due to the decomposition of phosphorus component in soil.

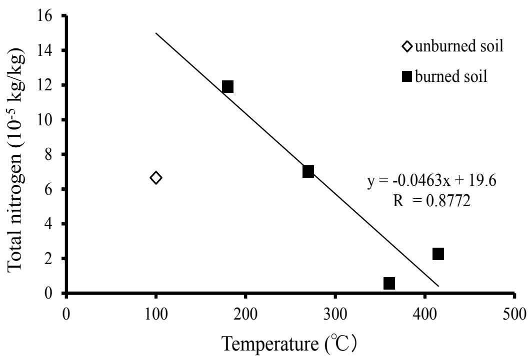


Fig. 10 Changes in total nitrogen with burning

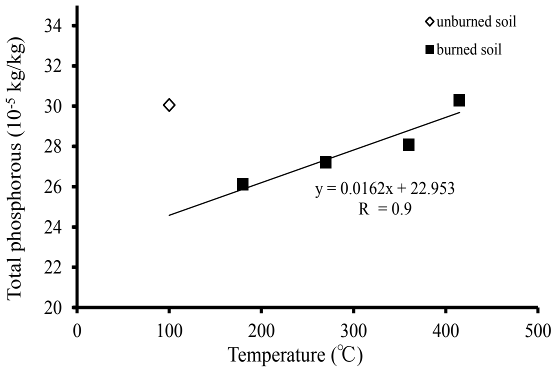


Fig. 11 Changes in total phosphorous with burning

CONCLUSION

The results from the observation of changes in burning density showed that burning density in Wenshui of Shanxi in 2009 at 0.0467 event/km^2/year was much larger than that in 2001 at 0.00141 event/km^2/year. Also, the results of onsite experiment on residue burning conducted in Wenshui indicated that when soil surface temperature rose to 415 degrees Celsius, it caused the decrease of microorganism population. Therefore, burning of crop residues significantly affects the micro fauna in the soil. In addition, burning of crop residues also influenced the acidity of soil as indicated by the increase of soil electrical conductivity (EC) and pH. Moreover, a significant decrease of total nitrogen component in the soil was observed. However, burning of crop residue has no significant effect on soil permeability as observed in the permeability test.

It was concluded that the burning of crop residues influenced the degradation of soil ecosystem and its quality. Therefore, treating of crop residues such as composting, for bio-fertilizer on crop is strongly recommended.

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