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Why Do Farmers Burn Rice Residue?

Examining Farmers' Choices in Punjab, Pakistan

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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.

Keywords: *Black carbon; Rice residue management; Seemingly unrelated regression; Punjab, Pakistan.*

Why Do Farmers Burn Rice Residue?

Examining Farmers' Choices in Punjab, Pakistan

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] Approximately 80 percent of the wheat crop in Punjab is grown after harvesting rice. Often, there is widespread late planting of wheat, especially when *basmati* rice is the preceding rice variety (Akhtar et al. 2002, Sharif et al., 1992; Amir and Aslam, 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 burn rice residue also 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 (Sidhu and Beri, 1989; Gupta et al., 2004). 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 (Hartley and Kessel, 2005; Prasad et al 1999; Malhi and Kutcher, 2007, Ganwar et al; 2006) and contribute to higher crop yields (Surekha et al; 2003; Prasad et al; 1999; Tripathi et al., 2007; Bahrani et al., 2007; Garg, 2008). Thus there appears to be a consensus that in the long run incorporation of residue, 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 (UNEP, 2009: Chung et al 2005; Forester et al; 2007, Ramanathan and Carmichael, 2008). 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% to 15% and enhance atmospheric solar heating by as much as 50% (UNEP. RRC.AP. 2012). One estimate attributes 30% to 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. We note that residue disposal is problem only when the wheat crop follows a rice crop and the turn-around time between the rice harvest and the sowing of wheat is very short. If fields are kept fallow, rice residue is allowed to decompose naturally. 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.

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

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? As both residue burning and *in situ* incorporation of crop residue appear to have long-term impacts on soil productivity. Moreover, 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; Nowak, 1987; Cary, 1992; Cary and Wilkinson, 1997). 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 (Neill and Lee, 2001; Litchenberg, 2004; Cary and Wilkinson, 1997). 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 percent 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.[2] Our study area includes Gujranwala and Sialkot districts, which are the two most important districts in Punjab in terms of the rice acreage

While the area under the rice-wheat system is mainly irrigated, rainfall heavily supplements irrigation water. 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 to 180 percent which is higher than the other irrigated cropping systems of the Punjab. Most crop rotations involve wheat, rice and fodder.

2 Of these, Gujranwala and Sialkot are the two most important districts in terms of the rice acreage, with 25.4 and 18.5 percent, respectively, of the rice-wheat system in the Punjab (Government of Punjab, 2009).

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 it's had *basit* 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 randomly from the three groups in proportion to their total number in the village.

We prepared a comprehensive questionnaire for collecting data from selected farmers, which was modified after pre-testing (see Questionnaire in Appendix B). We collected the data during 2010 using the personal interview method. The data collected pertained to crop residue management practices, rice yield, age, farming experience, educational level of farmer, awareness about losses in plant nutrients, organic matter, etc.

2.3 Residue Management Practices and Farm Characteristics

Rice and wheat are, as expected, the dominant crops in our study area, sharing more than 40 percent each of the total cropped area. *Super Basmati* is grown in 71 percent of the total rice area cultivated, followed by *Basmati 386* (21 percent) and other varieties (Appendix A).

Traditionally, farmers harvested the rice crop manually and then removed the rice crop residue for the purpose of feeding animals or for cooking. However, with the introduction of the 'combine harvester', farmers have begun leaving the *pural* or *kho* (upper part of the rice plant) in the field. The combine harvester is a machine that can do multiple tasks such as harvesting, threshing, winnowing and collection of grains. It allows farmers to harvest rice crop quickly and efficiently and enables farmers to reduce the turn-around time between the harvesting of rice and the sowing of wheat. The machine is used to harvest both wheat and rice. It harvests the rice crop about nine inches above ground. During the threshing process paddy is separated from the straw and stored in the bin at the top of the machine, while the straw is left behind in the field. Because gathering and removing of rice straw from the field at a time when the labor is needed for harvesting rice and sowing wheat is difficult, the use of this machine encourages farmers to burn rice residue. Some farmers remove the *pural* and burn or incorporate the lower parts of the straw into soil, while many farmers burn both the *pural* and lower parts of the straw.

Survey results in Table 1 show that complete removal of rice residue is the dominant practice among farmers, i.e. some 48% of farmers reported that residue removal was their dominant approach to residue management. This is followed by a 'full burn' i.e. burning of *pural* and lower parts of the rice plant (36%). Very few farmers removed *pural* and then burned the lower parts of the rice plant. Only a negligible percentage of farmers adopted removal of *pural* and incorporation of the lower parts of the rice plant and complete incorporation. Thus, two dominant strategies in residue management are 'full removal' and 'full burn'.

If we look at the overall area of rice allocated to different residue management practices, then we observe that the full burn method ranks first followed by removal (Table 2). Some 58 percent of area under rice is fully burned, while 25 percent of rice area has full removal of residue. The remaining area is either partially burnt or a small portion is incorporated into the field. We observed a similar pattern of adoption of different residue management practices for the different varieties of rice (see Table 2).[3]

What happens when residue is not burnt? Farmers report that the removed straw is mostly (87%) used for as animal feed. Some 8 percent of the removed residue is used as fuel, with only 5 percent being sold (Appendix A).

[3] However, in cases of sugarcane crop, almost the entire residue was removed. The main reason for this is the shortage of dry fodder during winter and farmers use sugarcane residue as feed for animals.

Almost 100 percent farmers own cattle, hence the use of straw as animal feed. We also asked farmers why some of them chose to remove rice residue. Some 63 percent of farmers stated that they used rice straws for animal feed, while 45 percent said they removed residue because it made it more convenient for them to use certain types of farm machinery to prepare the wheat field (see Appendix A).

Farmers' perceptions why they burn the rice residue indicated that majority of the surveyed respondents felt that the trend in rice residue burning was increasing. Field discussions suggest that this increasing trend is attributable to the use of the combine harvester. A large proportion (65%) of farmers felt that the inconvenience of using farm machinery for wheat field preparation was the main reason for the burning of rice residue. Some 46 percent of the respondents reported that the short turn-around time between the harvesting of the rice crop and the sowing of the wheat crop is the main reason for burning. Over 80 percent and 77 percent respondents, respectively, reported less availability of wheat *bhoosa* (or animal feed) and more numbers of animals per unit of area as the major reasons for the increasing trend in the use of rice residue as feed for animals. Ninety percent of respondents were of the view that incorporation of residue into soils lead to improvements in the physical properties of the soil (Appendix A).

Table 3 discusses some descriptive statistics of our sampled farmers. Of the total 400 respondents, 76 percent were owner operators. The average experience of the respondents as farmers was 28 years (the average age was 48 years). While 9 percent had over 10 years of education (above 10th standard) and for a majority of the respondents (92 percent), farming was their primary occupation. *Jat* was the dominant caste of the respondents and the average size of the farm was 12 acres. On average there were 1.5 fragments per farm while, again on average, a farmer was maintaining 9 animal units.[4]

3. Methods

3.1 Costs of Residue Management

In the study area, farmers resort to the following five practices for managing crop residues:

- Removal of rice crop residue (Full Removal);
- Removal of *pural* and burning of the lower parts of the rice stem (Partial Burn);
- Burning of *pural* and lower parts of the rice stem (Full Burn);
- Removal of *pural* and incorporation of the lower parts of the rice stem (Partial Incorporation);
- Complete incorporation of rice residue (Full Incorporation).

We discuss below methods used for estimation the costs of each type of practice. The costs estimated include labor costs, costs of machinery used, including depreciation, and interest costs. These costs include the costs involved in handling rice residue and in preparing the field for the next wheat crop.

3.1.1 Removal of Rice Residue (Full Removal)

This practice involves the collection, making of bundles, loading, transporting, unloading and stacking of rice straw. All these operations involve labor. We therefore estimated the total labor time spent on all these operations per acre and multiplied it by the prevailing wage rate for unskilled labor in the area in order to obtain the labor cost.

Since farmers use tractors and trolleys for the transportation of rice straw, we used the hiring rate prevalent in the area when they made use of the services. In the case of owned machinery, we estimated the operational cost per hour. This included the depreciation, interest, fuel, lubrication, repair, housing and labor cost of the tractor (Chaudhary et al., 1992). We calculated the depreciation cost of the tractor per hour by dividing the total depreciable amount by the number of the total working hours for the tractor (i.e., 10,000 hours). We calculated the depreciation cost per hour as (Kay and Edwards, 1994):

$$D = \frac{C-S}{L}$$

[4] Animals kept on the farm were converted into animal units by using the following conversion factors: bullock = 1.00, cow = 0.72, cow young ones = 0.54, buffalo = 1.28, buffalo young ones = 0.96, donkey = 0.57, sheep = 0.20, goat = 0.20, horse = 1.00, camel = 1.75.

where
D = Depreciation cost per hour
C = Market price of new tractor
S = Salvage or trade in value
L = Serviceable life

The annual interest cost was calculated by using the formula (Kay and Edwards, 1994):

$$I = \frac{(C + S) \times i}{L}$$

Where
I = Annual interest cost
i = Rate of interest farmers are expected to pay to Zarai Taraqiyati Bank of Pakistan (i.e. Agricultural Development Bank of Pakistan) to obtain credit

We obtained the interest cost per hour by dividing the annual interest cost by 1000 (in doing so, we assume that the tractor's life is 10 years or 10,000 hours and that it runs for 1000 hours per year). We estimated the fuel cost per hour by multiplying the fuel consumption per hour by the fuel price. We assumed the lubrication cost to be 10 percent of the fuel cost.

The repair cost includes the cost of the spare parts, wages of the mechanic, and the cost of transportation and the time needed to take the tractor to where the parts are available or to bring the parts to the tractor. We take the total repair cost of the tractor to be equal to 100 percent of the purchase price of the tractor (Chaudhry and Ahmad, 1982).

To estimate the cost of garage for the tractor, we used the present cost of construction of a similar garage. For the purposes of our study, we considered depreciation at the rate of 2.5 percent for the *pucca* (made of kiln bricks) garage and 5 percent for the *katcha* (i.e. made of mud bricks) garage. We determined the interest cost at the prevailing rate of interest charged by Zarai Taraqiyati Bank of Pakistan. We used the prevailing hiring rate of a tractor operator in order to estimate the labor cost/hour for operating machinery.

The procedure adopted to estimate the cost of the trolley used with the tractor was similar to that of the tractor. We took the average repair cost of the trolley to be 20 percent of the market price. In order to estimate the transportation cost, the time spent in hours of tractor/trolley for transportation of rice residue was multiplied by the cost per hour as shown above.

The preparation of the wheat field involves the use of the tractor along with a tractor implement (may be a disc plough or a rotavator) for the incorporation of rice residue into soil. We estimate the tractor cost per hour using the method already outlined above. For the tractor implements used with tractors, we estimated the depreciation, interest and repair costs for the purpose of determining the cost per hour. We then multiplied the average cost for the tractor and implements by the time spent to determine costs in the case of owned tractor and implement. However, if services were hired, we used the hiring rate per operation.[5]

3.1.2 Removal of Pural and Burning of Lower Parts of Rice Stem (Partial Burn)

This practice involves the use of labor for the collection, making of bundles, loading, transportation, unloading and stacking of *pural*. Further, farmers use labor to burn the lower parts of the rice stem and to avoid damage to other standing crops, trees, etc. We multiplied the labor used for the removal of *pural* and the burning of the lower part of the rice stem by the prevailing wage rate for unskilled labor to arrive at total labor cost. We estimated the cost for transportation of *pural* and the preparation of the wheat field by using the procedure outlined above.

5 The operational cost per hour of disc plow, rotavator, cultivator and planker was PKR 786.65 (US$ 9.34), 824.55 (US$ 9.84), 734.70 (US$ 8.76) and 713.98 (US$ 8.52), respectively for the farmers owning their own tractor and equipments. The respective rental rates per hour of these operations were PKR 782.65 (US$ 9.34), 753.10 (US$ 8.94), 806.85 (US$ 9.63) and 576.07 (US$ 6.87). Normally, we expect rental rates to be higher than the actual cost of machinery owners as in case of cultivation operation. However, in many cases farmers renting out these services do not recognize and consider the fixed cost component of machinery and consequently, the rental rate may be lower than the actual cost of the machinery owner.

3.1.3 Burning of Pural and Lower Parts of Rice Stem (Full Burn)

The procedure adopted for the estimation of the cost of this practice was similar to the above practice except that there was no labor cost for the removal of *pural*.

3.1.4 Removal of Pural and Incorporation of Lower Parts of Rice Stem (Partial Incorporation)

We estimated the cost of *pural* removal, cost of transporting *pural* and the cost of preparing the wheat field by using the procedure outlined above.

3.1.5 Complete Incorporation of Rice Residue (Full Incorporation)

Here, the procedure used for the estimation of the total cost was similar to the above except that there was no labor cost for removal of *pural*.

3.2 Estimating the Determinants of Rice Residue Burning

Farmers are assumed to maximize profit from their adoption of various rice crop residue management practices. Therefore, if a farmer has adopted a particular rice residue management practice (PR1), we expect profits, $\pi_{PR1} > \pi_{PR2}$, i.e. profits associated with the first residue management is expected to be greater than that from the second practice (PR2).

The traditional approach to technology adoption treats the adoption decision as a binary decision that is dependent on profitability, relative advantage and farm and farmer characteristics (Lee and Stewart, 1983; Feder et al., 1985; Jovanovic and Stolyarov, 1995; Marra et al., 2001; Qaim and Zilberman, 2003; Useche et al., 2009). These studies estimate the determinants of adoption by regressing the yes/no binary variable on a number of independent variables. In our case, farmers face multiple choices and therefore, this binary approach does not work.

Our survey identifies four major residue management practices in the study area: (1) full removal of rice residue; (2) partial burning or removal of *pural* and burning of the lower parts of the rice plant; (3) full burning of both *pural* and lower parts of the rice plant; and (4) removal of *pural* and incorporation of the lower parts of the rice plant. Thus, farmers are making a decision among these four alternative choices. Another practice – complete incorporation of rice residue – is ignored because only a small proportion of total rice area (1.00%) is allocated to this practice.

In estimating the determinants of adoption of a residue management practice, Ervin and Ervin (1982) discuss three stages in agriculture technology adoption. These stages include identifying the existence of the problem, deciding whether to adopt new agriculture technology and, finally, to what extent such technology should be adopted. Norris and Batie (1987) developed an integrated Tobit model for the last two stages of agricultural technology adoption i.e. estimation of likelihood of adoption and the amount of efforts (investment or acreage). To examine the decision to adopt one of four residue management practices, we regress a measure of the adoption decision on a number of independent variables.

The first issue that arises is how we measure the dependent variable, the adoption decision. Following Gould et al. (1989), we assume that the extent of adoption of each residue management practices can be represented by the percentage area under each practice. Thus, adoption of a certain practices is measured as the proportion of rice acreage under a particular residue management practice. Thus, this is a number between the range of 0 to 1. We do this because a farmer may adopt various rice residue management practices on different plots simultaneously.

We use two approaches to model the adoption of rice residue management: Seemingly Unrelated Regression (SUR) and Seemingly Unrelated Tobit Regression (SUTR) Model. These approaches take care of any correlation in errors that may exist between various residue management practices, which bear a close conceptual relationship to each other, and provides more efficient estimates than the single equation estimation used in many studies. Residue management choices are a set of endogenous decision variables for the farmer. Some farmers adopt all four practices and others may adopt a smaller subset; but, for any farmer, the land allocated to each practice adds up to 100%. However, since none of the dependent acreage share variables appears on the right hand side of any equation, the use of seemingly unrelated equations model is appropriate (Pindyck and Rubinfeld, 1998).

3.2.1 Seemingly Unrelated Regression Model

We can estimate four adoption decision equations independently by using ordinary least squares to obtain consistent and unbiased parameter estimates. However, the efficiency of the parameter estimates can be improved if we take into account the correlation between the error terms across equations. The correlation arises because the sum of acreage shares of various rice residue management practices is 100%. According to Zellner (1962), it is possible to gain efficiency in estimation if the system of seemingly unrelated equations is estimated using the generalized least square estimation.

The seemingly unrelated model of four equations can be represented as:

$$Y_i = X_i \beta_i + \mu_i \qquad i = 1, 2, 3, 4 \tag{1}$$

Where
Y_i is a N x 1 vector
X_i is a N x K_i matrix
β_i is a K_i x 1 vector
μ_i is N x 1 vector

The most efficient generalized least square estimation is obtained as (Greene, 2007):

$$\hat{\beta} = (X' \Omega^{-1} X)^{-1} (X' \Omega^{-1} Y)$$

where omega is a variance-covariance matrix.

The model is estimated by using the following specification:

$$\begin{aligned} \text{ARPRAC} = {} & \beta_0 + \beta_1 \mathit{GUJRANWALA} + \beta_2 \mathit{EXPERIENCE} + \beta_3 \mathit{OCCUPATION} + \beta_4 \mathit{EDUCATION} + \beta_5 \mathit{JAT} \\ & + \beta_6 \mathit{ARIAN} + \beta_7 \mathit{RAJPUT} + \beta_8 \mathit{SIZE} + \beta_9 \mathit{OWNEROPERATOR} + \beta_{10} \mathit{FRAGMENT} + \beta_{11} \mathit{CLAY} \\ & + \beta_{12} \mathit{ANIMALUNIT} + \beta_{13} \mathit{SUPERACREAGE} + \beta_{14} \mathit{TURNAROUND} + \beta_{15} \mathit{CONVENINCEMACHINERY} \\ & + \beta_{16} \mathit{PERCEPTIONYIELD} + \beta_{17} \mathit{PERCEPTIONSOILIMPROVE} + \beta_{18} \mathit{PERCEPTIONENVIRONMENT} \\ & + \beta_{19} \mathit{PERCENTFAMILYLABORUSE} + \beta_{20} \mathit{WAGERATE} + \mu \end{aligned} \tag{2}$$

Although Table 4 offers definitions of the variables, we give below a brief discussion of the dependent and independent variables used in the empirical estimation.

Adoption of a particular residue management practice (ARPAC): Our dependent variable is measured as the proportion of rice area under a particular residue management practice.

Geographic location of the farm in Gujranwala (GUJRANWALA): Since socio-economic and climatic factors may vary among locations, geographic location is considered as an important variable influencing rice residue management. Although it is difficult to say anything specific about the impact of the geographic location of farm, we expect a difference between Gujranwala and Sialkot districts. However, the expected sign for this variable is not known a *priori*.

Farming experience (EXPERIENCE): Experience is used as a proxy for the potential of farmers to carefully handle rice residue. The experienced farmers recognize the importance of rice residue in maintaining the soil fertility status of their farmlands and therefore, we expect experienced farmers to be less inclined towards the burning practice than less-experienced farmers. Many technology adoption studies treat experience as a determinant (Gould et al., 1989; Rahm and Huffman, 1984).

Primary occupation (OCCUPATION): If farming is the primary occupation of the farmer, he might be more interested in the sustainable use of the land resource in order to ensure his livelihood in the long run. This is expected to have a negative effect on the burning decision.

Education (EDUCATION): Since a higher level of education implies better technical knowledge (Gould et al., 1989; Harper et al., 1990; Rahm and Huffman, 1984; Sherrick et al., 2004; Wu and Babcock, 1998), know-how on residue management and farming skills, we expect educated farmers to have a better understanding of the negative effects of burning rice residue on soil properties and nutrients. This might incline them to practice non-burning alternatives in place of the open field-burning of residue.

Caste: Although it is difficult to say anything about the direction of the impact of different castes (JAT, ARIAN, RAJPUT and others) on the extent of adoption of various residue management practices. However, caste is an important social variable.

Size (SIZE): Scale of farming is identified by the literature as an important determinant of technology adoption (Carlson et al., 1981; Nowak, 1987; Cary, 1992; Cary and Wilkinson, 1997; Neill and Lee (2001). Since the availability of labor and the number of animal units per unit area decline with increase in farm size, we expect large farmers to resort crop residue burning practice more than owners of small farms.

Owner operator (OWNEROPERATOR): Since owner operators would be more concerned with the sustainability of the land resource than tenants and owner-cum- tenants, we expect them to adopt other alternatives to open field burning.

Number of fragments (FRAGMENT): Since an increase in the number of fragments of a farm has a negative impact on the efficiency of resource use, which would result in less production of paddy and residue, a relatively larger proportion of the residue would be used as feed for animals and for domestic cooking purposes. Therefore, we expect the number of fragments to have a negative effect on the probability of burning rice residue.

Soil type (CLAY): Clay loam soils are more suitable for the cultivation of rice than sandy soil, which would in turn lead to a relatively higher quantity of rice residue than other soils. Since farmers might be incorporating residue into the clay soil in order to improve the physical properties of that soil, we expect there to be less chance of burning rice residue on these soils, which is bound to have a negative effect on the burning decision.

Number of Animals (ANIMALUNIT): Many farmers use rice residue as feed for animals. Since an increase in animal strength is likely to result in an increase in the use of rice residue as feed, we expect this variable to have a negative effect on residue burning.

Super Basmati rice acreage (SUPERACREAGE): The fine grain super basmati rice variety matures late and yields more residue than the coarse varieties, which mature early and yield less residue. Therefore, to expedite the timely sowing of wheat and for easy management of residue, we expect residue burning practice to be higher in the case of super basmati rice than other coarse grain varieties.

Reduction in turn-around time (TURNARROUND): Since the timely sowing of the wheat crop after the rice crop ensures a high yield, farmers must do all they can to reduce the turn-around time between the harvesting of rice and the sowing of wheat. Thus, we expect the timely planters of wheat to adopt the practice of rice crop residue burning over the late planters.

Convenience in use of farm machinery (CONVENIENCEMACHINERY): Convenience in the use of farm machinery refers to the ease with which the farmer can prepare land for the next wheat crop using machinary. Therefore, we expect an increase in convenience to encourage the burning of residue. Convenience is measured as a binary variable (see table 3).

Perceptions on the effect of non-burning of residue on the yields of various crops (PERCEPTIONYIELD): If farmers perceive non-burning of residue to increase the yield of various crops, then we expect them to reduce burning and thereby a negative sign for this variable.

Perceptions on the effect of burning on the physical properties of soil (PERCEPTIONSOILIMPROVE): If farmers perceive the burning of residue to improve the physical properties of the soil, we expect that to have a positive influence on burning.

Perceptions on the impact of burning on environment (PERCEPTIONENVIRONMENT): If farmers perceive burning of residue to have a negative effect on the environment, then we expect a negative sign for this variable to discourage burning.

Availability of family labor to handle rice residue (PERCENTFAMILYLABORUSE): We expect availability of family labor for rice residue management would discourage the burning of rice residue.

Wage rate of unskilled labor (WAGERATE): An increase in wage rate is likely to encourage the adoption of a residue management practice which requires less labor. We expect an increase in the labor cost for handling rice residue and for preparing the wheat field due to a higher wage rate, therefore, it would encourage the burning decision.

3.2.2 Seemingly Unrelated Tobit Regression Model

We obtain estimates of the adoption model of residue management by using the seemingly unrelated Tobit regression (SUTR) model. The main reason for its use is because there are many farmers who do not adopt all the residue management practices. In such instances, the application of ordinary least square yields biased estimates of coefficients towards zero with increasing degree of bias as the percentage of censoring increases.

Following the Huang (1999) notation, if there are p rice residue management practices (equations) with N observations in the system, then we have the following SUTR model:

$$Y^*_{ij} = X'_{ij}\beta_i + \mu_{ij} \qquad 1 \le i \le P \tag{3}$$

$$Y_{ij} = \begin{Bmatrix} Y^*_{ij} \text{ if } Y^*_{ij} > 0 \\ 0 \text{ if } Y^*_{ij} = 0 \end{Bmatrix}$$

The observed values of Y_{ij} is expressed in terms of the unobserved latent variable Y^*_{ij} representing the use of the rice residue management practice. β_i is (k x 1) the vector of estimated coefficients, X_{ij} is the (N x K_i) matrix of explanatory variables XJ and $\mu_J = (\mu_{1J}, \mu_{2J}, \ldots\ldots \mu_{pJ})$ is a vector of error terms.

Since there are *p* rice residue management practices (equations), there would be 2^P possible combinations of residue management practices at their censoring points. Following Huang (1999), we can represent 2^P possible combinations by the following (2^P x 1) vector, S_i, i=1,2,..... 2^P.

$$S_i = \left[S_i = (0, \ldots..0)', \ldots.., S_h = \left[\underbrace{(0, \ldots.., 0)}_{r}, \underbrace{(+, \ldots.. +)}_{p-r} \right], \ldots\ldots..., S_{2^P} = (+, \ldots\ldots...., +)' \right] \tag{4}$$

where, Sk is (px1), k=1,2,..... 2P, r is the number of censored residue management practices, '+' indicates a positive value for the residue management practice and '0' implies a censored observation for the residue management practice. Following Huang (1999), Cornick et al., 1994 and Taylor and Phaneuf (2009), the likelihood function for the J-th respondent in the Sth case is given by:

$$L^{S_h}_J(\beta, \Sigma) = \int_{-\infty}^{-X_1\beta_1} \ldots\ldots \int_{-\infty}^{-Xp\beta_p} (2\pi)^{-\frac{n}{2}} |\Sigma|^{\frac{1}{2}} \exp\left[-\frac{1}{2}(Y^*_J\ X_J\beta)' |\Sigma|^{1} (Y^*_J\ X_J\beta)\right] d\mu_p \ldots.. d\mu_1 \tag{5}$$

The individual equations of the seemingly unrelated Tobit regression model have parameters that vary across respondents and rice residue management practices. We estimate the model for each of the rice residue management practice by using the specification given in section 4.2.1.

4. Results and Discussion

4.1 Cost of Residue Management and Land Preparation for Wheat

As Figure 2 shows, managing rice residue and preparing the wheat field is the most expensive when farmers fully remove the rice residue. At PKR 4586 (US$ 55) per acre, full removal is 6 % more expensive than the next most costly practice, which is partial incorporation. The lowest cost borne, PKR 3424 (US$ 41) per acre, is associated with farmers who undertook full burning of *pural* and the lower straw. Thus, burning of residue is the most economical method. Further, the t-tests of the difference in costs between the full burning practice (lowest cost practice) and other practices (except total incorporation practice where there are only two observations) show that the cost differences are statistically significant.

Costs can be disaggregated into labor costs for residue removal/burning and wheat field preparation costs. In terms of labor cost for residue removal, this is the highest for the full removal process followed by the partial burn practice. Labor cost is high for fully removing rice residue because this practice involves the use of labor for different operations such as removal, loading, transportation, unloading and stacking. Labor cost is zero when residue is fully incorporated as it does not involve handling of residue.

The cost of preparing the wheat field is the lowest at PKR 2991 (US$ 36) when rice residue is fully removed and the highest (PKR 4098 (US$ 49)) for the full incorporation practice. For the 'full removal' practice, fields are cleared by removing the entire rice residue, making it relatively easy to prepare the wheat fields. Preparing wheat fields under other practices is more expensive because it necessitates a greater use of equipments such as disc plow, cultivator and planker.

4.2 Farmer Opinions about the Effect of Residue Burning and Alternatives

Farmer knowledge and perceptions can influence technology adoption. Perceptions themselves can be viewed as a product of the farmer's personal characteristics (Ervin and Ervin, 1982). We were interested in examining farmer perceptions related to the connections between residue burning and farm productivity. We asked farmers questions about the impact of residue burning on yield, soils and the environment. We also probed their knowledge about alternatives.

As Appendix A describes a small proportion of the sample respondents (2.5 percent) thought that non-burning of residue increases the yields of various crops. However, a good 38 percent reported that they thought non-burning would reduce yields while some 60 thought that non-burning of residue has no impact on crop yields. In terms of impacts on soil quality, the pattern of responses is slightly different – 54 percent thought that burning of residue improves the physical properties of the soil and 42 percent reported no impact on the physical properties of soil due to burning of residue.

Interestingly, some 48 percent of respondents felt that the burning of rice residue had a negative impact on the environment. However, 30 percent of respondents had no opinion on the effect of burning on the environment (Figure 3).

One important question to gauge the knowledge of respondents was regarding alternative technologies to burning. Some 84 percent of farm respondents were unaware of any alternative technology. When the respondents who had knowledge of alternative technology were asked to list their reasons for not adopting alternative technology, over 76 percent reported that alternative technology was expensive while 21 percent reported that appropriate equipment was not available.

Overall, the information on perception suggests that farmers are more or less evenly divided in thinking that burning is or is not useful for soils and yields. Further, a large proportion is aware of at least some environmental impacts – possibly local air pollution. However, there is a strong sense that there is no alternative to burning. This perhaps, is the most significant result.

4.3 Results of the Models

We present the results of the seemingly unrelated regression (SUR) model and seemingly unrelated Tobit regression (SUTR) model in Tables 4 and 5, respectively. Since the signs and significance of the various explanatory variables are almost the same under SUR and SUTR models, we only discuss the results of the SUTR model. The explanatory variables that are significant in the allocation of rice acreage to various rice residue management practices are: (i) geographic location of the farm (particularly in Gujranwala district); (ii) convenience in use of farm machinery due to burning of residue; (iii) negative impact of burning on environment; (iv) farm size; (v) Rajput caste; and (vi) reduction in turn-around time between the harvesting of rice and the sowing of wheat crop. In most of the cases, the coefficients have the expected signs.

Of the significant variables, the geographic location of the farm in Gujranwala district is the most important variable in influencing rice area allocation to various rice residue management practices in both the models. The negative coefficient of Gujranwala for FULL REMOVAL implies that compared to Sialkot district, rice residue is removed from a smaller proportion of rice cultivated area in Gujranwala district. However, the positive coefficients of Gujranwala for PARTIAL BURN and FULL BURN show that the proportion of rice area placed under PARTIAL BURN and FULL BURN is more in the Gujranwala district as compared to the Sialkot district. This might be due to the fewer number of animals per unit area in the Gujranwala district in comparison with the Sialkot district where rice residue is used more frequently as feed for animals. It should be noted that we drop the PARTIAL INCORPORATION equation to avoid singularity of the error covariance matrix.

Size of the farm is an important factor influencing the proportion of rice area under various residue management practices. Farm size has a negative and significant influence on the proportion of rice area allocated to FULL REMOVAL. Thus, as hypothesized, the larger the farms, the less likely it is that farmers will fully remove their residue. Farm size, on the other hand, increases the proportion of land where either the entire residue is burned (FULL BURN) or where pural is removed and the rest burned (PARTIAL BURN). An increase in farm size is associated with fewer animals per unit area, which results in a lower demand for rice residue as feed, increasing the burning of residue.

Among the various castes, the ‘other’ caste category, which includes Gujjar, Syed, Sheikh, etc., is treated as the reference caste. The Rajput caste has a negative and significant influence on the proportion of area allocated to FULL REMOVAL while it has a positive and significant influence on FULL BURN. Thus, Rajput farmers are less likely to adopt full removal and more frequently choose to burn the entire residue relative to other castes.

Owner-operated farms result in a larger proportion of rice area allocated to FULL REMOVAL, while this factor has a significant negative influence on FULL BURN. Thus, it seems that the farmers of owner-operated farms have a long term planning horizon and may be more concerned with the sustainable use of land resources as compared to either owner-cum-tenant or tenant farms.

Convenience in the use of farm machinery also plays an important role in the allocation of rice area to various rice residue management practices. The results show that this explanatory variable has a significant negative impact on the proportion of area under the FULL REMOVAL practice, while it has a significant positive impact for both PARTIAL BURN and FULL BURN. This suggests that in order to obtain a higher yield of wheat, farmers require immediate clearing of the rice field, which makes it easier to use farm machinery for growing the wheat crop. They achieve this through burning of residue completely or partly.

Reduction in turnaround time between the harvesting of rice and the sowing of the wheat crop variable has a negative and significant impact (at 5 percent level) on the proportion of rice area under the FULL REMOVAL, a positive and significant influence (at 1 percent level) on FULL BURN. The reduction in turn-around time is required to avoid delay in the sowing of wheat, which could reduce wheat yields by 30 kg per day (Aktar et al., 1992). Farmers try to avoid delay through the allocation of more rice area to burning practices.

Finally, a few variables individually influence the proportion of the total rice area allocated to a particular residue management practice. Among these influences, family labor used for the handling of rice residue has a significant positive influence on PARTIAL BURN while animal strength has a significant positive effect on FULL REMOVAL. Farmer’s perception that burning of rice residue has a negative impact on the environment, on the other hand, has a significant and positive influence on FULL BURN. This is in spite of farmers’ knowledge about it. A plausible explanation would be that these farmers do not consider environmental impacts important when choosing alternative rice residue management practices.

To summarize, full removal and full burning are two ends of the options faced by farmers for managing residue. Factors that positively and significantly increase land area allocated to full residue removal include owner operated farms and animal strength. On the other hand, factors that seem to increase the land allocated to full burning are geographic location of farm in Gujranwala district, farmers belonging to the Rajput caste, increase in farm size, reduction in turnaround time between the harvesting of rice and the sowing of the wheat crop, convenience in the use of farm machinery for wheat sowing and farmer’s perception that burning of rice residue has a negative impact on the environment. The last environmental perception variable is an anomaly that is difficult to explain as farmers who think there may be a negative environmental effect from burning, seem to allocate more land for burning.

5. Conclusions and Policy Recommendations

This study addresses an important issue, namely, the burning of rice crop residue, which is a common problem in the Indo-Gangetic plains of Pakistan and India. Rice residue burning has emerged as a serious policy concern in recent years because of its contributions to atmospheric brown clouds over South Asia and the release of black carbon, with implications for regional and local climate. This study reports evidence on why farmers burn residue from two districts in Punjab, Pakistan. By understanding farmer motivations, we hope to identify solutions that may reduce residue burning.

Wheat and rice are the dominant crops in the study area. In terms of residue management, a large proportion of farmers i.e. some 48% fully remove rice residue before growing wheat. However, in terms of area allocated to different residue management practices, fully burning of rice residue dominates. About 58% of rice area is fully burnt in the sample farms. A majority of farmers reported an increase in the burning of rice residue after the entry of the 'combine harvester'. This technology allows farmers to harvest their rice crop more quickly and efficiently but leaves straw on the ground. Since labor is very busy at the end of the rice season in harvesting rice and sowing wheat, this machine encourages farmers to burn rice residue in the field.

We undertook statistical analyses to examine what factors influenced residue management strategies at the farm level. Results from these analyses show that the proportion of rice area allocated to complete removal of rice residue increased when farms were owner operated and livestock numbers were high. Farmers who are owner-operators seem to lean towards full removal of residue, possibly due to their longer-term vision. Households who have larger numbers of livestock, understandably, are more inclined towards residue removal to feed their animals.

On the other hand, farmers who mostly burned their rice residue or allocated a higher proportion of land to this practice, were influenced by factors such as size of the farm, convenience with which machinery could be used for the wheat crop and reduction in time between the rice and wheat crops. Thus, farmers burn residue mainly due to inconveniences faced in the use of farm machinery for preparing the post-rice wheat field and because of the short turn-around time between the harvesting of rice and the sowing of wheat. Many farmers also harbor a perception that burning residue increases crop yields or soil qualities.

In order to understand how costly residue management was to farmers, we estimated the costs of different practices. The total cost of handling rice residue and preparing the wheat field after rice when farmers fully burn rice residue, i.e. when they burn the pural and the lower parts of the rice plant, is PKR 3424 (USD 41) per acre. This practice costs substantially less relative to other practices. Incorporation of rice residue, which is the next best alternative in terms of the cost of handling residue and preparing wheat field, costs 20% more than the cost of a full burn. Nonetheless, as noted, the most important alternate practice is full residue removal. This practice is, on average, some 34% more costly than simply burning the residue.

There are multiple reasons why farmers who remove residue may be continuing to do so even though it is a costlier practice. We were unable to document net profits to farmers who adopt different residue management practices. Thus, it may be that profits are higher when residue is removed, acting as an incentive to farmers. It is also possible that farmers who need the residue for animal feed are maximizing their joint returns from animals and agriculture; thus they prefer to remove residue versus burning it.

Farmers who are burning their residue will need some form of incentive to move them towards rice residue incorporation, which is the next best alternative. Adopting full incorporation or removing pural and incorporating the lower parts of rice stem, however, requires investment in new planting equipment which needs to be subsidized. The average subsidy required to incentivize farmers to move towards residue incorporation would be in the range of PKR 674-908 (US$ 8-11) per acre. This is the difference between the average cost of fully burning and the average cost of full or partial incorporation of residue into the soils.

Farmers in Pakistan currently face short-term private costs from 'not-burning'. However, there are may well be longer-term private benefits in terms of soil quality. There will also be public benefits related to air pollution and climate change. Thus, policy makers should consider different steps for reducing rice straw burning. They can encourage the industrial use of rice residue by strengthening commercial markets for residue. They can also introduce and subsidize equipment required for the incorporating rice residue into the soils. In this connection, the Government could promote machines such as the Happy Seeder that is currently in use in the Indian Punjab. This machine helps to sow wheat immediately after the rice harvest, using rice straw as mulch. It does not increase the cost of wheat field preparation and precludes the need for burning rice residue (Gupta, 2012).

Agricultural scientists need to conduct research to determine both the short run and long run impacts of residue burning versus other residue management practices on crop yields, soil quality, weeds, insects etc. in the rice-wheat cropping system of Punjab. However, simultaneously, agricultural extension services can highlight for farmers, the climate and air pollution related damages associated with the burning of residue, as well as the long-term benefits of residue incorporation on soil properties.

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Tables

Table 1: Dominant Crop Residue Management Practices followed by Farmers

Practice	Farmers following Dominant Practice	
	Number	Percent
Removal of Rice Residue	191	48
Removal of pural and Burning of Lower Parts of Rice Stem	43	11
Removal of pural and Incorporation of Lower Parts of Rice Stem	20	5
Burning of pural and Lower Parts of Rice Stem	144	36
Complete Incorporation	2	0.50
Total	**400**	**100.00**

Table 2: Proportion of Rice Area with Various Varieties under Different Residue Management Practices

Variety	Area (acres)	Pattern of Residue Management (Percent of Total Rice Area)				
		Complete Removal of Residue	Removal of *pural* and Burning of Lower Parts of Rice Plant	Burning of *pural* and Lower Parts of Rice Plant	Removal of *pural* and Incorporation of Lower Parts of Rice Plant	Complete Incorporation
Super Basmati	2,677	25	12	59	3	1
Basmati 386	810	26	12	53	9	0
Other Varieties	303	23	12	62	3	0
All Varieties	3,790	25	12	58	4	1

Table 3: Definition and Descriptive Statistics of the Variables Used in the Models

Variable	Description	Mean	Std. Dev	Min	Max
FULL REMOVAL	Proportion of rice area under complete removal of rice residue practice, i.e., ARPRAC=FULL REMOVAL	0.50	0.47	0	1
PARTIAL BURN	Proportion of rice area under removal of pural and burning of lower parts of rice plant practice, i.e., ARPRAC=PARTIAL BURN	0.11	0.29	0	1
FULL BURN	Proportion of rice area under burning of pural and burning of lower parts of rice plant practice, i.e., ARPRAC=FULL BURN	0.34	0.44	0	1
PARTIAL INCORPORATION	Proportion of rice area under removal of pural and incorporation of lower parts of rice plant practice, i.e., ARPRAC=PARTIAL INCORPORATION	0.05	0.21	0	1
GUJRANWALA	1 if farm is located in Gujranwala district; 0 otherwise	0.50	0.50	0	1
EXPERIENCE	Farming experience of farmer in years	27.63	15.99	1	70
OCCUPATION	1 if farming is the primary occupation; 0 otherwise	0.92	0.27	0	1
EDUCATION	1 if education level of farmer is above matric; 0 otherwise	0.09	0.28	0	1
JAT	1 if caste of farmer is Jat; 0 otherwise	0.57	0.50	0	1
ARIAN	1 if caste of farmer is Arian; 0 otherwise	0.06	0.24	0	1
RAJPT	1 if caste of farmer is Rajput; 0 otherwise	0.13	0.33	0	1
SIZE	Operational size of farm in acres	11.91	14.96	0.62	100
OWNEROPERATOR	1 if farmer is owner operator; 0 otherwise	0.76	0.43	0	1
FRAGMENT	Number of places where the farm land is situated	1.51	0.78	1	4
CLAY	1 if the dominant soil type is clayey; 0 otherwise	0.34	0.48	0	1
ANIMALUNIT	Animal units on the farm	8.91	11.43	0	130
SUPERACREAGE	Proportion of rice acreage allocated to super basmati to total rice acreage	73.42	38.05	0	100
TURNARROUND	1 if the intention of respondent is to reduce turn-around time between harvesting of rice and sowing of wheat; 0 otherwise	0.10	0.29	0	1
CONVENIENCE-MACHINERY	1 if burning of residue results in convenience in use of farm machinery; 0 otherwise	0.58	0.49	0	1
PERCEPTION-YIELD	1 if the perception of the farmer is that non-burning of residue will increase the yield of various crops; 0 otherwise	0.60	0.49	0	1
PERCEPTION-SOILIMPROVE	1 if the perception of the farmer is that burning of residue will improve the physical properties of soil in the long run; 0 otherwise	0.54	0.50	0	1
PERCEPTION-ENVIRONMENT	1 if the farmer thinks that burning of residue has negative impact on environment; 0 otherwise	0.48	0.50	0	1
PERCENTFAMILY-LABORUSE	Use of family labor for handling rice residue in percent	78.81	37.23	0	100
WAGERATE	Prevailing wage rate of unskilled labor in the village in rupees	292.02	30.64	150	400

Table 4: Results of Seemingly Unrelated Regression Model

Variable	Removal of Rice Residue (FULL REMOVAL)	Removal of *pural* and Burning of Lower Parts of Rice Plant (PARTIAL BURN)	Burning of *pural* and Lower Parts of Rice Plant (FULL BURN)	Removal of *pural* and Incorporation of Lower Parts of Rice Plant (PARTIAL INCORPORATION)
GUJRANWALA	-0.231***	0.0698**	0.0934**	0.0678***
	(0.0428)	(0.0315)	(0.0419)	(0.0226)
EXPERIENCE	-0.00227*	0.00123	0.000544	0.000487
	(0.00126)	(0.000929)	(0.00124)	(0.000667)
OCCUPATION	0.0102	-0.00727	-0.0210	0.0180
	(0.0798)	(0.0587)	(0.0781)	(0.0421)
EDUCATION	0.0428	-0.0213	-0.000227	-0.0213
	(0.0805)	(0.0592)	(0.0787)	(0.0425)
JAT	-0.0247	0.0105	-0.0148	0.0290
	(0.0499)	(0.0367)	(0.0488)	(0.0263)
ARIAN	-0.101	0.0314	-0.0545	0.124***
	(0.0879)	(0.0646)	(0.0859)	(0.0464)
RAJPUT	-0.224***	-0.0172	0.157**	0.0847**
	(0.0701)	(0.0516)	(0.0686)	(0.0370)
SIZE	-0.0102***	0.00195	0.00889***	-0.000678
	(0.00171)	(0.00126)	(0.00167)	(0.000902)
OWNEROPERATOR	0.102**	0.00273	-0.0978**	-0.00651
	(0.0498)	(0.0367)	(0.0487)	(0.0263)
FRAGMENT	0.0119	-0.0198	-0.0113	0.0192
	(0.0293)	(0.0215)	(0.0286)	(0.0154)
Clay	-0.00177	0.0527*	-0.0374	-0.0135
	(0.0425)	(0.0313)	(0.0416)	(0.0225)
ANIMALUNIT	0.00402**	-0.00160	-0.00232	-9.47e-05
	(0.00202)	(0.00149)	(0.00198)	(0.00107)
SUPERACREAGE	-8.22e-05	-8.79e-05	0.000713	-0.000543*
	(0.000527)	(0.000387)	(0.000515)	(0.000278)
TURNARROUND	-0.199***	0.0622	0.158**	-0.0209
	(0.0675)	(0.0496)	(0.0660)	(0.0356)
CONVENIENCEMACHINERY	-0.274***	0.0652**	0.226***	-0.0174
	(0.0431)	(0.0317)	(0.0421)	(0.0227)
PERCEPTIONYIELD	-0.0254	0.0467	-0.0271	0.00582
	(0.0503)	(0.0370)	(0.0492)	(0.0265)
PERCEPTIONSOILIMPROVE	0.0555	-0.0607*	0.0332	-0.0279
	(0.0500)	(0.0368)	(0.0489)	(0.0264)
PERCEPTIONENVIRONMENT	0.0222	-0.0680**	0.110***	-0.0643***
	(0.0433)	(0.0318)	(0.0423)	(0.0228)
PERCENTFAMILYLABORUSE	-0.000804	0.000603	0.000471	-0.000270
	(0.000553)	(0.000407)	(0.000541)	(0.000292)
WAGERATE	-0.000226	0.000574	-0.000285	-6.33e-05
	(0.000657)	(0.000483)	(0.000642)	(0.000347)
Constant	0.992***	-0.173	0.105	0.0764
	(0.232)	(0.170)	(0.227)	(0.122)
Observations	398	398	398	398
R-squared	0.358	0.086	0.296	0.108

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: Results of Seemingly Unrelated Tobit Regression Model

Variable	Removal of Rice Residue (FULL REMOVAL)	Removal of pural and Burning of Lower Parts of Rice Plant (PARTIAL BURN)	Burning of pural and Lower Parts of Rice Plant (FULL BURN)
GUJRANWALA	-1.085***	1.086***	0.414**
	(0.236)	(0.417)	(0.193)
EXPERIENCE	-0.00719	0.0134	0.000128
	(0.00631)	(0.0114)	(0.00589)
OCCUPATION	-0.00186	0.0960	-0.107
	(0.391)	(0.798)	(0.329)
EDUCATION	0.294	-0.264	-0.0774
	(0.405)	(0.675)	(0.346)
JAT	-0.269	0.179	0.0545
	(0.255)	(0.487)	(0.220)
ARIAN	-0.470	0.129	-0.169
	(0.440)	(0.882)	(0.496)
RAJPUT	-1.037***	-0.300	0.655**
	(0.379)	(0.767)	(0.310)
SIZE	-0.0408***	0.0309**	0.0308***
	(0.0121)	(0.0151)	(0.00850)
OWNEROPERATOR	0.450*	0.0982	-0.455*
	(0.263)	(0.472)	(0.234)
FRAGMENT	0.104	-0.264	-0.0629
	(0.140)	(0.295)	(0.129)
Clay	-0.0871	0.583	-0.121
	(0.221)	(0.370)	(0.200)
ANIMALUNIT	0.0186**	-0.0268	-0.00920
	(0.00840)	(0.0197)	(0.00696)
SUPERACREAGE	0.000797	-0.00262	0.00329
	(0.00279)	(0.00526)	(0.00265)
TURNARROUND	-0.917**	0.652	0.834***
	(0.366)	(0.557)	(0.322)
CONVENIENCEMACHINERY	-1.217***	0.895**	1.102***
	(0.249)	(0.456)	(0.218)
PERCEPTIONYIELD	-0.142	0.498	-0.119
	(0.257)	(0.456)	(0.243)
PERCEPTIONSOILIMPROVE	0.295	-0.720	0.152
	(0.259)	(0.486)	(0.238)
PERCEPTIONENVIRONMENT	0.147	-0.599	0.487**
	(0.215)	(0.409)	(0.198)
PERCENTFAMILYLABORUSE	-0.00363	0.00831*	0.00185
	(0.00282)	(0.00491)	(0.00251)
WAGERATE	-0.000112	0.00734	-0.00103
	(0.00361)	(0.00672)	(0.00321)
Constant	2.460*	-6.581**	-1.462
	(1.266)	(2.750)	(1.128)
Observations	398	398	398

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: Due to the small number of observations, we could not get the coefficient for the 'Removal of pural and incorporation of the lower parts of the rice plant (PARTIAL INCORPORATION)' practice.

Figures

Figure 1: Map of the Punjab with Districts

Note: The underlined districts lie in the rice-wheat cropping system of the Punjab, Pakistan, while the districts underlined double constitute the study area

Figure 2: Cost of Handling of Rice Residue and Preparation of Wheat Field after Various Residue Management Practices

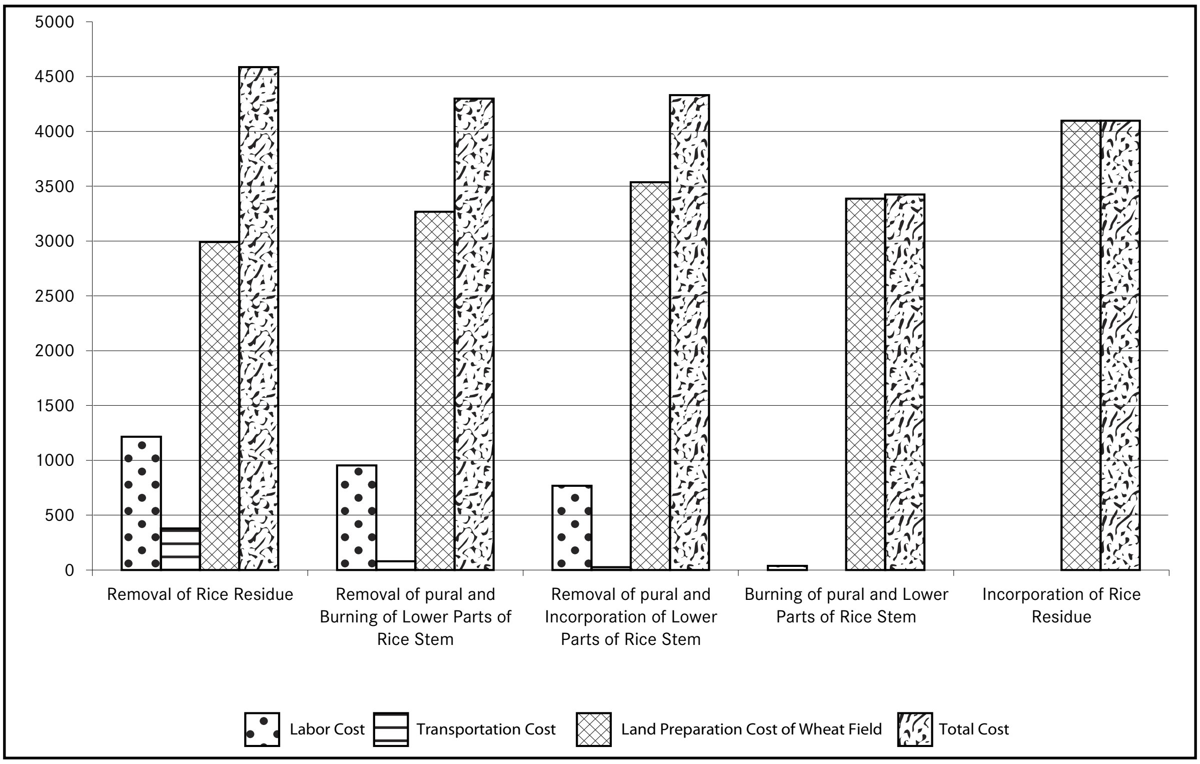
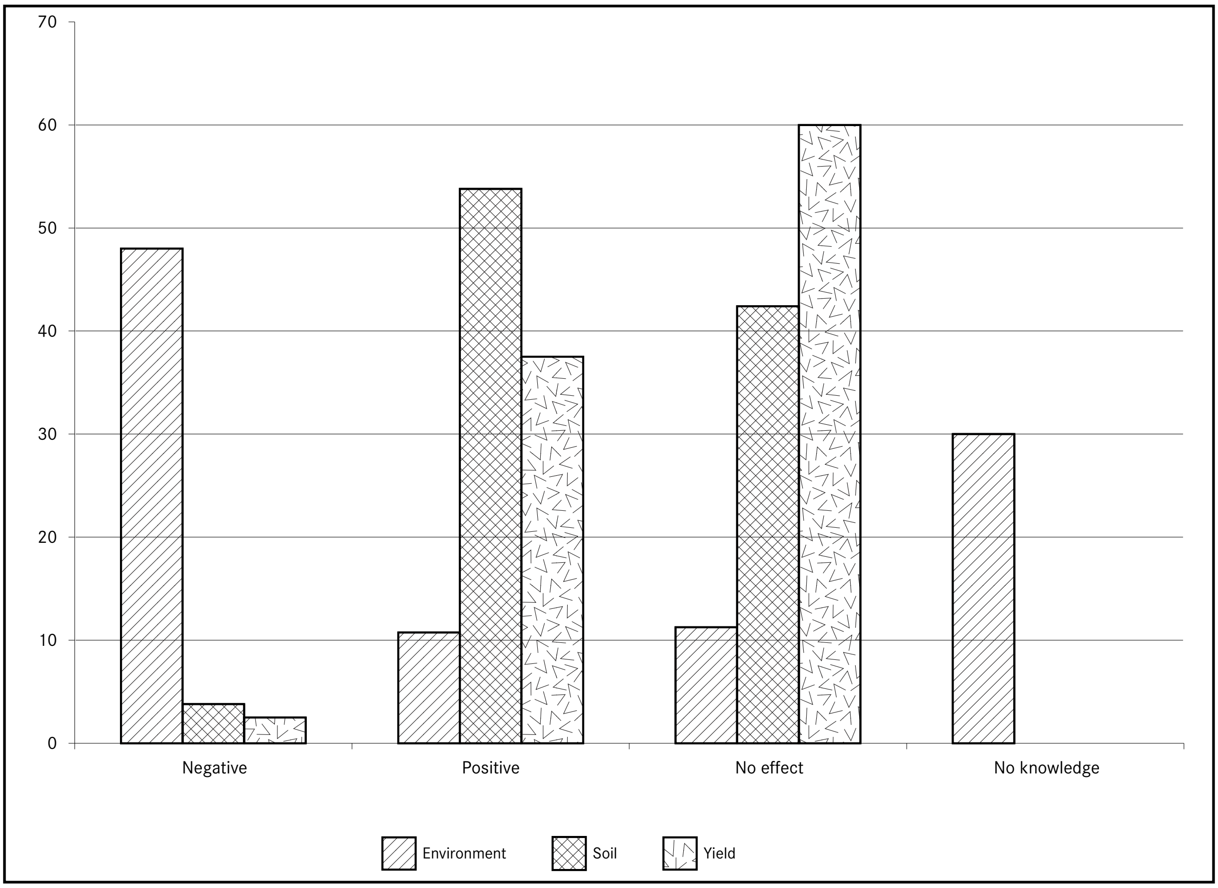


Figure 3: Perceptions about the Impact of Rice Residue Burning on the Environment, Soil and Yield



Annexes

Appendix A: General Features of the Farmers and Farms

Variable	Units	Mean
Respondent age	Years	47.49
Farming experience	Years	27.63
Farming as primary occupation	%	92.00
Farming as secondary occupation	%	8.00
Respondents illiterate	%	51.00
Respondents with up to ten years of education	%	40.00
Respondents with above ten years of education	%	9.00
Respondents of Jat caste	%	57.00
Respondents of Arian caste	%	6.00
Respondents of Rajput caste	%	13.00
Respondents of other castes	%	24.00
Owner operators	%	76.00
Owner-cum-tenants	%	20.00
Tenants	%	4.00
Area under super basmati of the total rice area	%	70.63
Area under basmati 386 of the total rice area	%	21.37
Area under other varieties of the total rice area	%	8.00
Adult buffaloes per farm	Number	4.03
Young buffalo stock per farm	Number	2.37
Adult cows	Number	0.91
Young cow stock	Number	0.72
Area under rice of total cropped area	%	42.91
Area under wheat of total cropped area	%	40.16
Area under fodder of total cropped area	%	10.98
Paddy yield per acre of super basmati	In 40 kg	38.62
Paddy yield per acre of basmati 386	In 40 kg	46.24
Overall paddy yield per acre of rice	In 40 kg	40.60
Straw yield per acre of super basmati	In 40 kg	39.53
Straw yield per acre of basmati 386	In 40 kg	43.04
Overall straw yield per acre of rice	In 40 kg	40.05
Labor use per acre for handling of residue in removal of rice residue practice	Hours	33.29
Labor use per acre for handling of residue in removal of pural and burning of lower parts of rice stem practice	Hours	26.12
Labor use per acre for handling of residue in removal of pural and incorporation of lower parts of rice stem practice	Hours	21.06
Proportion of straw burnt when pural was removed and lower parts of rice stem were burnt	%	53.75-58.12
Proportion of straw burnt when pural and lower parts of rice stem were burnt	%	60.27-69.59
Use of removed rice residue as feed	%	87.21
Use of removed rice residue as fuel	%	7.87
Removed residue sold	%	4.92
Advantage of use of removed rice residue as feed	%	62.5
Convenient use of farm equipments as an advantage in rice residue removal	%	44.75
Improvement in physical properties of soil as an advantage in incorporation of rice residue	%	90.00
Less requirement of fertilizer as an advantage in incorporation of rice residue	%	15.75
Short turn-around time between harvesting of rice and sowing of wheat as the reason for burning of rice residue	%	46.00
Inconvenience in use of farm machinery because of rice residue as the reason for burning of rice residue	%	64.75

Variable	Units	Mean
Perception of respondents that non-burning of residue increases yields of various crops	%	2.50
Perception of respondents that non-burning of residue decreases yields of various crops	%	37.50
Perception of respondents that non-burning of residue has no effect on the yield of various crops	%	60
Perception of respondents that burning of residue improves the physical properties of soil	%	53.80
Perception of respondents that burning of residue deteriorates the physical properties of soil	%	3.80
Perception of respondents that burning of residue has no effect on the physical properties of soil	%	42.40
Perception of respondents that burning of residue increases plant nutrients in soil	%	15.50
Perception of respondents that burning of residue decreases plant nutrients in soil	%	27.00
Perception of respondents that burning of residue has no effect on plant nutrients in soil	%	11.50
Respondents reporting that they do not know the effect of burning of residue on plant nutrients in soil	%	46.00
Perception of respondents that burning of residue increases organic matter in soil	%	27.80
Perception of respondents that burning of residue decreases organic matter in soil	%	50.22
Respondents reporting that they do not know the effect of burning of residue on organic matter in soil	%	21.97
Perception of respondents that burning of residue has negative impact on environment	%	48.00
Perception of respondents that burning of residue has positive impact on environment	%	10.75
Perception of respondents that burning of residue has no impact on environment	%	11.25
Respondents reporting that they do not know the impact of burning of residue on environment	%	30.00
Use of rice residue as feed for animals as the reason for not burning the residue	%	94.50
Use of rice residue as fuel for animals as the reason for not burning the residue	%	23.50
Respondents reporting an increasing trend in burning of rice residue	%	61.25
Respondents reporting a decreasing trend in burning of rice residue	%	31.00
Respondents reporting no change in burning of rice residue	%	7.75
Respondents reporting an increasing trend in burning of residue due to use of combine harvester	%	72.24
Respondents reporting an increasing trend in burning of residue due to more area under rice	%	9.80
Respondents reporting an increasing trend in burning of residue due to absence of buyers	%	6.12
Respondents reporting an increasing trend in use of rice residue as feed	%	61.25
Respondents reporting a decreasing trend in use of rice residue as feed	%	26.25
Respondents reporting no change in use of rice residue as feed	%	12.50
Respondents reporting an increasing trend in use of rice residue as feed due to less availability of wheat bhoosa	%	82.45
Respondents reporting an increasing trend in use of rice residue as feed due to more number of animals per unit area	%	77.14
Respondents reporting a decreasing trend in use of rice residue as feed due to reduction in milk yield	%	47.62
Respondents reporting a decreasing trend in use of rice residue as feed due to adverse effects on the health of animals	%	53.33

Appendix B: Questionnaire

Economics of Rice Crop Residue Burning in the Rice–Wheat Cropping System of the Punjab, Pakistan

Name of Farmer: ______________________ Father's Name: ________________________

Name of Village:_____________ *Tehsil* ___________________District: ______________

What is your age? __________________ (years)

What is your farming experience? _____________(years)

What is the nature of your farming occupation? Primary———1, Secondary———2.

What is your education? _______ Illiterate….1, Up to Matric….2, Above Matric….3

What is your caste? _______ *Jat*….1, *Arain*….2, *Rajput*….3, *Gujjar*….4, Others….5

1. Operational Farm Holding:

a. How much land is owned by you? ___________________(acres)

b. How much land do you rent from others? ______________(acres)

c. How much land is rented to others by you? _______________(acres)

d. Operational farm size (i.e., a+b-c): ___________________ (acres)

What is the number of places where the land is situated? ___________________

2. Plot Size and Soil Type:

Could you provide the following information about all the plots/fragments?

Plot Number	**What is the soil type of the plot?** **Clayey….1, Silt loam….2, Sandy loam….3**

3. Livestock on the Farm:

a. What is the number of adult buffaloes on your farm? _______________

b. What is the number of young buffaloes on your farm? _____________

c. What is the number of adult cows on your farm? __________________

d. What is the number of young cows on your farm? _________________

e. What is the number of bullocks on your farm? ___________________

f. What is the number of donkeys on your farm? ___________________

g. What is the number of horses on your farm? ____________________

h. What is the number of camels on your farm? ____________________

i. What is the number of sheep on your farm? ______________________

j. What is the number of goats on your farm? ______________________

4. Cropping Pattern and Residue Management of Various Crops:

a. Area and Residue Management of Rice Crop

Plot Number	What varieties of rice crop did you cultivate? Super basmati....1, Basmati 386....2, Basmati 385....3, Irri Fan....4, Super Fan ....5, Malta.....6, Irri 9....7, Irri 6 ....8, JS 282 ....9, Others 10	Area (acres)	Pattern of Residue Management (acres)				
			What is the area from which the residue was removed 100 percent (acres)?	What is the area from which pural was removed and lower parts of stem were burnt (acres)?	What is the area from which pural and lower parts of stem were burnt (acres)?	What is the area from which the pural was removed and lower parts of the stem were incorporated into soil (acres)?	What is the area where the entire residue was incorporated into the soil (acres)?

b. Area and Residue Management of Other Crops on all Plots

What crops other than rice did you cultivate? Sugarcane....1 *Kharif* fodder....2 Wheat....3 Rabi fodder....4 Vegetables....5	Area (acres)	*Tell me the area where residue was removed (acres)?	*Tell me the area where residue was burnt (acres)?	*Tell me the area where residue was incorporated (acres)?
*Enumerators [?]: Do not ask these questions for fodder and vegetables				

5. Yield of rice and ratio of paddy to straw. Please ask the following information from the farmer.

What is the plot No.?	What is the variety? Super basmati....1, Basmati 386....2, Basmati 385....3, Irri Fan....4, Super Fan ....5, Malta.....6, Irri 9....7, Irri 6 ....8, JS 282 ....9, Others 10	What is the yield of paddy in 40 kg?	What is the ratio of paddy to straw?

6. Did you plant wheat before the end of November (or mid of Muggar): Yes...1, No...2, ___________

7. How did you dispose of the removed rice residue? (give percent) (Leave blank if residue was not removed):

a. How much was used for feeding of animals? ________________
b. How much was used as fuel? ______________________________
c. How much was sold? ____________________________________

If sold, then provide information about the place of sale and name of buyer:

What is the Variety? Super basmati….1, Basmati 386….2, Basmati 385….3, Irri Fan….4, Super Fan ….5, Malta…..6, Irri 9….7, Irri 6 ….8, JS 282 ….9, Others ….10	**What is the place of sale? Rice field…1, village…2, town market…3**	**Who is the buyer? Rural user…1, Village dealer…2, Industrial user…3**	**What did you charge per 40 kg of rice residue?**

8. a. Does a market exist for rice residue for industrial use? Yes…1, No…2 ______

b. Did you buy fodder for your animals? Yes…1, No…2 _____________________

If yes, how much area was purchased (in acres) ________________________________

9. Use of labor associated with various rice residue management practices (in labor hour)

	Labor use	**A**	**B**	**C**	**D**
I	How many labor hours were spent on the removal of the entire rice residue?		X	X	X
II	How many labor hours were spent on the removal of pural?	X			X
III	How many labor hours were spent on loading, transportation, unloading and stacking?				X
IV	How many labor hours were spent on the burning of rice residue, controlling of fire to avoid damage to trees, crops etc.	X			

A…Removal of rice residue, B…Removal of pural and burning of lower parts of rice stem, C…Removal of pural and incorporation of lower part of rice stem, D. Burning of pural and lower parts of rice stem.

How much family labor is used for I to IV operations (percent)?___________________

What is the prevailing wage rate of unskilled labor in the village? _________________

What is the value of the hand tool used for burning?________________________________

What is the proportion of the hand tool used this year (percent)? __________________

What is the dominant practice followed?

a. Removal of rice residue;_______________________________________

b. Removal of pural and burning of lower parts of rice stem; _________

c. Removal of pural and incorporation of lower part of rice stem;____

d. Burning of pural and lower parts of rice stem;____________________

e. Complete Incorporation._______________________________________

10. How do you transport residue for different rice residue management practices?

What was the means of transportation?	A	B	C	What is the amount paid/prevailing rate per acre if own tractor and trolley were not used?
Hiring of tractor				
Own tractor and trolley				
Any other				

A. Removal of rice residue, B. Removal of pural and burning of lower parts of rice stem, C. Removal of pural and incorporation of lower part of rice stem,

If own tractor and trolley were used:

a. What is the make of your tractor? ____________________________
b. What is the market price of new trolley under use? ______________
c. What is the fuel consumption/hours (liter)? ______________________
d. What was the price per liter?__________________________________
e. What is the present cost of tractor shed? _________________________
f. What is the prevailing daily rate of skilled worker? _______________
g. How many tractor and trolley hours were used for the transportation of rice residue of one acre? _____
h. What was the value of stacked rice residue of one acre? ____________

11. Use of tractor and implements for preparation of field for wheat crop/following crop in rabi season after various crop residue management practices:

Equipment used	How many times was the operation performed (number)?					What is the time per operation in case of own tractor and equipment?
	A	B	C	D	E	
Disc Plow						
Rotavator						
Cultivator						
Planking						
Any other (specify)						

A. After the removal of rice residue; B. After the removal of pural and burning of lower parts of rice stem; C. After the removal of pural and incorporation of lower part of rice stem; D. After the burning of pural and lower parts of rice stem; E. Incorporation of rice residue

a. Hiring rate per operation if services were hired:
   i. What is the hiring rate for the operation of disc plow?____________
   ii. What is the hiring rate for the operation of rotavator? ____________
   iii. What is the hiring rate for the operation of cultivator? ____________
   iv. What is the hiring rate for the operation of planking?_____________
   v. What is the hiring rate for the operation of any other equipment (specify)? ___________________________

b. In case of owned tractor and equipment:
   i. What is the make of your tractor? ______________________________
   ii. What is the market price of new disc plow under use?_____________
   iii. What is the market price of new rotavator under use?______________
   iv. What is the market price of cultivator under use? _________________
   v. What is the market price of new planker under use?_______________

vi. What is the fuel consumption/hour? ___________________________

vii. What is the price per liter? ____________________________________

viii. What is the present cost of tractor and equipment shed? ___________

ix. What is the prevailing daily rate of skilled worker? _______________

12. Proportion of straw burnt of total straw produced with various rice residue management practices:

Variety **Super basmati…1** **Basmati 386….2,** **Basmati 385….3, Irri Fan….4, Super Fan ….5, Malta…..6,** **Irri 9….7, Irri 6 ….8,** **JS 282 ….9, Others ….10**	**What was the proportion of straw burnt when the pural was removed and lower parts of rice stem were burnt?**	**What was the proportion of straw burnt when the pural and lower parts of rice stem were burnt?**

13. Proportion of straw incorporated of total straw produced with various practices:

Variety **Super basmati…1** **Basmati 386….2,** **Basmati 385….3,** **Irri Fan….4, Super Fan ….5,** **Malta…..6, Irri 9….7, Irri 6 ….8,** **JS 282 ….9, Others ….10**	**What was the proportion of straw incorporated when pural was removed and lower part of rice stem was burnt (%)?**	**Removal of pural and the proportion of straw incorporated when pural was removed and lower part of rice stem was incorporated (%)**	**What was the proportion of straw incorporated when pural and lower parts of rice stem were burnt (%)**

14. What is the intention of crop residue burning (let the respondent respond and tick accordingly):
    a. To control insects, weeds and diseases;
    b. To reduce turn-around time between harvesting of rice and sowing of wheat;
    c. The profitability of burning over non-burning;
    d. Convenience in use of farm machinery;
    e. Other (specify).______________________________

    Is farm machinery available for incorporation of rice residue: Yes…1, No…2 __________

15. What are the advantages of the removal of rice residue (let the respondent respond and tick accordingly):
    a. Farm equipment can be used more conveniently;
    b. Rice residue can be used as feed;
    c. Source of fuel for domestic cooking;
    d. Any other (specify) __________________

16. What are the reasons for burning rice residue in the field (let the respondent respond and tick accordingly):
    a. Short turn-around time between harvesting of rice and sowing of wheat;
    b. Non-availability of appropriate farm machinery for incorporation;
    c. Farm equipment cannot be used conveniently;
    d. Burning increases the yield of the following wheat crop;
    e. No market exists for the residue in the industry;
    f. Any other (specify) ____________________

17. What are the advantages of incorporation of rice residue (let the respondent respond and tick accordingly):
    a. Improve the physical properties of soil;
    b. No negative impact on the environment;
    c. Require less fertilizer for the following crop;
    d. Other (specify) ______________________________

18. What are the reasons for not burning rice residue (let the respondent respond and tick accordingly)?
    a. Rice residue is used as feed for animals;
    b. Rice residue is used as fuel for home cooking;
    c. Rice residue is incorporated in soil to improve the physical properties;
    d. Other (specify) _________________________________

19. What is the minimum amount of compensation you would need each season in order to give up the practice of burning of rice residue? __________________

20. Do you think non-burning of residue will bring a change in the yield of various crops (let the respondent respond and tick accordingly)?
    a. No change;
    b. Yield decreases;
    c. Yield increases.

21. What are your perceptions about the long run effects of residue burning on the yield of the following wheat crop (let the respondent respond and tick accordingly)?
    a. Yield increases;
    b. Yield decreases;
    c. No effect.

22. What are your perceptions about the long-term effects of residue burning on the yield of rice (let the respondent respond and tick accordingly)?
    a. Yield increases;
    b. Yield decreases;
    c. No effect.

23. What are your perceptions about the long-term effects of residue burning on the physical properties of soil (let the respondent respond and tick accordingly)?
    a. Improved soil;
    b. Deteriorated soil;
    c. No effect.

24. Awareness about the effects of burning rice residue:

    Do you think residue burning
    a. Increases nutrients in soil? ______________
    b. Decreases nutrients in soil? _____________
    c. No effect on soil. ______________________
    d. Do not know. __________________________

    Do you think residue burning
    a. Increases organic matter in soil? _________
    b. Decreases organic matter in soil? ________
    c. No effect on soil. ______________________
    d. Do not know. __________________________

Do you think residue burning has

a. A positive impact on environment? ________
b. A negative impact on environment? _______
c. No impact on environment? ____________
d. Do not know. _________________________

25. Adoption of some other methods/technology in place of burning:

Do you know of any alternative technology to burning? yes…1, No…2 _________

If answer is yes, why is the technology not adopted (let the respondent respond and tick accordingly)?

a. Appropriate equipment is not available;
b. Alternative technology is not profitable;
c. Alternative technology is expensive;
d. Alternative technology is not appropriate;
e. Alternative technology disturbs the level of field.

26. What is the trend in the burning of rice residue? __________

Trend increasing…1, Trend decreasing…2, No change ….3

a. If trend is increasing, why? (let the respondent respond and tick accordingly):
    i. Because of use of combine harvester;
    ii. No buyer of rice residue;
    iii. More area under rice crop;
    iv. Any other (specify) ___________________

b. If trend is decreasing, why? (let the respondent respond and tick accordingly):
    i. More use of rice residue as feed for animals;
    ii. Use of rice residue as fuel for cooking purposes;
    iii. More buyers because of its industrial use;
    iv. Any other (specify) _______________

When did the practice of rice residue burning begin (in years)? ___________

What were farmers doing before that? ____________________________________

28. What is the trend in the use of rice residue as feed for animals? _________

Trend increasing…1, Trend decreasing…2, No change ….3

a. If trend is increasing why? (let the respondent respond and tick accordingly):
    i. Less availability of wheat bhoosa;
    ii. More number of animals per unit area;
    iii. Attempts to improve milk productivity;
    iv. Any other (specify) ___________________

b. If trend is decreasing, why? (let the respondent respond and tick accordingly):
    i. Decrease in milk productivity when used as feed for animals;
    ii. Adverse effect on the health of animals;
    iii. Any other (specify) _______________

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