An Economic Analysis of Paddy Stubble Management Technology in Amritsar District of Punjab

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Lavleen Kaur Sandhu [1], Mohit Rampal [2], Narinderpal Singh [3]
[1,2.3] Department of Agriculture, Khalsa college, Amritsar, Punjab India.
[1] Corresponding author: gurlavs@yahoo.com

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Abstract: The present study was undertaken to assess the economic evaluation of paddy stubble management technology in Amritsar district of Punjab. The study was based on the primary data collected for 2018-19 year from farmers selected through multistage random cum purposive sampling technique. The requisite primary as well as secondary data was collected to accomplish the objectives of study. The data was analyzed by using tabular analysis, chi-square and logit analysis. The study concluded that cost of paddy per acre increased with the adoption of paddy stubble management technology. With the use of paddy stubble management technology, the cost of inputs per acre decreased and yield of crop increased. The decreased cost of inputs and increased yield of paddy per acre compensates the cost of paddy stubble management technology. It was found in the study that age, availability of machinery with the farmers, less use of inputs due to adoption of technology and land operated by the farmers were the main reasons for adoption of the technology. Opinion survey of the farmers revealed that high cost of paddy stubble management technology, non-availability of stubble management technology with co-operatives were main constraints among non adopters of the technology. For maximum adoption of paddy stubble management technology, it is suggested that more paddy stubble management machines should be made available at co-operatives and it less cost. There is an urge to create awareness among farming communities to incline them to understand importance of crop residues in conservation agriculture for sustainability and resilience of Indian agriculture. It was also suggested that farmers who adopt stubble management technology should be given incentives for its adoption.

Keywords: Stubble management, Adopters, non-adopters, paddy, burning

Introduction

It is estimated that approximately 500-550 Metric ton of crop residues are produced per year in the country. However, a large portion of the residue is burnt on farm primarily to clear the field for sowing of the succeeding crop. The problem of on farm burning of crop residues is intensifying in recent years due to shortage of human labour, high cost of removing the crop residues by conventional methods and use of combines for harvesting of crops (Jain *et al.,* 2012).Farmer 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 corporation 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 microbials biomass, increase the potential for nutrient recycling (Hartley and Kessel, 2005; Prasad *et al.,* 1999; Malhi and Kutcherr, 2007, Ganwar *et al.,*2006) and contribute to higher crop yields (Surekha *et al.* 2003;

Prasad *et al.* 1999; 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.

Burning is an easiest and economical option for management of crop/ biomass residues. Due to lack of awareness or not availability of suitable technologies it is generally practices everywhere. Burning of crop residues not only degrade the atmospheric quality but also affect the climate and ultimate the human health. Crop residue and biomass burning (forest fires) are considered as a major source of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), volatile organic compounds (VOC), Nitrogen oxides and halogen compounds. Biomass burning is a major source of gaseous pollution such as carbon monoxide (CO), methane (CH_4), nitrous oxides (NOx) and hydrocarbons in the troposphere. Researchers found that most of the particulate released due to agriculture crop residue burning (ACRB) are smaller than 10 microns (PM_{10}), and easily enter into the lungs, causing heart problems.(Satyendra et.al,2013) The flaming of paddy stubbles causes soil nutrient loss of organic carbon (3850 million Kg), nitrogen (59 million Kg), phosphorus (20 million Kg) and potassium (34 million Kg)(Arora et. al,2017)

Paddy residue management is important in rice wheat cropping system. 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 and mulching of residue into the soil through use of appropriate farm machinery such as the rotavator , the disc harrow,S-SMS and Happy Seeder.

To make available the paddy straw stubble management technology to farmer's government provided equipment to farmers for free through cooperative societies. Roadmap of Rs 1300 to end stubble burning in Punjab was made. The plan suggested that there are 13000 panchayats in Punjab and If three sets of turbo happy seeder (THS) and super straw management system (S-SMS) machines were given to these panchayats it would require Rs 1300 crore for Punjab as each THS and S-SMS machine cost 1.2 lakh and Rs 1.5 lakh. (The Tribune, 2017). The government is focusing on delivering state of the art machines to the farmers to manage the stubble and make Punjab a zero-stubble burning state. To achieve the task of zero stubble burning, Punjabs agriculture department will provide more than 28,000 agro machines/ farm equipment to the state's farmers with a subsidy component of Rs.278 crore during the current fiscal year. While 80 percent subsidy will be given to cooperative societies and farmers group, individuals will get a subsidy of 50 percent. The department has received around 12,000 applications from individual farmers and farmers groups and Primary agriculture cooperative societies (PACS) till date for subsidized machineries.

Thus, there is urgent need to manage the residues of paddy crop for sustainability and stability of the system. Keeping in view the urgent need of paddy stubble management technology present study was undertaken in Amritsar district with following objectives in view (a)To study the impact of stubble management technology on resource use and return from farm(b) To study the factors affecting the adoption of stubble management technology and suggestions thereof.

Methodology

Keeping in view, the rapid growth of polluted environment, the Amritsar district was purposively selected for the present study. Multi-stage purposive cum random sampling technique was followed for the selection of the study area. At first stage development blocks from selected district i.e. Ajnala block and Harsha-chhina block were selected randomly. At the second stage, four villages from each of these of two blocks were purposively chosen. A list of villages was taken from Chief Agricultural Officer who manage the paddy straw through incorporation or mulching. At third stage 40 adopters and 40 non adopters of stubble management technology were selected from the villages. Therefore, a total sample of 80 farmers (40 adopters plus 40 non-adopters) from four villages were selected for the study purpose.

Table 1. List of selected villages from the Amritsar district

DISTRICT	BLOCK SELECTED	SAMPLE VILLAGE	ADOPTERS	NON-ADOPTERS	
Amritsar	Ajnala	Rajjian	10	10	Total 80 sample respondents in the study area.
		Bhoewali	10	10	
	Harcha-chhina	Mallu-Nangal	10	10	
		Ucha-Killa	10	10	
Total			40	40	

The required information pertaining to the size of operational holding, human labour, seed, fertilizer, pesticides, insecticides, machinery, area, production, productivity of paddy crop was collected from the selected adopters and non-adopters. The data pertaining to the agricultural year 2018-19 were taken for the present study. For achievement of the first objective averages, percentages were worked out.

Chi-Square analysis and Multivariate logistic regression techniques have been used to identify the factors affecting the adoption of paddy stubble management technology among sample respondents. Socio- economic factors are often categorical and not interval scale. The models where dependent variable is categorical, multiple linear regression cannot be carried out as assumption of this technique that dependent variable should be continuous or interval scale not met. Hence LR may be thought of an approach that is similar to multiple linear regression but takes into account the fact that dependent variable is categorical. Independent variables can be interval scale or categorical; if categorical they should be dummy or indicator coded (Trammer and Eliot,2008).

The explanatory variables for the logit model for the sample cases are as explained in the following text:

X_1 = Age (complete, ranging between 31 to 76)
X_2 = Education (No. of years of schooling; ranging between 0 to 18)
X_3 = Family size (Number of members; ranging between 3 and 9)
X_4 = Availability of machinery with the farmers
1– If available with the farmer
0 = If not available the farmer
X_5 = Availability of machinery from cooperatives
1 = If available from cooperatives
0 = If not available from cooperatives
X_6 = Increasing yield
1 – Increase in yield
0 = If not increase in yield
X_7 = Less used inputs
1 = Less used inputs
0 = If more used inputs
X_8 = Land operated area (In acres, ranging between 3 to 30)

Result and Discussion

Paddy is grown on 30 lakh hectares in Punjab. After harvesting, about 20 million tons of paddy straw is left in the fields. It is estimated that 15 million tone of paddy straw is burnt every year. Most of the stubble burning takes place over three weeks in October-November, releasing particulates and smog forming carbon monoxide and nitrogen oxide, which drift from the fields over almost the entire Gangetic plain. This pollution contributes around 12-60 percent of particulate concentrations depending upon the generation of other pollutants in different locations, winds, temperature and other local factors. Farmers themselves are doubly harmed by the local air pollution caused, and by the loss of soil nutrients such as Nitrogen, Potassium, Phosphorous and Sulphur due to burning. This pollution has many adverse effects on human as well as animals' health. Straw burning causes the burning of trees and plants around the fields and on roadsides which result in the loss of biodiversity.

Residue Management Practices Adopted in Punjab

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 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 turnaround time between harvesting of rice and sowing of wheat. The machine is used to both rice and wheat. It harvests rice crop around nine inches above the ground. During 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 labour is needed for harvesting rice and sowing of wheat is difficult, the use of this machine encourages farmers to burn rice residue. Some farmers burn the rice residue and some farmers incorporates the lower part of the paddy into fields (Ahmed and Ahmed ,2013).

In Punjab two straw management options are used. First is In-situ paddy straw management. It includes Mulching and Incorporation. Mulching includes following machines.

1) Mulcher Machine
2) Happy Seeder
3)Super straw management System

Machine Used In Incorporation

1)Paddy straw chopper
2) Rotavator or Disc harrow
3) Reversible Mould Board Plough

Ex-situ Management (Baler)

It is used to compress raked residues wheat, fodders, sugarcane, legumes etc into compact bales that are easy to handle, transport, and store. It is less used because collection and transportation of voluminous mass of paddy residue is cumbersome, therefore, ex-situ residue management is still not an economically viable option. Choudhary *et al.,*2018)

Table 2: Dominant paddy residue management practices followed by farmers in paddy crop

Stubble Management Options	No. of Farmers
In situ	
• Mulching	28 (70)
• Incorporation	12 (30)
Ex-Situ	
• Baler	0
Total	40

As discussed above there are two paddy stubble management options. First is In-situ which includes mulching and incorporation and second is Ex-situ. But all respondents adopted in situ options for paddy stubble management. About 70 percent respondents adopted mulching paddy stubble management option and 30 percent adopted incorporation. No respondent in the study area adopted ex-situ paddy stubble management option.

Table 3: Machinery used in dominant paddy residue management practices (In situ)

Particulars (paddy) (In situ)	Total number of farmers
Combine Harvester+Super SMS +Happy Seeder (Mulching)	28 (70)
Paddy chopper +R.M.B plough + Rotavator (Incorporation)	12 (30)
Total	**40**

Dominant crop residue management practices followed by farmers in paddy crop were Super SMS + Happy seeder (Mulching) and Paddy chopper+ R.M.B plough + Rotavator (Incorporation) (Table 3). The first operation which was used for in-situ management of paddy straw involved combine harvester and spreading of chopped straw with S-SMS (Super straw management system). After this operation happy seeder is used to sow wheat . Around 70 percent respondents in the study area adopted Combine harvester +Super SMS +Happy seeder. In second operation for chopping and spreading of rice straw and stubble in the field paddy Straw chopper cum spreader, R.M.B plough and Rotavator was used. In all 30 percent adopters used Paddy chopper + R.M.B plough + Rotavator technology for management of paddy straw. Around 80 percent subsidy is offered on machines bought by cooperative societies or by group comprising eight members, while 50 percent subsidy is given to individual buyers. The cost of machines fixed by the government is Rs.1.12 lakh for super SMS machines, Rs2.1 lakh for straw chopper, Rs.1.89 lakh for reversible plough, Rs.95000 for rotavator and Rs.50000 for zero till drill. As discussed in the previous table in-situ management of paddy straw was dominant practice among the adopters. In-situ management of paddy straw includes Mulching and Incorporation

Table 4: Detail of the agriculture machinery owned by the residents in the study area

Machine (Paddy)	Number of Respondents
Happy Seeder	15 (46.8)
SMS Machine	0 (0)
Paddy Chopper	5 (15.6)
R.M.B Plough	4 (12.5)
Rotavator	8 (25)
Total	32 (99.9)

It was found in the study area that SMS Machine, Paddy Chopper, R.M.B plough, Rotavator were used for in situ management of paddy in the study area. Table 4 shows the agricultural machinery owned by adopters of paddy stubble management technology in the study area. Around 46.8 percent respondents owned happy seeder, 25 percent respondents owned rotavator,15.6 percent respondents owned paddy chopper, and no respondent owned SMS Machine in the study area.SMS machine was used on custom hiring basis in the study area. The S-SMS is an attachment that can be fitted into any combine harvester. It ensures that any loose straw thrown by the combine is also cut and spread evenly on the field. While happy seeder can sow wheat without clearing the stubble spread by S-SMS. Together the two machines not only dispense with the need for burning paddy residue, but actually allow

wheat to be planted on fields without burning. The cost of custom hiring of S-SMS and combine Harvester was Rs. 300 per acre and Rs. 1500 per care respectively.

Table 5: Straw management by respondents (In years)

Years	Adopters (Paddy)
3-5	29 (72.5)
6-10	11 (27.5)
11-15	0 (0)
More than 15	0 (0)
Total	**40(100)**

For how many years straw incorporation is practiced by the farmers has an important bearing on soil health. Crop residues are parts of the plants left in the field after crops have been harvested and threshed. Straw incorporation notably affected the soil nutrients. The recycling of crop residues has the advantage of converting the surplus farm waste into useful product for meeting nutrient requirement of succeeding crops. Crop straw contains considerable organic matter, which when blended into the soil, improves the soil physical, chemical and biological properties contributing to increased yield. Table 5 shows the straw managed by the respondents in the study area. Around 72.5 percent respondents were managing the paddy straw since last 3-5 years and 27.5 percent were managing the paddy straw from last 6-10 years.

Table 6: Cost of dominant paddy residue management technologies in the study area (Custom hiring and Owned machinery)

Particulars	Cost per acre (custom hiring)	Cost per acre (owned machinery)
Combine Harvester + S-SMS+ Happy Seeder (Mulching)	Rs 1800	-
Paddy chopper + R.M.B plough + Rotavator (Incorporation)	Rs 3400	Rs 975

Mainly in the study area two paddy dominant paddy residue management technologies were being used. First was combine harvester + Super SMS+Happy Seeder and second was paddy chopper + R.M.B plough + Rotavator. Respondents in the study area owned few machines and few machines were taken on custom hiring for the adoption of stubble management. In case of custom hiring where farmers do not own any machinery first operation i.e. Custom Hiring and super SMS cost Rs 1800 and for second operation Paddy chopper + R.M.B plough + Rotavator cost Rs 3400. The cost of hiring super combine harvester was Rs 1500 and S- SMS from cooperative society was cost Rs 300 on per acre. Second operation adopted for stubble management included paddy chopper,

R.M.B plough and Rotavator. The cost of custom hiring for paddy chopper was Rs 400 per acre, Rs 1500.per acre for R.M.B plough and Rs. 1500per acre for Rotavator.

It was found in the study area that some farmers owned machines for paddy stubble management. Some farmers owned paddy chopper, R.M.B plough and rotavator. The cost of fuel used for paddy chopper was Rs.195 per acre, Rs 520 per acre for R.M.B plough and Rs. 260 per acre for rotavator. The total cost of fuel used by the adopters for incorporation machinery owned by the adopters were Rs.975 per acre in the study area. No selected farmer owned combine harvester and S-SMS.

Table 7: Cost and Returns of paddy cultivation among adopters and non adopters of paddy stubble management technology (Rs per Acre)

(In-situ)

Crop Paddy	Cost per Acre (Adopters) Mulching Custom Hiring	Cost per acre (Adopters) Incorporation Custom Hiring	Cost per Acre (Adopters) Incorporation Owned	Cost per acre (Non Adopters)
Seed	500	500	500	500
Cost of preparatory tillage	3000	3000	3000	1200
Transplanting Cost	2500	2500	2500	2500
Plant protection chemical	1500	1500	1500	2000
Urea	540	540	540	810
DAP (kg)	700	700	700	1400
MOP (kg)	400	400	400	950
Micro-Nutrient(kg)	650	650	650	1300
Casual labour payment(hours)	750	750	750	950
Harvesting cost	1500	1500	1500	1500
Transportation cost	1000	1000	1000	1000
Stubble management technology	Super S.M.S + Happy Seeder	Paddy Chopper+R.M.B plough+ Rotavator	Paddy chopper + R.M.B plough + Rotavator	Burned
Cost of stubble management technology	1800	3400	Rs.975	-
Total Variable cost	14,840	16,440	12,215	14,110
Yield(quintal)	28 (50,820)	28 (50,820)	28 (50,820)	24 (43,560)
Return over variable cost	35,980	34,380	36,605	29,450

Impact of stubble management technology on cost and return of paddy cultivation (custom hiring)

Two practices were used for managing the paddy stubble by the respondents in the study area. First practices were combining harvester + Super S.M.S + Happy Seeder. As discussed earlier Happy seeder was used for sowing wheat after S-SMS. The cost of Happy seeder is not included in paddy crop. Second was Paddy chopper +R.M. B plough + Rotavator. Combine harvester and S-SMS was not owned by any of the adopters in the study area. Some machines such as Rotavator, Paddy chopper and RMB plough was owned by some of the respondents. Table 5.12 shows the cost and returns of paddy for adopters of paddy stubble management technology and non adopters of paddy stubble management technology. The first three columns show decreased use of all inputs among adopters as compared to non adopters of stubble management technology. By the adoption of stubble management technology, the cost of inputs used in the paddy crop decreased on the one hand and yield increased on the other hand. For non adopters of paddy stubble management technology cost of paddy cultivation per acre was higher as all higher doses of all inputs were used due to burning of paddy residue. Transplanting Cost of paddy was Rs2500 per acre, plant protection chemical cost was Rs 2000 per acre, Urea cost was Rs 810 per acre, DAP(kg) cost was Rs1400per acre ,MOP(kg) cost was Rs 950 per acre ,Micro-nutrients (kg) cost was Rs 1300 per acre and Casual labour payments (hours) cost was Rs750 among adopters and non adopters of paddy stubble management technology. But the difference was among use of other inputs such as urea, DAP, MOP, Micronutrients and casual labour. Urea cost Rs,810 per acre, DAP costs Rs.1400, MOP costs Rs.950 micro nutrients costs Rs.1300 and casual labour cost Rs.950 among farmers who burn the residue of paddy crop whereas the urea cost Rs. 540, DAP costs Rs.700, MOP cost Rs.400, micro nutrient Rs. cost Rs.650, casual labour cost Rs.750 per acre among adopters of paddy stubble management technology.

Total variable costs of paddy per acre was Rs. 14840, Rs.16440, Rs12,215 for Combine Harvester + S-SMS +Happy Seeder (custom Hiring), Paddy Chopper + R.M.B plough + Rotavator (Custom Hiring) and Paddy Chopper + R.M.B plough + Rotavator (owned) respectively. The variable cost of paddy per acre for non adopters of stubble management technology was Rs.14,110 per acre. Variable cost of paddy was more among adopters as it involves the cost of stubble management technology. The cost of stubble management technology was Rs.1800 for Combine Harvester + S-SMS +Happy Seeder (custom Hiring), Rs.3400 for Paddy Chopper + R.M.B plough + Rotavator (Custom Hiring) and for Rs.975 Paddy Chopper + R.M.B plough + Rotavator (owned) . Yield of paddy was high among adopters than non adopters of the technology. It was 28 qtls per acre for adopters and 24 qtls for non adopters of the stubble management technology. Returns over variable cost was also higher among adopters than non adopters of the paddy stubble management technology. It was Rs.35,980 Combine Harvester + S-Sms , Rs.34380 for Paddy Chopper +R.M.B plough +Rotavator(Custom Hiring) and Rs.36,605 Paddy Chopper + R.M.B plough + Rotavator (owned) . Returns over variable cost was Rs.29,450 for non-adopters of paddy stubble management technology.

The above analysis was done to find out whether adoption of paddy stubble management technology increased or decreased the returns over variable costs of paddy crop. The above analysis clearly shows that cost of paddy per acre increased with the adoption of paddy stubble management technology. With the use of paddy stubble management technology, the cost of inputs per acre decreased and yield of crop increased. The decreased cost of inputs and increased yield of paddy per acre compensates the cost of paddy stubble management technology (Dhillon *et al.,* 2007)

Factors Affecting Adoption of Paddy Stubble Management Technology in The Study Area

To identify the factors affecting adoption of paddy stubble management technology , chi-square model and logit model was used in which adoption of paddy stubble management technology was regressed with independent variables namely age, education, family size, availability of machinery with the farmers, availability of machinery from co-operatives, less used inputs, increase in yield and land operated area of the farmers.

Table 8: Consolidated table for studying association between Adoption (ADP), on one hand, and rest of the variables, on the other

Variable	Statistic	Value	Conclusion
AGE	**χ^2-Value**	25.953	Association is Highly Significant
	DF	2	
	p-Value	< 0.0001	
	Remark	***	
EDN	**χ^2-Value**	14.84	Association is Significant
	DF	5	
	p-Value	0.0111	
	Remark	*	
FMS	**χ^2-Value**	9.783	Association is Statistically Non-Significant
	DF	6	
	p-Value	0.1341	
	Remark	NS	
AMF	**χ^2-Value**	8.645	Association is Highly Significant
	DF	1	
	p-Value	0.0033	
	Remark	**	
AMC	**χ^2-Value**	0.931	Association is Statistically Non-Significant
	DF	1	
	p-Value	0.3346	
	Remark	NS	
INY	**χ^2-Value**	5.267	Association is Significant
	DF	1	
	p-Value	0.0217	
	Remark	*	
LSI	**χ^2-Value**	9.956	Association is Highly Significant
	DF	1	
	p-Value	0.0016	
	Remark	**	
LOA	**χ^2-Value**	53.926	Association is Highly Significant
	DF	2	
	p-Value	< 0.0001	
	Remark	***	

A chi-square statistic is one way to show a relationship between two categorical variables. It is used to determine whether there is significant association between two variables. Applying the chi-square test for association it was found that there is significant association between age and adoption of stubble management technology. It is highly significant at 2 degree of freedom as p value is less than 0.0001. Less used inputs and Land operated area were highly significant at 1 degree of freedom and 2 degree of freedom respectively. It means they have strong association with the adoption of paddy stubble management technology in the study area. Availability of machinery with the farmers was also found to be highly significant at 1 degree of freedom. It means availability of machinery with the farmers affected the adoption of paddy stubble management technology in the study area.

Education and Increase in yield were significant at 5 degree of freedom and at 1 degree of freedom. Availability of machinery from the co-operatives and Family size were found to be Non-significant. They did not affect adoption of stubble management technology in the study area.

Table 9: Results of logit modeling of adoption (ADP) v/s each of the explanatory variables in isolation (Multivariate Logistic Regression Analysis)

Explanatory variables	Intercept	Regression coefficient	Remark
AGE	5.3851*** (0.0002)	-0.1105*** (0.0001)	Highly significant
EDN	-1.4722* (0.0201)	0.1461* (0.0113)	Significant
FMS	0.9781 (0.139)	-0.2002 (0.117)	Non-significant
AMF	-0.6286* (0.0423)	1.5041** (0.0020)	Highly significant
AMC	-0.1823 (0.501)	0.5878 (0.230)	Non-significant
INY	-0.4568 (0.1193)	1.1987* (0.0131)	Significant
LSI	-0.6931* (0.0283)	1.6094** (0.0010)	Highly significant
LOA	-15.4583** (0.0030)	1.3287** (0.0039)	Highly significant

Figures within parentheses indicate p-values of the estimates.

For further confirmation of results logit model was applied with each of the explanatory variables in isolation, and it was found that the results are, more or less, similar to those obtained through χ^2-analysis.
Multivariate logistic regression analysis was used to identify those variables which affect the respondents to use the paddy stubble management technology. When we apply logit model with each of the explanatory variables in isolation, the results are, more or less, similar to those obtained through χ^2-analysis. Age, Availability of machinery with the farmers, less used inputs, land operated area were highly significant whereas Education and Increase in yield due to adoption of technology were significant. Family size, Availability of machinery from co-operatives were Non- significant.

Opinion Survey of the Sample Farmers

No doubt paddy stubble management technology is a resource conservative technology and farmers in Punjab are adopting this technology very fast. To make the adoption of this technology still faster, there is a need to identify the constraints inhibiting the adoption of this technology and solutions thereof. So, an opinion survey was carried out

Diffusion Pattern of The Paddy Stubble Management Technology

The respondents were imparted the knowledge of the paddy stubble management technology by various agencies like state governments, agricultural departments, co-operative societies, krishi vigyan kendars, fellow farmers etc. The main source of technology diffusion was fellow farmers and about 35 percent of the farmers came to know and adopted the technology through learning from each other. The progressive farmers of the area adopted

the technology and encouraged others to follow. The co-operatives societies also played an important role in the diffusion of the technology; their share was about 14 percent (table 12). Around 18.5 farmers came to know about the technology from kisan mela and 7.5 percent farmers learned about technology from others sources such as government or agriculture department, seminars, campaigns etc.

Table 12: Source of inspiration for adopting paddy stubble management technology by the sample farms

Sources	Percent Response
Friends/ Relatives	25
Fellow farmers	35
Co-operative society	14
Kisan mela	18.5
Other sources	7.5

Note: Other sources include Government/agriculture departments, seminars, campaigns etc.

Constraints/Problem in Adoption of Paddy Stubble Management Technology

The information presented in Table 13 brings out that about 25 percent of the non-adopters reported the problem of non-availability of the paddy stubble management technology in the peak season.

Table 13: Constraints/Problems faced by non-adopters of paddy stubble management technology, Punjab, 2018-19

Constraints	Percent Response
Non-availability of paddy stubble management technology	25
High cost of technology	45
Small size of holding	18
Lack of awareness	12

Note: The responses correspond to the non- availability of technology

About 45 percent of non-adopters reported that the reason of their non-adoption was the high cost of paddy stubble management technology. While 12 percent of non-adopters reported that they were not fully aware of the technology, resulting in non-adoption of the technology. About 18 percent of non-adopters reported that the reason of the non-adoption of the technology was their small and marginal holding.

Conclusion

The study concluded that the adoption of paddy stubble management technology increased the cost of production for paddy crop per acre but the adoption also decreased the use of other inputs such as plant protection chemical, urea, DAP, MOP, micro-nutrients, payment casual labour. Due to adoption of stubble management technology, yield of paddy increased. Overall returns over variable cost was more among adopters than non-adopters of the technology.

For maximum adoption of paddy stubble management technology, it was suggested that more paddy stubble management machines should be made available at co-operatives and at less cost. It was also found in the study area that ex-situ management of crops is not adopted by the farmers because collection and transportation of voluminous mass of paddy residue is cumbersome. For ex-situ management of paddy straw there is a need of cooperation among the farmers, industry and government. The whole-hearted efforts of the above said nexus is needed for management of paddy straw management. The main reason for burning of paddy stubble was that the

interval between existing rice-wheat cropping system is so brief farmers burn residues in the field to fasten and facilitate tillage for the next crop. This gap is only for one week. At this short time the demand of stubble management technology is more than its supply. Farmers want to adopt the technology but due to shortage of availability of technology they are forced to burn the residue. So it is suggested the timely availability of machines should be made available to the farmers and huge subsidies given to the farmers for its adoption. It is also suggested that farmers who adopt stubble management technology should be given incentives for its adoption.

References

1. Baharani M L, Raufat M H and Ghadiri H (2007) Influence of wheat residue management on irrigated corn grain production in reduced tillage system. Soil *and Tillage Research* 94:305-309
2. Erenstein (2002) Crop Residue Mulching in tropical and Semi –tropical countries: An evaluation of residue availability and other technological Implications. *Soil and Tillage Research* 67 :115-133
3. Ganwar K, S Singh, K K Sharma, Sharma S K and Tomar O K (2006) Alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo Gangetic Plains. *Soil and Tillage Research* 88:242-257
4. Gupta P K, Sahai S, Singh, N Dixit, C K Singh, Sharma D P, Sharma C, Tiwari M K , Gupta R K and Garg S C (2004) , Residue burning in rice wheat cropping system : causes and Implications. *Current Science*. 87(2) 1713-1717
5. Gupta N, (2019) Paddy residue burning in Punjab: Understanding farmers perspectives and rural air pollution. Council *on energy, environment and water*
6. Hartley C and Kessel C V (2005) Residue management, soil organic matter and fertility in California rice system. Conference Proceedings, California Plant and soil conference, American Society of Agronomy, Modesto Double Tree Hotel ,11500 9 th street, Modesto, California.
7. Heard J, Cavers C and Adrian G (2005) Up in smoke nutrient loss with straw burning *Better crops* 90:10 - 11
8. Jain N, Pathak H and Bhatia A (2012) Crop residues management with conservation agriculture: potential, constraints and policy needs. Indian *Agriculture research Institute*
9. Malhi S S, Kutcher H R (2007) Small grains stubble burning on tillage effects on soil organic C and N and aggregation in north eastern Saskatchewan. Soil and Tillage Research 94: 353 -361
10. Prasad R, Ganaiah b and Aipe K C (199) Effect of crop residue management in rice wheat cropping system and yields of crops and on soil fertility, *Experimental*
11. *Agriculture* 35: 427 -435
12. Sidhu H S and Beri V (1989) Effects of crop residue management on the yields of different crops and soil properties. *Biological Wastes* 27: 15-27