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SUBJECT I
COPING WITH RISKS AND CLIMATE CHANGE THROUGH CONSERVATION OF NATURAL RESOURCES WITH PARTICULAR REFERENCE TO AGRICULTURE: APPROPRIATE TECHNOLOGIES AND PRACTICES

Management of Paddy Straw in Punjab: An Economic Analysis of Different Techniques

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ABSTRACT

The study analyses the economics of wheat cultivation under different methods of paddy straw management. Data were collected during 2017-18 from 85 farmers from Ludhiana and Sangrur districts of Punjab practicing paddy straw management techniques (wet mixing of straw, dry mixing of straw and Happy seeder) as well as conventional method of wheat sowing after burning paddy straw. The study found that Happy seeder was the most profitable technique in managing paddy straw before sowing of wheat. The use of Happy seeder helped in saving of water by 732 m^3, tractor use by 27.47 per cent, reduction of particulate matter by 18 kg, CO by 360 kg, CO_2 by 8.76 t, ash by 1.2 t and SO_2 by 12 kg per ha. However, non-availability of high HP tractor and Happy seeder, rodent attack, and non-decomposition of straw were the major problems faced by the farmers in the adoption of this technology. The study brought out that the farmers are well aware about the health hazards posed by burning straw but due to shortage of labour and short window of time between paddy harvesting and sowing of wheat compels them to easily resort to burning of paddy straw. The study suggests for paying farmers for ecosystem services by adding paddy residue management cost in the MSP of wheat. Implementation of this requires real-time data management using Artificial Intelligence, remote sensing and GIS.

Keywords: Crop residual burning, Conventional method, Paddy straw management techniques, Resources conservation technologies.

JEL: Q1, Q2, Q4

I

INTRODUCTION

North-India at present finds itself in the midst of a paradoxical situation of prodigious production of rice and wheat (food grains) for meeting the country's food security needs, co-existing with increasing problem of straw disposal. About 85-90 per cent of this paddy straw is burnt in the fields, and to some extent, wheat straw is also being burnt during the *rabi* harvesting season. Though, the problem of paddy straw burning exists in many states, the scale is larger in Punjab and Haryana. An estimated 35 million tonnes of rice straw is torched over two to three weeks every

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year during October and November in these states. In addition to human and animal health hazards due to air pollution, it causes loss of vital components such as nitrogen, phosphorus, sulphur and potassium from the top soil layer, making the land less fertile and unviable for agriculture in the long run (Mandal *et al*., 2004; Lohan *et al*., 2018). Chakrabarti *et al*., (2019) found that the economic cost of exposure to air pollution from crop residual burning stands at USD 30 billion or nearly Rs. 2 lakh crore annually for the three north Indian states of Punjab, Haryana and Delhi.

The farmers resort to burning of rice straw as the window between harvesting of paddy and sowing of wheat is of just 2-3 weeks which does not allow for time consuming operations of clearing paddy straw from the fields. The requirement of dry fodder for cattle is mostly met by the wheat straw available sufficiently and supplemented by basmati straw, if required. Besides, fodder crops are grown under sufficient area in the state. The equipment and the process of cutting and ploughing back or collecting and transporting straw involves huge cost beyond the reach of small and marginal farmers. High content of silicon dioxide (SiO_2) in straw resists its decomposition when incorporated/retained in the soil for the next crop. Incorporation of straw in the soil is physically difficult and requires more tillage operations to sow wheat which enhances the operation/sowing costs. Then there is a fear of possibility of carrying forward infections/diseases with straw if ploughed back into soil. In addition, acute shortage of labour for collecting and storage of rice straw also leads farmers towards straw burning (Government of Punjab, 2014).

Punjab is primarily a rice-wheat growing state and it contributed nearly one-third of the central pool of food grains during 2016-17 (Government of Punjab, 2017). Though modern agriculture in Punjab was successful in achieving the targeted food demand, yet it contributed to environmental problems in some situations such as loss of biodiversity and soil fertility and water scarcity (McIntyre *et al*., 2009; Ramesh *et al*., 2016). Therefore, the major challenge currently to the state is to enhance the productivity and profitability of crops while effectively handling the problem of agricultural biomass residue or crop residue burning. Further, there is dire need of an energy, water and labour efficient alternate system that helps to sustain soil and environmental quality and produce more at less cost (Jat *et al*., 2011; Gathala *et al*., 2011). Besides recently released early maturing varieties of paddy (PR121, PR126 and PR127) there is also the availability of alternate technologies to stop farmers from burning residues and which does not even increase field preparation costs or alter crop yields like Happy seeder. Happy seeder cuts and lifts rice straw, sows wheat into the bare soil, and deposit the straw over the sown area as mulch. This allows farmers to sow wheat immediately after their paddy harvest without the need to burn any paddy residue for land preparation (Gupta, 2012).

Many studies in the past were undertaken with the objectives of comparing the economics of wheat production with conventional methods from other methods like rotaseeder, zero tillage, Happy seeder, etc. (Tripathi *et al*., 2013; Gupta, 2012; Sidhu *et al*., 2010). But no study has been undertaken which evaluates paddy residue

management practices before wheat sowing. The present study analyses the economics of wheat cultivation under different methods of paddy straw management which has been undertaken by the farmers during the year 2017-18 before sowing of wheat crop. The study has also emphasised to evaluate and compare the costs and returns from different resource conservation technologies undertaken in wheat cultivation.

II

DATA AND METHODOLOGY

The districts with adequate number of farmers adopting the various paddy residue management practices, in sowing of wheat crop, were identified through consultation with various stakeholders', viz., Officials of Department of Agriculture, PAU Research Engineers/ Extension Specialists and Pioneer Farmers, Sangrur and Ludhiana districts, being the leading districts in the adoption of resource conservation technologies (RCT's), were selected for choosing a representative sample. From both the districts, 85 farmers practising paddy straw management techniques such as; dry mixing/wet mixing of paddy straw in soil and sowing wheat with rota-seeder/ seed drill and secondly, without burning straw, using Happy seeder to sow wheat were purposively selected. Besides, farmers undertaking conventional method of wheat sowing after burning paddy straw also formed the part of the sample. The primary data were collected by personally interviewing the respondent farmers.

III

RESULTS AND DISCUSSION

Paddy Straw Management Practices Followed in Wheat Cultivation

Before going into the details of input-output pattern of wheat crop, it is pre-requisite to know the paddy straw management technologies adopted by the sampled farm households. The following straw management techniques were practised on the selected farms:

Wet Mixing: After harvesting of paddy using combine, straw was chopped with straw reaper. Then the field was irrigated and powered by tractor using various implements such as disc harrow, rotavator etc. to plough and mix the paddy straw into the soil in wet conditions. After the field reached at the adequate moisture level for sowing, wheat was sown using rota-seeder or seed drill.

Dry Mixing: After harvesting of paddy, straw was chopped with a straw reaper. The straw was incorporated into the soil by using various tractor driven implements such as; disc harrow, rotavator, cultivator, etc. However, difference in this technique is that no pre-sowing irrigation was applied to the field and only available moisture of

last irrigation given to paddy crop was used for straw incorporation. Thereafter, wheat was sown using seed-drill or rota-seeder.

Happy Seeder: Paddy straw was cut using a straw reaper and wheat was sown in the standing stubbles using 'Happy seeder' run by tractor. No preparatory tillage is required in this practice.

Conventional Tillage Post Burning Straw: As per common practice, the paddy straw was burnt after cutting it using a straw reaper. Afterwards, field was prepared by ploughing using tractor driven disc harrow, cultivator, etc. and wheat was sown using seed-cum- fertiliser drill.

Input Use under Different Straw Management Techniques

The input use pattern in wheat sowing on the sampled farms revealed that seed rate was the highest (120.63 kg/ha) on the farms where wheat was sown using Happy seeder followed by dry mixing of paddy straw (110.88 kg/ha) and wet mixing of paddy straw (106.25 kg/ha.) (Table 1). In comparison to this, on farms with conventional practice of straw burning, the seed rate used was relatively low at 102kg/ha. The main reason for differential seed rate use was farmer's perception, as they perceived that paddy straw management technologies lead to some germination related problems which calls for higher seed rate use to compensate for the problem of low germination.

TABLE 1. INPUT USE PATTERN AND YIELD OF WHEAT CROP USER DIFFERENT PADDY STRAW MANAGEMENT TECHNIQUES IN PUNJAB (2017-18)

(*per ha*)

	Farmers following straw management technologies						Conventional practice of straw burning	
	Wet mixing		Dry mixing		Happy seeder			
Particulars	Q	V	Q	V	Q	V	Q	V
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Seed (kg)	106.25	2757.50	110.88	2882.50	120.63*	3137.50	102.00	2655.00
Fertiliser (kg)	485.00	5860.00	490.00	5815.00	465.00	5292.50	487.50	5610.00
Plant protection	-	2360.00	-	2037.50	-	1995.00	-	1632.50
Irrigation (hrs)	87.50	485.63	75.00	416.25	57.50*	319.13	72.50	402.38
Human labour (hrs)	124.50	5207.50	115.25	4542.50	91.35*	3770.00	110.00	4170.00
Combine harvesting (hrs)	1.25	3340.00	1.48	3390.00	1.58	3430.00	1.30	3280.00
Straw reaper (hrs)	5.00	5570.00	5.00	5530.00	5.00	5435.00	4.38	5125.00
Tractor use (hrs)	17.00*	10445.00	14.30**	8670.00	9.18*	6015.00	12.65	6750.00
Yield (qtl)	51.50	89227.50	54.45	94467.50	54.50	94570.00	53.95	93617.50

Source: The authors estimation based of survey data. Used t-statistic to test the significance of difference between two means i.e. input use in wheat sowing after applying paddy straw management techniques vis-a-vis conventional practice of wheat sowing after straw burning. * and **Significant at 1 and 5 per cent level of significance, respectively.

Note: Q is quantity and V is value (in Rs).

Fertiliser usage varied from 465 kg/ ha on farms where wheat was sown using Happy seeder technology to 490 kg/ha on the farms where dry mixing of paddy straw was undertaken before wheat sowing. The expenses on plant protection measures were the least (Rs. 1632.50/ha) on farms where conventional method of wheat sowing was followed while it was the highest (Rs.2360) on the farms adopting wet mixing of paddy straw before wheat sowing.

The irrigation hours use was found to be 20 per cent in case of Happy seeder as compared to conventional method of residue burning. Thus, wheat crop sown by using Happy seeder required less irrigation as compared to other straw management technologies adopted on the sampled farms. The 20 per cent of average water requirement of water for wheat crop of 3661 m^3/ha (Kaur *et al*., 2010) works out to around 732 m^3/ha. This helps in not only saving water but also energy cost and environmental footprints. Similarly, the tractor use per ha in straw management operation and sowing of wheat crop by Happy seeder was also less by 27.47 per cent as compared to conventional method of residue burning. Straw management using Happy seeder have much greater impact in reducing environmental externalities. Burning of one tonne of straw releases 3 kg of particulate matter (PM), 60 kg CO, 1,460 kg CO2, 199 kg ash, and 2 kg of SO2 (Gupta *et al*., 2004). Therefore, assuming average straw production of 6 t/ha use of Happy seeder can reduce 18 kg of particulate matter, 360 kg of Co, 8.76 t of CO2, 1.2 t of ash and 12 kg of SO2 per ha.

Yield of Wheat under Different Paddy Straw Management Techniques

Except for wet mixing of paddy straw, there was no significant difference in the yield under different straw management technologies adopted on the sample farms vis-à-vis conventional practice. The average yield was 54.50 q/ha on farms where wheat was sown using Happy seeder followed by dry mixing (54.45q/ha). The yield was observed to be relatively low (51.50 q/ha) in case of wet mixing technology of straw incorporation (Table 1). Thus, it can be inferred that straw management technology has no direct bearing on the yield of wheat crop, except in case where it was sown after undertaking wet mixing of paddy straw which resulted in significant delay in wheat sowing and reduction in yield.

Returns from Wheat Crop

An analysis of variable cost structure revealed that cost of machine use was about 50 per cent of the total variable cost (Table 2). Machine usage was higher because tractor along with implements was used for paddy straw management followed by sowing of wheat crop and after crop harvesting, using a combine harvester; tractor is also used for transportation/ marketing of produce and thereafter for making of wheat straw. To work out the cost of machine usage, custom hiring rates prevailing in the study area for all these farm operations were used. In absolute terms, expenses on machine labour use per ha of wheat sowing were the highest on the farms

(Rs.19355/ha) where wet mixing of paddy straw was undertaken and were the least in the case of Happy seeder technology (Rs.14880/ha). Thus, in comparison to conventional practice of straw burning, paddy straw incorporation operation resulted in increase in machine usage cost by Rs.4200 per ha in wet mixing (27.71 per cent) and by Rs.2435 per ha in case of dry mixing of paddy straw (16.07 per cent). On the contrary, use of Happy seeder technology has helped in decreasing the cost of machinery by 1.81 per cent as compared to conventional practice of straw burning. Though marginally, but besides reduction in cost this also helps in reducing emissions from fuel burning.

TABLE 2. COST-RETURN STRUCTURE OF WHEAT CULTIVATION UNDER DIFFERENT METHODS OF PADDY STRAW MANAGEMENT

(*Rs./ha*)

Particulars	Farmers following straw management technologies			Conventional practice of straw burning
	Wet mixing	Dry mixing	Happy seeder	
(1)	(2)	(3)	(4)	(5)
Human labour use	5208	4543	3770	4170
	(14.14)	(13.35)	(12.54)	(13.76)
Machine labour use	19355	17590	14880	15155
	(52.54)	(51.69)	(49.51)	(50.03)
Cost of seed used	2758	2883	3138	2655
	(7.49)	(8.47)	(10.44)	(8.77)
Cost of fertiliser used	5860	5815	5293	5610
	(15.90)	(17.09)	(17.61)	(18.52)
Cost of plant protection measures	2360	2038	1995	1633
	(6.41)	(5.98)	(6.64)	(5.39)
Irrigation charges	485	415	320	403
	(1.32)	(1.22)	(1.06)	(1.33)
Interest on variable cost @ 9 per cent pa for half the period of crop season	810	748	660	665
	(2.20)	(2.20)	(2.20)	(2.20)
Total variable cost	36835	34030	30055	30290
Returns-main product	89228	94468	94570	93618
Returns-by product	8893	9323	9415	8983
Gross returns	98120	103790	103985	102600
Returns over variable cost (ROVC)	61285	69760	73930	72310
Difference of ROVC in comparison to conventional practice	-11025	-2550	1620	--
	(-17.98)	(-3.65)	(2.19)	

The estimated gross returns did not vary much in different straw management practices and were the highest at Rs.103985/ha on the farms using Happy seeder and lowest (Rs. 98120/ha) on farms where wet mixing of paddy straw was followed. Moreover, farmers using Happy seeder, dry mixing and conventional practice received almost equal gross returns with slight variation. Returns over variable cost (ROVC) were the highest (Rs.73930/ha) on the farms where wheat was sown using Happy seeder and were the least on the farms following wet mixing practice (Rs.61285). In case of wet mixing practice, ROVC were nearly 18 per cent lower than conventional practice while it was about 4 per cent lower in dry mixing. In case of Happy seeder technology, ROVC were about two per cent higher than conventional practice of wheat sowing. Hence, the difference in cost components of

different technologies, especially with regard to variable cost on paddy straw incorporation, lead to varying returns over variable cost under various straw management practices in wheat cultivation.

IV

PROBLEMS FACED IN PADDY STRAW MANAGEMENT

Problems Faced by Farmers During Wet Mixing and Dry Mixing of Paddy Straw: The responses of farmers in percentage terms with respect to the problems faced by them in wet or dry mixing of paddy straw incorporation are presented in Table 3. The survey revealed that weed infestation and non-decomposition of the straw were the top two problems faced by the farmers. The presence of non-decomposed straw in the newly sown wheat for quite a long time makes the situation ideal for insect and pest attacks. With about 26 per cent responses, insect/pest problem was the third problem perceived by the farmers as of high intensity. Though of low intensity, non-availability of machinery required for paddy straw incorporation, especially rotavator was also perceived by quite a large number of farmers (74 per cent). Since wet or dry incorporation of paddy straw requires many operations to prepare the fields, it often leads to delay in the sowing of the succeeding wheat crop.

TABLE 3. PROBLEMS FACED BY FARMERS DURING WET MIXING AND DRY MIXING OF PADDY STRAW

(*per cent*)

Problem	Intensity of problem			
	No problem	Low	Medium	High
(1)	(2)	(3)	(4)	(5)
1. Low seed germination	77.14	22.86	0.00	0.00
2. Delay in wheat sowing	42.86	34.29	22.85	0.00
3. Weed infestation	0.00	37.14	34.29	28.57
4. Insect/pest problem	0.00	31.43	42.86	25.71
5. Problem of availability of rotavator	25.72	45.71	22.86	5.71
6. Rodent attack	77.14	14.29	8.57	0.00
7. Non-decomposition of straw	14.29	22.86	34.29	28.56
8. Crop lodging	28.57	37.14	34.29	0.00

Problems Faced by Farmers using Happy Seeder: The information provided in Table 4 shows that the farmers, who undertook sowing of wheat by using Happy seeder faced three major problems with high intensity, i.e., non-availability of high HP tractor (31.43 per cent), rodent attack (28.57 per cent) and non-decomposition of straw (25.71 per cent). These problems were also the three highest ranked problems, among the problems of moderate nature, by about 63 per cent, 57 per cent and 66 per cent farmers, respectively. Quite a large number of farmers (71 per cent) also ranked the problem of non-availability of Happy seeder as high and medium intensity problems.

TABLE 4. PROBLEMS FACED BY FARMERS USING HAPPY SEEDER FOR SOWING OF WHEAT

(*per cent*)

Problem	Intensity of problem			
	No problem	Low	Medium	High
(1)	(2)	(3)	(4)	(5)
1. Low seed germination	31.43	42.86	25.71	0.00
2. Weed infestation	0.00	48.57	40.00	11.43
3. Insect/pest problem	0.00	57.14	28.57	14.29
4. Non-availability of Happy seeder	0.00	28.57	54.29	17.14
5. Rodent attack	0.00	14.29	57.14	28.57
6. Non-availability of high HP tractor	0.00	5.72	62.85	31.43
7. Non-decomposition of straw	0.00	8.57	65.71	25.71
8. Crop lodging	51.43	20.00	28.57	0.00

Farmer's Awareness and Suggestions on Paddy Residue Management

The selected farmers were well aware about paddy straw burning posing a health hazard for the human and livestock as revealed by about 93 per cent farmers (Table 5). According to them, straw burning also results in loss of friendly insects/birds/reptiles as reported by nearly 66 per cent farmers. Farmers also showed their awareness about benefits of straw incorporation such as; straw incorporation helps in conserving soil moisture (62.35 per cent), increases soil fertility (55.29 per cent) and chopped residue can be used as mulch (68.24 per cent). The major reason of straw burning as revealed by 82.35 per cent farmers was it being easy/ economical method followed by other reasons such as shortage of labour (77.65 per cent) for removal of straw and the short time between paddy harvesting and sowing of next crop (34.12 per cent).

TABLE 5. FARMERS AWARENESS REGARDING PADDY RESIDUE MANAGEMENT/BURNING AND REASONS THEREOF

(*per cent*)

Particulars	Agree	Do not agree
(1)	(2)	(3)
1. Burning of paddy straw creates health hazard for human and livestock	92.94	7.06
2. Straw incorporation helps in conserving soil moisture	62.35	37.65
3. Straw incorporation enhances soil fertility	55.29	44.71
4. Chopped residue can be used as mulch	68.24	31.76
5. Burning results in loss of friendly insects/birds/reptiles etc.	65.88	34.12
Reasons for burning paddy straw		
1. Shortage of time between harvesting and sowing of next crop	34.12	25.88
2. Burning is more economical	82.35	17.65
3. Shortage of labour for removal of paddy straw	77.65	22.35

Farmer's Suggestions to Address the Problem of Straw Burning

Farmer's suggestions to address the issue of paddy straw burning have been compiled in Table 6. One of the major suggestion by all the farmers was to increase the MSP by taking into account increased cost of paddy straw incorporation in the soil and strictly banning straw burning (72.94 per cent). Ensuring availability of residue management machines (52.94 per cent) and using paddy straw in industries

like paper mills, energy generation plants (56.47 per cent) were the other suggestions. Farmers also suggested about developing short duration and high yielding varieties of paddy (40 per cent) and developing implements/ machines compatible with low HP tractors.

TABLE 6. FARMERS' RESPONSE/SUGGESTIONS TO CONTROL THE PADDY STRAW BURNING

(*per cent*)

Suggestions (1)	Yes (2)	Do not agree (3)
For Government		
1. Increase MSP equivalent to residue management cost	100.00	0.00
2. Ensure availability of residue management machines	52.94	47.06
3. Promote use of paddy straw in different industries	56.47	43.53
4. Strictly ban straw burning	72.94	27.06
For Researchers/Engineers		
1. Develop short duration HYVs	40.00	60.00
2. Develop implements/machines compatible with low/medium HP tractors	69.41	30.59

V

CONCLUSIONS

From the above discussion it can be inferred that some of the enlisted technologies, viz., wet/dry mixing of paddy straw before wheat sowing put financial burden, to the tune of about Rs.2500 to Rs.4250 per ha on the farmers but are also environment friendly, which is very important benefit to cherish about. But in some cases it was observed that after wet mixing of paddy straw, wheat sowing got delayed due to soil reaching at the desired moisture level quite late for sowing. An economic analysis of wheat sown with Happy seeder inferred that this technique is quite successful and its implication is that it can result in decreasing input cost by skipping the field preparation/ preparatory tillage operations and at the same time getting almost equal yield as that of conventional method of wheat sowing. However, some of the constraints reported include problem of rodents, problem in hiring of Happy seeder on rent due to its low availability and high HP tractors required for operating it. These problems can be tackled by following the adequate crop production practices along with making these machines available to the farmers on custom hiring basis. This technology can save 732 m^3/ha of water and can reduce 18 kg of particulate matter, 360 of Co, 8.76 t of CO2, 1.2 t of ash and 12 kg of SO2 per ha.

The study brought out that farmers are well aware about the health hazards posed by burning straw but due to shortage of window between paddy harvesting and sowing of wheat compels them to easy way out of burning paddy straw. Some of the policy options such as disincentives on paddy straw burning, subsidies of Happy seeder are available however paying farmers for ecosystem services is the need of the hour. Compensating farmers by adding paddy residue management cost in the MSP itself and ensuring availability of residue management machines at subsidised rates and promoting use of paddy straw in paper mills, energy generations plants etc. could be some of the options for tackling the problem of managing paddy straw in the state.

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