Land Use Policy 47 (2015) 448–458

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Why do farmers burn rice residue? Examining farmers' choices in Punjab, Pakistan

Tanvir Ahmed[a,*], Bashir Ahmad[b], Waseem Ahmad[c]

[a] Associate Professor, Department of Economics, Forman Christian College (A Chartered University) Lahore, Pakistan
[b] Professor Emeritus, Institute of Agricultural and Resource Economics, University of Agriculture, Faisalabad, Pakistan
[c] Assistant Professor, Institute of Business Management Sciences, University of Agriculture, Faisalabad, Pakistan

ARTICLE INFO

Article history:
Received 10 August 2014
Received in revised form 19 April 2015
Accepted 7 May 2015

Keywords:
Black carbon
Rice residue management
Seemingly unrelated regression
Punjab
Pakistan

ABSTRACT

Burning agriculture residues has multiple negative effects including local air pollution, increase in black carbon and contributions to regional and global climate change. This study seeks to understand why farmers burn rice residue by analyzing the residue adoption choices of farmers in the rice–wheat cropping system of Punjab, Pakistan. Rice residue has to be burned, removed or incorporated into the soil in order to prepare fields for the next wheat crop. The most favored residue management practice in Punjab, in terms of total rice area, is complete burning of rice residue, followed by removal of rice residue. When farmers remove residue, it is pre-dominantly because they use it to feed animals. Each practice has different cost implications. Complete residue removal costs PKR 4586 (US$ 55) per acre, on average. Further, complete residue removal is, on average, 34% costlier to farmers than full burning of residue. Thus, farmers would need to be subsidized to avoid residue burning practices. A number of socio-economic factors influence farmers' residue management decisions. For example, the proportion of rice area allocated to full residue removal practice increases if the farm is owner operated or if the farmer has a larger number of livestock. On the other hand, the proportion of area that is fully burned increases with farm size, reduction in turn-around time between the harvesting of rice and the sowing of wheat, and the ease with which farm machinery can be used for preparing the wheat field. The study concludes that without some technological innovations to make rice residue removal and wheat field preparation less costly, it likely that this trend in residue burning will continue.

1. Introduction

With a total area of about 1.1 million hectares, the rice–wheat cropping is the dominant cropping system in many districts in Punjab, Pakistan, (Amir and Aslam, 1992).[1] There is widespread late planting of wheat, especially when *basmati* rice is the preceding rice variety (Akhtar et al., 2002; Amir and Aslam, 1992; Sharif et al., 1992). The need to prepare fields for the wheat crop results in hasty burning of rice residue. In recent years, this common farming practice has emerged as a major concern for multiple environmental reasons.

Farmers also burn rice residue because many believe that it has a beneficial effect on yields. The literature on burning, however, suggests that burning straw after harvesting rice can have both positive and negative effects on soil quality in the short and long run. Burning increases the availability of some nutrients, such as phosphorus and potassium in the short run (Erenstein, 2002) and new research suggests that it may increase the productivity of the crop in the next season (Haider, 2012). However, it can also result in the loss of plant nutrients, such as nitrogen, potash, sulphur (Gupta et al., 2004; Heard et al., 2006) and negatively affect the local microbial population and organic carbon (Heard et al., 2006). On the other hand, non-burning of residue and its incorporation can, in the long run, improve soil chemical properties (Gupta et al., 2004; Sidhu and Bari, 1989). Residue incorporation can increase nitrogen uptake (Verma and Bhagat, 1992), result in higher soil organic matter, organic carbon and microbial biomass, increase the potential for nutrient recycling (Ganwar et al., 2006; Hartley and Kessel, 2005; Malhi and Kutcher, 2007; Prasad et al., 1999) and contribute to higher crop yields (Bahrani et al., 2007; Garg, 2008; Prasad et al., 1999; Surekha et al., 2003; Tripathi et al., 2007). Thus, there appears to be a consensus that in the long run incorporation of residue,

* Corresponding author. Tel.: +92 42 99231581 88x400/300 7600690.
E-mail addresses: tanvirahmed@fccollege.edu.pk (T. Ahmed), bashir.ahmad@uaf.edu.pk (B. Ahmad), waseem.ahmad@uaf.edu.pk (W. Ahmad).

[1] The area is largely irrigated, with an annual rainfall varying from 425 mm to 800 mm (Aslam et al., 2002).

http://dx.doi.org/10.1016/j.landusepol.2015.05.004

as compared to burning, improves the soil quality. Nevertheless, this needs to be confirmed under the conditions prevailing in the rice–wheat cropping system in Punjab, Pakistan.

A growing major concern regarding residue burning emerges from its effects on air pollution and climate change. Incomplete combustion of biomass such as agriculture residues generates black carbon (Kante, 2009) which is the second largest contributor to global warming after carbon dioxide (Chung et al., 2005; Forster et al., 2007; Ramanathan and Carmichael, 2008; UNEP, 2009). Black carbon absorbs radiation and warms the atmosphere at regional and global scales. Increased concentration of black carbon and other pollutants, observed in the high Himalayas, is expected to enhance glacier melting. Black carbon emissions and other types of aerosols have also given rise to atmospheric brown clouds (ABCs) in Asia (Nakajima, 2009). The aerosols in ABCs decrease the amount of sunlight reaching the earth's surface by 10–15% and enhance atmospheric solar heating by as much as 50% (UNEP.RRC.AP., 2012). One estimate attributes 30–50% of the human contributions to global warming to black carbon, methane and ozone (Ramanathan et al., 2009). In general, atmospheric brown clouds and their interactions with greenhouse gases can significantly affect climate, hydrological cycle, glacier melting, agricultural and human health (UNEP.RRC.AP., 2012).

Farmers in Punjab adopt a variety of residue management practices. These practices include: (a) burning of rice residue after the rice harvest in order to prepare the wheat field, improve tillage efficiency and reduce the need of herbicides and pesticides to control for diseases, weeds and pests; (b) removal of rice straw and its use as animal feed, fuel for cooking purposes, and for manufacturing paper, and hardboard; and (c) incorporation of residue into the soil through use of appropriate farm machinery, such as the rotavator and disc harrow. However, wheat field preparation and the profitability of the wheat crop crucially depends on how residue from the previous rice crop is managed. The question then is why some farmer's burn rice residue and others do not.

Our study seeks to understand farmers' residue management decisions by addressing three separate questions: (1) what are the private costs to farmers of rice residue burning versus alternatives to this practice? (2) What are the factors that determine farmers' decision to burn or not burn rice residue? And (3) what are farmer perceptions regarding different rice residue management practices? Understanding perceptions and costs would be useful for designing local agricultural policies and as well as climate change mitigation policies.

Generally, there are a number of factors that farmers consider in deciding whether to adopt any cropping practice. However, little research has been done to date on the factors that influence the adoption of a particular residue management technology (Gupta, 2012). Thus, our study builds on methodological issues derived from related work done by authors such as Casewell and Zilberman (1985), who analyze the factors affecting the adoption of alternative irrigation technologies.

A subset of agricultural studies useful to us has looked at what determines a farmer's conservation behavior (Carlson et al., 1981; Cary, 1992; Cary and Wilkinson, 1997; Nowak, 1987). One result is that the scale of operation has an influence on conservation, but the effects of the scale vary for different conservation practices (Cary and Wilkinson, 1997; Nowak, 1987). Similarly, a study by Sinden and King (1990), reports how various land-related and personal factors influence the perceptions of farmers, while economic and institutional factors influence the decision to adopt soil conservation measures. Other factors that are important for adopting conservation practices, as identified in the literature, include tenure security, slope of land, off farm gross income of household, output prices, salinity problem, perception of long-term profits etc., but these vary depending on the nature of the problem (Cary and Wilkinson, 1997; Lichtenberg, 2004; Neill and Lee, 2001). Further, multiple practices are followed even by a single farmer. We take these issues into account in designing our study to examine burning and incorporation practices.

The remaining paper is organized as follows. Section 2 is concerned with the study area, sampling design and the general characteristics of the farmers and farms. Section 3 deals with the methods used for estimating the cost of handling of residue and preparing wheat field. Section 4 reports the results on adoption of various residue management practices, cost of land preparation for wheat crop, perceptions of farmers about the effects of residue burning on the crop yields and the results. The final section concludes and offers policy suggestions.

2. Study area and data

2.1. Study area

Pakistan can be categorized into three broad agro-ecological zones: the irrigated lowlands, the rain-fed lowlands and the mountain areas. The irrigated plains of Pakistan are one of the largest irrigated systems in the world and are dominated by a number of major cropping systems. While wheat is the major *rabi* crop (i.e., the autumn–spring season from November to April), covering approximately 80% of the cropped area in the *rabi* season, the major *kharif* crop (i.e., the spring–summer season from May to October) varies depending on the climate, soils, etc., of the zone (Byerlee and Husain, 1992). In the province of Punjab, the rice–wheat cropping system is the major system in areas where rice is the most important crop in the *kharif* season. This occurs in the districts of Sialkot, Gujranwala, Lahore, Sheikhupura, Mandi Bahe-ud-Din Gujrat, Narowal and Hafizabad. Our study area includes Gujranwala and Sialkot districts, which are the two most important districts in Punjab in terms of the rice acreage with 25.4% and 18.5%, respectively, of the rice–wheat system in Punjab (Government of Punjab, 2009).

A majority of the farmers in the area are small farmers (with less than 5 acres of land), and a relatively small percentage of famers are large landholders (20 acres or more farmland). While almost all farmers use tubewell water to supplement canal irrigation, in Sialkot many farmers exclusively rely on tubewell water. The average cropping intensity is 170–180% which is higher than the other irrigated cropping systems of the Punjab. Most crop rotations involve wheat, rice and fodder.

2.2. Sampling design

We used a stratified two-stage sampling design for identifying farmers for our study. The Federal Bureau of Statistics (FBS), the national organization responsible for the collection and dissemination of statistics, considers the village as the primary sampling unit (PSUs) for rural domains. We, therefore, took the sampling frame (the lists of villages/*mouzas*/*dehs*) used by FBS for the 1998 population census and listed villages selected by the FBS in each *tehsil* according to its hadbast number (which is a specific method for assigning a particular number to a village). We then randomly selected 10 villages from each district using the random number table.

Farmers within the sample PSUs became our secondary sampling unit. We prepared a list of farmers in each village and arranged it in ascending order of operational farm size. We further classified farmers into three groups, i.e., small farmers (with less than 5 acres), medium farmers (between 5 and 7.5 acres) and large farmers (with 7.5 acres and above). We selected 20 farmers from each village ran-