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A CASE STUDY

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Regression models for assessment of post harvest grain losses for rice combine harvester

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ABSTRACT
Rice is harvested, when the panicle start changing its colour, the depended factor of moisture content and timely harvesting is one of the vital operations for getting optimum yields. To understand the complex conditions, regression equations would judge or forecast the suitable time for the machine (Escorts make class combine harvester) and crop (rice) parameters before harvesting. These equations would help to suffice for minimising the pre and post harvest grain losses.

Key words : Rice, Combine harvester, Post harvest grain losses, Regression models, Moisture content

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INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food in India (Pillai, 1996), which is the second most important cereal crop after wheat. It is having high calorific value of 21.2 per cent (U.S.D.A., 1970) as compared to other crop. It is a member of the graminae family along with wheat and corn. Rice is one of the three crops on which human being largely depend for their daily food requirements. Today, the consumption of rice is greater than before because of increase in population, migration of peasants to cities and improvement of living standards (Yadav and Yadav, 1992). This might be due to distribution of people and food habit and also environmental determinations. Bridging the gap between the demand and production of food grains is an important task before the scientists. The solutions to bridge the gap are: improve post harvest management practices, put more land under cultivation, introduce high yielding varieties and improve husbandry practices. Minimizing the post harvest losses is practically viable. Post harvest losses implies a measurable quantitative and qualitative loss of a given product that occurs during different phases of processing right from harvest to till bagging (He *et.al.,*1997). Harvesting is one of the vital operations in crop production and timely harvesting is essential for getting optimum yields. The percentage of ripe grains in the panicles determines the harvesting time. The crop is ready for harvest when 80 per cent of the panicles turn straw-coloured and the grains in the lower portions of the panicle reach the hard-dough stage.

In recent years, there has been an acute shortage of agricultural labourers during harvesting season due to increased employment opportunities in urban areas for rural youth. Due to non-availability of labour and increased demand in work efficiency, an introduction of rice combine harvester becomes a need of the hour. Its introduction will balance these aspects simultaneously without any delay, as late harvesting would result in increased grain losses. One of the important reasons for late harvesting

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could be the labour shortage (Goel *et al.*, 2002).

However, the efficiency of combine harvester is affected by crop conditions at the time of harvest, operation speed and width of cutter bar. During the field operations the operator has to adjust the machine systems to suit the crop condition in the field. Many time, it is not practiced due to urgency and negligence about grain losses. Farmers are not aware the quantitative losses incurring during the operation and no agency is guiding them properly to reduce these post harvest losses in the field condition. Ultimately the grain production per unit area is not improved. Further, the non-availability of the precise information from the operator or user may affect the necessary modifications required to improve the working of the machine, to suit the local crop conditions.

To ascertain the above problems, a regression models were used to judge the harvesting time, by reducing the post harvest grain losses in the field while using rice combine harvester.

MATERIALS AND METHODS

The experiments were conducted in the province of Karnataka, Raichur district to ascertain the post harvest grain losses by using combine harvester. A class combine (Escorts make – track type, 2.1 m cutter bar width) was selected to assess the grain looses with comparison of manual harvesting for IR64 rice variety. The different operational parameters were taken during the field evaluation. The preharvest losses were tested based on the standard test procedure (FMO, 1987).

Field survey:

A field survey was conducted in both the blocks. The respondents were chosen in order to gather information and data on the use of combine harvester, the costs involved, problems associated with the ownership, farmers' opinion and degree of satisfaction and other relevant issues as considered. The responses were scrutinized, compiled and analyzed for drawing inferences.

Field test parameters:

The parameters considered prior to harvesting operation were area of the field, crop variety, plant height, mode of planting, grain moisture content, grain straw ratio, type of soil and soil moisture content. During operation the field parameters *viz.,* pre harvest loss, cutting loss, drying loss, bundling loss, conveying loss, threshing loss, winnowing loss, time taken for harvesting, bundling, conveying, threshing, winnowing and cost of operation were recorded by using standard test procedures (FMO, 1987).

Machine operational parameters:

The operational parameters were recorded when the machine was operating in the field. These included forward speed of the machine, effective working width, cutting height, fuel consumption, time elements (as used in computing field capacity and efficiency), estimated grain yield and quality of paddy. The field evaluation trials were carried out according to BIS and RNAM test codes.

Statistical analysis:

The different mathematical equations were used for best fit and explored to find out cause and effect of these variables. The random data were used for simulating the crop and machine parameter values at different intervals. The statistical package for social science (SPSS), 10.0 package was used for the statistical analysis and estimation.

Regression model methodology:

In experimental investigation, a better understanding and detailed explanation of the mechanism that governs the phenomenon can be gained if a comprehensive list of pertinent or variables are prepared. Such list for the Escorts combine harvester was made under three main categories of variables *i.e.*, crop, machine and crop-machine system. Two parameters were taken in the harvester *viz.*, width of cutter bar and speed of the machine. Since the standard width of cutter bar already used was 2.1 m, it has reduced the width. Regarding the speed of the machine, the existing speed in the specific field condition was kept as a constant and allowed variation on either side of this mean (centre of gravity).

RESULTS AND ANALYSIS

The experiment was carried out at Sindhanur and Manvi blocks of Raichur District in Karnataka, India to assess the grain losses by using rice combine harvester and compared with conventional system. Farmers' opinions were collected through the set of questionnaires prepared during the study.

Table 1 reveals that out of 60 farmers 52 farmers (87 %) were using rice combine harvester, whereas the remaining resort to the conventional method of harvesting. The reasons for not using combine harvester might be due to lack of confidence in the machine coupled with other factors like: small land holdings, water logged conditions, difficult in collection of straw and non-availability of machine in time. Further few general opinions observed from the statements of the farmers were to improve nation's productivity by using

Table 1: Farmers' opinion on rice combine harvester

Sr. No.	Parameters	Farmers using rice combine harvester (%)	Farmers using conventional method (%)
Reasons for using machine			
1.	Shortage of labour	87	
2.	High wage of labour	78	
3.	High machine capacity	89	
4.	Lower grain losses	73	
5.	Easy and convenient	85	
6.	Cost of operation less	90	
7.	Saves time	93	
8.	Timely harvesting	94	
9.	Land preparation next season	95	
10.	Immediate returns	85	
11.	Searching of labour avoided	91	
Reasons for conventional harvesting			
1.	Small land holding		57
2.	Water logging condition		35
3.	Lack of confidence		23
4.	Non-availability of the machine in time		45
5.	Difficult in collection of straw		38

mechanization (48 %), to develop all crop combine harvester (63 %) and machine affects labourers who depend on daily wages (18 %).

The manual harvesting experiment were conducted in ten different fields of two selected blocks of Sindhanur and Manvi (Table 2). In Sindhanur block the grain losses were observed from 10.24 to 12.36 per cent with an average of 11.02 per cent. The field capacity varied from 0.33 to 0.80 hectare per hour with an average of 0.49 hectare per hour. The moisture content of the grain was recorded from of 17.48 to 19.36 per cent. The average estimated yield and purity of grain were found to be 2.75 tonnes per hectare and 92.42 per cent, respectively. In Manvi block the total grain losses ranged from 9.21 to 13.35 per cent with an average of 11.26 per cent. The field capacity varied from 0.37 to 0.82 hectare per hour with an average of 0.63 hectare per hour. The moisture content of the grain was varied from 17.45 to 19.25 per cent. The average estimated yield and purity of grain were found to be 2.95 tonnes per hectare and 92.12 per cent, respectively. The total cost for conventional operations was found to be Rs. 3126.00 per hectare by considering all the actual cost incurred during the field observation.

The machine was tested in 25 different fields of two

Table 2: Field evaluation of conventional harvesting system

Sr. No.	Moisture content (%)		Total losses (%)		Field capacity (ha/h)		Estimated yield (t/ha)		Purity of grain (%)	
	Sindhanur	Manvi	Sindhanur	Manvi	Sindhanur	Manvi	Sindhanur	Manvi	Sindhanur	Manvi
1.	19.26	18.40	11.25	10.25	0.33	0.55	2.85	2.83	92.45	92.15
2.	19.36	17.45	10.98	11.36	0.58	0.58	2.95	2.99	93.15	92.34
3.	18.24	17.48	11.48	13.35	0.54	0.82	3.05	3.10	92.48	95.36
4.	19.00	19.25	12.36	11.35	0.35	0.37	2.84	2.87	92.18	90.02
5.	18.98	17.48	10.25	11.35	0.80	0.60	2.19	3.16	92.48	92.48
6.	17.98	17.48	10.49	11.35	0.53	0.61	2.45	2.68	93.12	92.65
7.	17.48	18.48	11.12	12.45	0.34	0.78	2.94	2.94	91.45	91.48
8.	18.00	17.56	10.24	9.80	0.58	0.56	2.76	3.01	92.75	92.06
9.	17.64	17.80	11.65	12.12	0.39	0.59	2.46	2.46	92.48	92.48
10.	18.45	18.28	10.36	9.21	0.42	0.79	3.01	3.46	91.65	90.13
Avg	18.44	17.97	11.02	11.26	0.49	0.63	2.75	2.95	92.42	92.12

Table 3: Field evaluation of combine harvester

Sr..No	Observations	Sindhanur	Manvi
1.	Moisture content (%)	17.56	17.80
2.	Total grain losses (%)	2.91	2.89
3.	Field capacity (ha/h)	0.53	0.60
4.	Estimated yield (t/ha)	3.14	2.92
5.	Purity of grain (%)	92.35	91.76
6.	Field efficiency (%)	94.62	95.79

selected blocks of Sindhanur and Manvi. The Table 3 reveals that, the average values of moisture content (%), total grain losses (%), field capacity (ha/h), estimated yield (t/h), purity of grain (%) and field efficiency (%) were 17.56, 2.91, 0.53, 3.14, 92.35 and 94.62, respectively in case of Sindhanur block, whereas is Manvi block. These were 17.80, 2.89, 0.60, 2.92, 91.76 and 95.79, respectively. There was not much variation in the different parameters. The total cost of operation by using combine harvester was Rs. 1374.00 per hectare by considering actual cost incurred during the experiment. The break even area of using the machine goes down to 59 hectares and the pay back period is 0.93 year, if the net availability of the total area is 1000 ha.

After analysing the actual post harvest grain losses in the field experiment, the random technique was used to evolve suitable equations, which could provide optimum levels of moisture content, width of cut and speed to reduce the grain losses. In order to achieve this, the scatter diagram of each one of the independent variables with the loss was observed. The scatter diagram expressed a 'U' shaped variation, which implies that there exists an optimum level for each one of the parameters, which can minimize the loss. Apart from this the 'ANOVA' carried out between the blocks, it didn't show any significant difference in any of the mean value of these parameters. This helped to collate all the data available for combine harvester in both the blocks. Hence, all the 50 observations were taken together. Even in the combined effect, the scatter diagram exhibited same type of variations with respect to each one of the variable. Hence, a 'Multivariate Quadratic' type of function was prepared. The variables selected were cutter bar loss (Y), moisture content of straw (x_1), width of cut (x_2) and time taken for 20 m travel *i.e.,* speed (x_3).

The mathematical form of the proposed function was,

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_1^2 + b_5x_2^2 + b_6x_3^2 + b_7x_1x_2 + b_8x_1x_3 + b_9x_2x_3$$

The mixed terms like (x_1x_2), (x_1x_3) and (x_2x_3) were used to know whether there were any interactions present among the independent variables considered. The step-down procedure was preferred in the estimation of the parameters in the proposed equation, since it eliminates those variables in the equation, which do not contribute anything towards the explanatory power of the dependent variable. The Table 4 represents the details pertaining to coefficients for the regressing equation for cutter bar loss.

The R^2, coefficient of multiple determinations is 0.9549 which is significant at one per cent level of probability indicating the fact that 95.49 per cent of the variations in the dependent variable were being explained by the three independent variables included in the regression. Since the objective of the estimation of parameters for minimizing the grain loss, the estimated equation was partially differentiated with respect to each one of the variables and equated to zero. The differentiated equations are as follows :

$$Y = 67.7534 - 0.5066\ x_1 - 46.035\ x_2 - 0.4287\ x_3 + 0.0035\ x_1^2 + 11.9991\ x_2^2 + 0.0095\ x_3^2$$

Differentiating the above equation with respect to x_1, x_2, and x_3 partially and it represents the minimum cutter bar losses, since the coefficients of the second degree terms are 'Positive' in each case. Thus, when the moisture content of straw (%) is 72.37, width of cut (m) is 1.91 and speed of the machine (sec) is 22.56, the total grain loss will be minimum 0.43 %. These intervals can be nomenclatured as a 'Confidence Band' in the three dimensional space for minimizing the cutter bar losses for moisture content of straw (%) 68.25 to 76.50, width of cut (m) 1.85 to 2.03 and speed (sec) 21.50 to 23.50.

Table 4 : The coefficients of the regression equation for cutter bar loss

Sr.No.	Variables	Regression coefficients	Standard error	Level of significance	R^2
1.	Constant (b_0)	67.7534	-	-	0.9549
2.	Moisture content of straw (x_1)	-0.5066	0.0184	0.0000	
3.	Width of cut (x_2)	-46.0350	0.0219	0.0000	
4.	Time taken for 20 m distance (x_3)	-0.4287	0.0153	0.0000	
5.	Square of x_1 (x_1^2)	0.0035	0.0187	0.0000	
6.	Square of x_2 (x_2^2)	11.9991	0.0219	0.0000	
7.	Square of x_3 (x_3^2)	0.0095	0.0187	0.0000	

Table 5. The coefficients of regression equation for threshing loss

Sr.No.	Variables	Regression coefficients	Standard error	Level of significance	R^2
1.	Constant (b_0)	-197.5331	-	-	0.9609
2.	Moisture content of grain (x_1)	3.2818	0.0907	0.0000	
3.	Width of cut (x_2)	173.87	0.1380	0.0000	
4.	Time taken for 20 m distance (x_3)	0.4480	0.0679	0.0000	
5.	Square of x_1 (x_1^2)	- 0.0933	0.0898	0.0000	
6.	Square of x_2 (x_2^2)	- 45.6620	0.1387	0.0000	
7.	Square of x_3 (x_3^2)	- 0.0099	0.0675	0.0000	

In the first stage, the variations are allowed on only one variable below and above the optimal solution. The increase and decrease on both sides were stopped whenever the loss goes beyond a critical level (it has fixed 0.65 % loss as the critical level). This process was repeated for each one of the variables and the resulting interval in each are 68.25 to 76.50 for moisture content of straw, 1.85 to 2.03 for cutter bar width (m) and 21.50 to 23.50 for time taken (sec). Now in order to test the combined effect, simulated 25 such types of values for the trials. The details of coefficients regression equation for threshing losses is given in Table 5 and the variables selected are threshing loss (Y), moisture content of grain (x_1), width of cut (x_2) and time taken for 20 m travel *i.e.,* speed (x_3).

The R^2, coefficient of multiple determination is 0.9609 which is significant at one percent level of probability indicating the fact that 96.09 per cent of the variations in the threshing loss is being accounted by the changes in the three variables. For the estimation of parameters which minimizes the loss, the estimated equation was partially differentiated with respect to each one of the variables and equated to the zero. The differentiated equations are as follows:

$$\mathbf{Y = -197.5331 + 3.2818\,x_1 + 173.87\,x_2 + 0.4480\,x_3 - 0.0933\,x_1^2 - 45.6620\,x_2^2 - 0.0099\,x_3^2}$$

Differentiating the above equation with respect to x_1, x_2, and x_3, partially and moisture content of grain is 17.58 per cent, width of cut is 1.90 m and speed of the machine is 22.62 sec, the total grain loss is 1.91 %. As in the previous case, these intervals can be nomenclatured as a 'Confidence Band' in the three dimensional space for minimizing the threshing loss is moisture content of grain (%) 19.50 to 21.00, width of cut (m) 1.85 to 1.95 and speed (sec) 19.00 to 25.00.

Two more important parameters in the design of combined harvester where losses occur are in sieve and straw walker. The data when executed showed very high correlation of 0.932 between the two variables moisture content of grain and moisture content of straw. Hence, in order to avoid multicollinarity, it was decided to take one of the two since the result, which is true for one, will be exactly true for the other. The Table 6 represents the coefficient of regression equation for sieve losses (Y) with the dependent variable are moisture content of straw (x_1), width of cut (x_2), speed (x_3) and moisture content of grain (x_4) as independent variables.

The best fitted equation as in the earlier cases is with R^2, the coefficient of multiple determination is 0.9174 which is significant at one per cent level of probability indicating the fact that 91.74 per cent of the variations in the sieve loss is being explained by the changes in the four independent variables included in the model. The estimated equation was partially differentiated with respect to each one of the variables and equated to the zero. The differentiated equations are as follows:

Table 6: The coefficients regression equation for sieve losses

Sr.No	Variables	Regression coefficients	Standard error	Level of significance	R^2
1.	Constant (b_0)	29.8395	-	-	0.9174
2.	Moisture content of straw (x_1)	- 0.2063	0.0142	0.0000	
3.	Width of cut (x_2)	- 19.6767	0.0206	0.0000	
4.	Time taken for 20 m distance (x_3)	- 0.0637	0.0147	0.0000	
5.	Moisture content of grain (x_4)	- 0.3038	0.0193	0.0000	
6.	Square of x_1 (x_1^2)	0.0014	0.0144	0.0000	
7.	Square of x_2 (x_2^2)	5.1247	0.0206	0.0000	
8.	Square of x_3 (x_3^2)	0.0014	0.0147	0.0000	
9.	Square of x_4 (x_4^2)	0.0088	0.0193	0.0000	

$$Y = 29.8395 - 0.2063\,x1 - 19.6767\,x2 - 0.0637\,x3 - 0.3038\,x4 + 0.0014\,x12 + 5.1247\,x22 + 0.0014\,x32 + 0.0088\,x42$$

Differentiating the above equation with respect to x_1, x_2, x_3 and x_4 partially and the moisture content of straw is 73.67 per cent, width of cut is 1.91 m, speed of the machine is 22.75 sec and moisture content of grain is 17.26 per cent, the total grain loss is less than 1 per cent *i.e.* 0.005 %. The intervals can be nomenclatured as a 'Confidence Bands' in the three dimensional space for minimizing the sieve and straw walker losses (separation losses) for moisture content of grain (%) 16.25 to 19.50, moisture content of straw (%) 68.25 to 77.49, width of cut (m) 1.89 to 2.04 and speed (sec) 19.45 to 25.12.

The Table 7 shows the comparative study of observed or actual and predicting or estimated post harvest grain losses in the field condition by using combine harvester. The predicted looses of cutter bar / harvesting, threshing and separation losses were found almost nearing to the actual or observed values during the experiment. Therefore, the data reveals that, the predicted values may be treated as at par with the observed values.

Table 7: Comparative study of observed and predicted post harvest grain losses

Sr. No.	Description	Observed	Predicted
1.	Cutter bar losses	0.425	0.403
2.	Threshing losses	1.763	1.754
3.	Sieve losses	0.207	0.204
4.	Total losses	2.395	2.361

Conclusion:

The study was conducted to assess the post harvest grain losses. The preliminary survey was conducted to callout the opinion about the combine harvester, it shows that, the combine harvester will save the grain, minimise the harvesting time. The experiment was conducted in two blocks by comparing with traditional and combine harvester. It reveals that the combine harvester saves more than 2.28 times cost. A suitable regression equation was used to simulate for judging the losses for considering the crop and machine parameter. The regression equations were considered with four primary factors *viz*., moisture content of straw, moisture content of grain, width of cut and time taken. In the case of the cutter bar width through the equation the researcher has obtained an interval within which the width can be oscillated so that it will not affect the end value of the result *i.e.,* minimization of loss. In a similar way the interval was given for speed and moisture level of straw. Hence, the interval jointly has given allowance for large amount of variations in these parameters. The optimum intervals for three parameters were tested in the field condition for validation. The simulated values were confirmed with the actual and predicted values by comparing with the field condition. The actual or observed values shows 2.395 per cent as compared to the predicted values was 2.361 per cent.

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