

# Evaluation of yield monitoring system installed on indigenous grain combine harvester for rice crop

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**Abstract:** Precision agriculture is a methodology to identify and exploit variability within an agricultural field. In India, a yield is measured during marketing of harvested crop and as a gross yield of the land owned by the farmer. The yield monitor mounted over grain combine harvester measures and records information such as grain flow, grain moisture, area covered and location. An automated yield monitoring system consisting of a yield sensor, global positioning system (GPS), field computer with custom software was mounted on a self propelled indigenous grain combine harvester for real-time crop yield mapping along with moisture data. By means of optical sensors (light emitter and detector), the height of the grain on the elevator paddles was measured and converted in the grain mass flow. Three rice fields were harvested to evaluate the performance of the yield monitor for grain yield and moisture mapping of harvested grains. The actual yield maps were generated by using Arc GIS software from the data collected for three different rice fields. The total area harvested by using indigenous combine harvester fitted with yield monitor and moisture sensor was 0.84 ha comprising three fields (1, 2 and 3) having areas 0.3, 0.22 and 0.32 ha respectively. On an average, yields for all the three fields (1, 2 and 3) were 4,325.91, 5,093.14 and 4,287.66 kg ha<sup>-1</sup> with moisture content of 21.42%, 22.78% and 20.42% (wet basis) recorded respectively. On an average, yield variations recorded for all the three fields (1, 2 and 3) were having 30.59%, 40.80% and 40.39% coefficient of variation respectively. The minimum and maximum yields recorded within all the fields harvested were 577.08 and 7,661.48 kg ha<sup>-1</sup> with an average yield of 4,287.66 kg ha<sup>-1</sup> having 37.26% coefficient of variation (CV) in all the three fields.

**Keywords:** Combine harvester, precision agriculture, sensor; yield maps, yield monitor

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## 1 Introduction

In Punjab, the total areas under combine harvesting rice and wheat are 91% and 82% respectively (Singh and Shukla, 2005). The present trend in state is to use high capacity machines on custom hiring basis. The marginal and small farms cannot enjoy the benefits of mechanization through individual ownership. Custom hiring of farm machinery including combine harvester is

the only means by which small farmer can reap the benefits of farm mechanization. About 90%-95% of total 425 thousand combines operated in India are on custom hiring basis (Sharma et al., 1998). A yield is measured during marketing of harvested crop and as a gross yield of the land owned by the farmer. Nowadays, custom hiring charges are paid by the farmers on area basis rather than output basis.

A yield monitor is a recent development in precision farming that allows farmers to assess the yield variability in the field during harvesting of crop (Shearer et al., 1999). By using the yield monitor in combine harvester, charges for custom hiring may be charged by the operators on the weight basis rather than area basis.

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In earlier research, a load cell based monitor was developed for grain combine harvester (Singh et al., 2011; Sharma et al., 2012). This yield monitor measured the weight of grain collected in an auxiliary tank situated inside of the main grain tank and displayed yield data over the display unit near the seat of the driver. The limitations in this system were time consumed for stopping the combine and emptying the auxiliary tank reduced the combined field capacity and system was not capable to generate yield maps during real time harvesting. The moisture content of the grain was also measured manually during the harvesting. The accuracy of yield monitor is adversely affected by moisture content (Grisso et al., 2002).

Keeping in view the limitations of previous developed yield monitor, there was need to develop a continuous type of yield monitor which can measure the yield with moisture content continuously and generate yield maps in real time harvesting. For this purpose, optical sensor based yield monitor was developed and installed on combine harvester.

## 2 Materials and methods

Self propelled combine harvester was used to harvest the rice crop. The yield monitor was developed and installed on the combine. The system consisted of different components like optical sensor, moisture sensor, global positioning system (GPS) receivers to determine combine location and data acquisition system explained below. The yield was determined as a product of the various parameters being sensed.

### 2.1 Grain yield sensor

Grain yield was measured by an optical sensor (non contact type) installed near the top of the clean grain elevator (Figure 1). The transmitter and receiver together with lens and lens holders were secured to a hinged mounting bracket which is riveted to the elevator housing. Sensor operation was indicated by a light emitting diode (L.E.D.) on the end of each sensor. An infrared (non visible) light beam transmitted across the elevator paddles from one side to the other. A receiver detects the light beam broken or not broken. For each paddle pass, the sensor detects the beam broken. The

more grain there is on the paddle, the longer the time the beam is broken. The following calculations were used for volume and mass flow measurements (Equation (1) and Equation (2)).

$$\text{Volume flow} = \text{Height} \times \text{Elevator speed (r min}^{-1}) \times \text{Calibration factor} \quad (1)$$

$$\text{Mass flow} = \text{Volume Flow} \times \text{Test Weight} \quad (2)$$

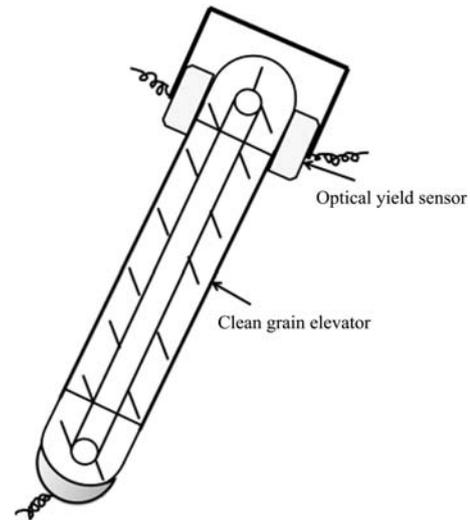


Figure 1 Optical yield sensor mounted on the clean grain elevator

### 2.2 Moisture sensor

To obtain an accurate yield, yield and moisture data were required simultaneously. Moisture sensors were often located in the clean grain elevator. The moisture sensor was essentially a conductive shell or a series of metal plates with an electrically isolated internal metal fin. As grain rises in the clean grain elevator, a small amount enters the top of the moisture sensor and moves between the metal plates. Moisture content was determined on dielectric property of harvested grain. Grains having different moisture contents affect differently the capacitance which was sensed by two conductive metal surfaces.

### 2.3 Global positioning system

In the sensor based yield monitoring system, GPS utilizes the signal received from different satellites available and feedback control to measure the desired location, and also uses this signal to display the combine speed. A significant advantage of GPS mapping technology was to observe its sub meter accuracy. The Global Positioning System (GPS) was a combination of space and ground-based segments that together

comprises a radio-navigation facility. GPS was mounted on the combine cab, centre of combine at the highest point from the ground level.

## 2.4 Field computer

A field computer was located in front of the driver's seat. Field computer stores different sensors output signals for storage and display and for later use. It contains the GPS receiver interface, external data storage devices, graphical user interface and controls the interaction of these devices. It displays several functions like integrations and calibrations of the sensors, on line speed, moisture content, area covered and yield per hectare while combine was in operation.

## 2.5 Junction box

Junction box was data collection unit that records the data of yield sensor, moisture sensor and GPS receiver. It also records the width of cut and speed of operation. Field name, crop type, calibration number and correction factor were also entered in the junction box. The junction box despite being weather proof should preferably be mounted inside the cab to give maximum physical safety and protection.

## 2.6 Evaluation of yield monitor

### 2.6.1 Calibration

Width of cutter bar, offset position (front or behind and left or right from the center line of cutter bar) of GPS and height of GPS from above the ground were inserted for the existing combine harvester. Baud rate (19200) was set for GPS in the port A of field computer. The desired display units were selected for the yield ( $\text{kg ha}^{-1}$ ), work rate ( $\text{ha h}^{-1}$ ), forward speed ( $\text{km h}^{-1}$ ), total area (ha), total weight (t), crop density ( $\text{kg m}^{-1}$ ), distance (m), and speed of operation ( $\text{m s}^{-1}$ ) and then set in the field computer.

The tare setting was used to re-zero the yield sensor for the percentage of time which the beam was broken by clean grain in the grain elevator. For tare setting, combine harvester was placed on level ground. The clean grain elevator was operated empty, at threshing RPM and the tare value set. Combine was operated in field at maximum forward speed.

### 2.6.2 Field tests

Yield monitor was installed on the combine harvester,

and rice crop was harvested. The combine cutter bar of width of 4 m was put in the initial settings. The field tests were performed in fields to fine tune the system and make sure it was working correctly. Real-time yield and moisture of grain display in  $\text{t ha}^{-1}$  and % (wet basis) were displayed on the field computer. The rice yield was automatically measured and recorded in the hard drive (USB drive) and a map was created with the help of software. The performance of the software and hardware of yield monitor was assessed by surveying the three fields of different sizes. The Arc GIS software was used to process the yield data to estimate the yield at particular location.

### 2.6.3 System check up

Before starting the operations, the yield sensor and GPS signal were properly checked. The yield sensor was checked by operating the combine at normal harvesting RPM with the clean grain elevator empty. The diagnostics screen indicated a frequency for each sensor currently connected to the system. This value indicated the number of elevator paddles passing the sensor each second. Operation of the grain or yield sensor may be verified by observing the LEDs on sensor body. The green LED was the transmitter element which was visible and the red LED was flashing. The speed sensor was checked by driving the machine forward. The forward speed displayed on the field computer screen corresponded to the actual combine forward speed. A voltage reading indicated that the sensor was functioning.

## 3 Results and discussions

Rice crop yield range ( $\text{kg ha}^{-1}$ ) and average moisture content variability data for different fields are given in Table 1. The maps for yield and moisture content for different fields are plotted in Figure 2, Figure 3 and Figure 4.

### 3.1 Yield and moisture content variability for field 1

The yield and moisture content variations within field no. 1 are plotted in Figure 2. Field no. 1 ( $75081^{\circ}07.22''$  E  $30091^{\circ}08.35''$  N) having total area 0.30 ha was harvested by using yield monitor fitted combine harvester. The area of 0.0036 ha (1.2%) was having yield in the range of

**Table 1 Yield range (kg ha<sup>-1</sup>) and average moisture content variability for different fields**

Field No.	Total area /ha	Yield range /kg ha <sup>-1</sup>	Area / ha (%)	Average yield /kg ha <sup>-1</sup>	Average moisture /%
Field No.1	0.3	1000-2000	0.0036(01.20)	1899.61	21.44
		2000-3000	0.0828(27.60)	2782.16	21.47
		3000-4000	0.0444(14.80)	3303.80	21.42
		4000-5000	0.0852(28.40)	4776.20	21.38
		5000-6000	0.0460(15.33)	5601.99	21.45
		More than 6000	0.0440(14.60)	6254.89	21.25
		Mean		4325.91	21.42
	SD		1323.59	-	
	CV		30.59	-	
Field No.2	0.22	Below 1000	0.0048(02.18)	577.08	21.97
		1000-2000	0.0096(04.36)	1709.37	22.42
		2000-3000	0.0104(04.72)	2500.00	22.84
		3000-4000	0.0336(15.27)	3693.27	23.04
		4000-5000	0.0676(30.72)	4494.37	23.08
		5000-6000	0.0378(17.18)	5544.16	23.10
		More than 6000	0.0592(26.90)	7661.48	23.03
	Mean		5093.14	22.78	
	SD		2078.06	-	
CV		40.80	-		
Field No.3	0.32	Below 1000	0.0080(2.50)	590.00	20.58
		1000-2000	0.0476(14.87)	1533.82	20.55
		2000-3000	0.0728(22.75)	2534.34	20.53
		3000-4000	0.0600(18.75)	3557.66	20.45
		4000-5000	0.1060(33.12)	4360.00	20.32
		5000-6000	0.0180(05.60)	5463.33	20.21
		More than 6000	0.0120(03.75)	6752.50	20.36
	Mean		3443.95	20.42	
	SD		1391.31	-	
CV		40.39	-		
Gross Mean		4287.66			
Gross SD		1597.65			
Gross CV		37.26			

1,000-2,000 kg ha<sup>-1</sup> with average yield of 1,899.61 kg ha<sup>-1</sup> and average moisture content of 21.44%. The area of 0.0828 ha (27.6%) was having yield in the range of 2,000-3,000 kg ha<sup>-1</sup> with an average yield of 2,782.16 kg ha<sup>-1</sup> and average moisture content of 21.47%. The maximum yield range i.e. more than 6,000 kg ha<sup>-1</sup> with an average yield of 6,254.89 kg ha<sup>-1</sup> was in 0.0440 ha i.e. 14.6% of the total area harvested by the combine harvester fitted with yield monitor and the moisture content in this area was 21.25%. The average yield for field no. 1 was 4,325.91 kg ha<sup>-1</sup> with variation in yield having S.D. of 1,323.69 kg ha<sup>-1</sup> and C.V. of 30.59%.

The minimum moisture range (shown in red) was 18.06%-20.33% with average moisture content of 19.79% in 0.0136 ha of the total area harvested and the maximum moisture range (shown in blue) was 21.274%-21.879% with average moisture of 21.646% in 0.2336 ha of total harvested area. The average moisture content of the area harvested for field was 21.42% (wet basis).

### 3.2 Yield and moisture content variability for field 2

The yield and moisture content variations within field are shown in Figure 3. Field no. 2 (75081'88.52" E 30090'95.02" N) was having total area 0.22 ha harvested by combine harvester fitted with yield monitor. The minimum yield range i.e. below 1,000 kg ha<sup>-1</sup> was measured with average yield of 577.08 kg ha<sup>-1</sup> in 0.0048 ha i.e. 2.18% area harvested with average moisture of 21.97%. The area of 0.0096 ha i.e. 4.36% harvested was having yield in the range of 1,000-2,000 kg ha<sup>-1</sup> with an average yield of 1,709.37 kg ha<sup>-1</sup> with moisture content of 22.42%. The area of 0.0378 ha (17.18%) was having yield in the range of 5,000-6,000 kg ha<sup>-1</sup> with an average yield of 5,544.16 kg/ha and moisture content of 23.1%. The maximum yield range i.e. above 6,000 kg ha<sup>-1</sup> was having an average yield of 7,661.48 kg ha<sup>-1</sup> and moisture content 23.03% in 0.0592 ha (26.9%) of the total area harvested by the combine harvester. The average yield for field no. 2 was 5,093.14 kg ha<sup>-1</sup> with variation in yield having S.D. of 2,078.06 kg ha<sup>-1</sup> and C.V. of 40.80%. The minimum moisture content range of 20.569%-21.999% with average moisture content of 21.63% was in 0.0564 ha of the total harvested area and the maximum moisture range of 23.31%-23.54% with average moisture of 23.416% was in 0.0384 ha of total harvested area. The average moisture content of the field no. 2 was 22.78%.

### 3.3 Yield and moisture content variability for field 3

The yield and moisture content variations within field no. 3 are shown in Figure 3. Field no. 3 (75081'14.52" E 30091'01.59" N) was having total area 0.32 ha harvested by using indigenous combine harvester fitted with yield monitor. The minimum yield range i.e. below 1,000 kg ha<sup>-1</sup> was measured having an average yield of 590 kg ha<sup>-1</sup> and average moisture content of 20.58% in 0.0080 ha i.e. 2.5% total harvested area.

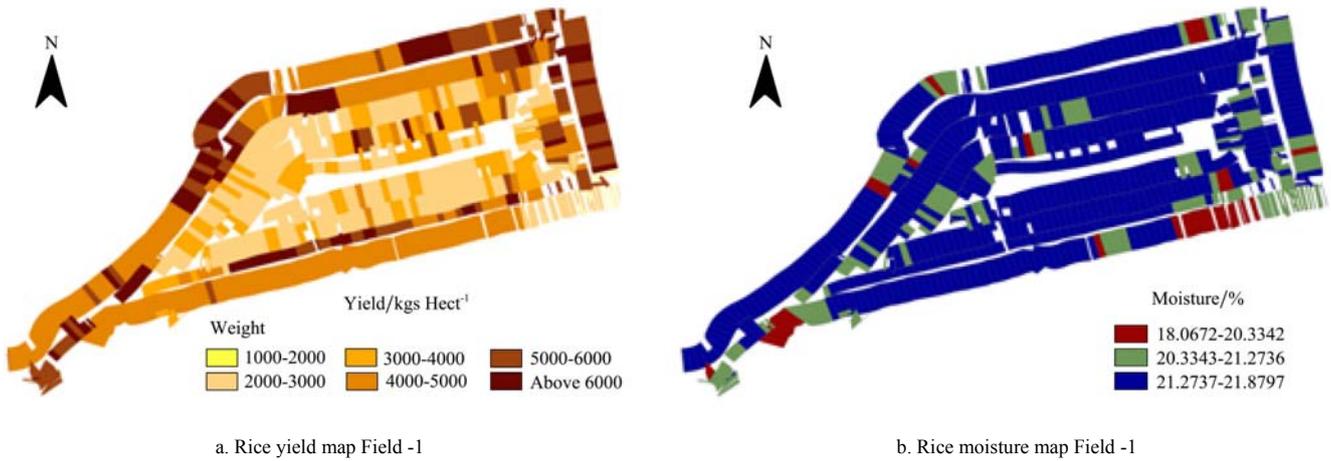


Figure 2 Yield and moisture variation of Field no 1

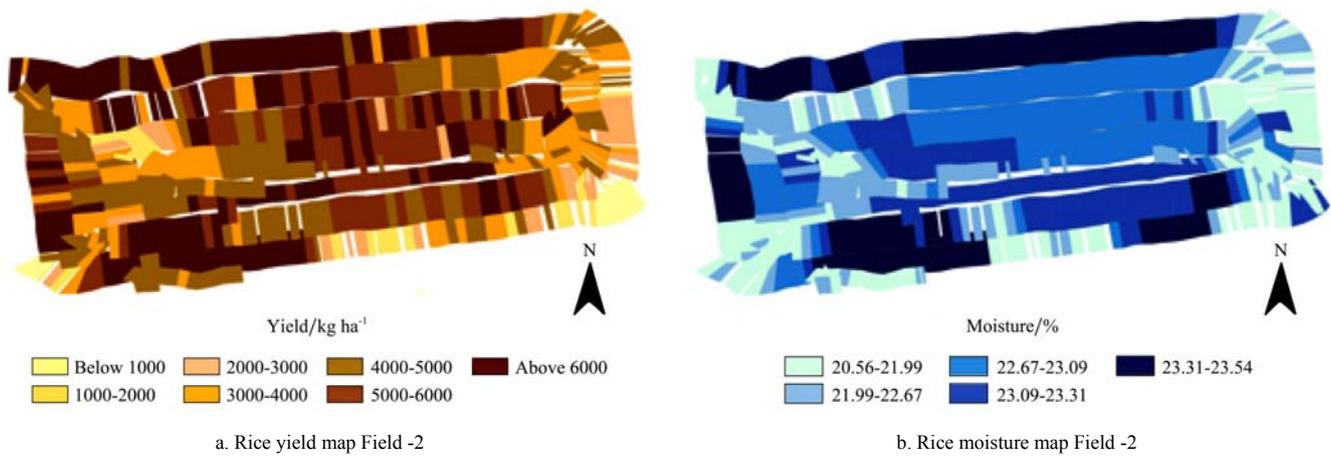


Figure 3 Yield and moisture variation of Field no 2

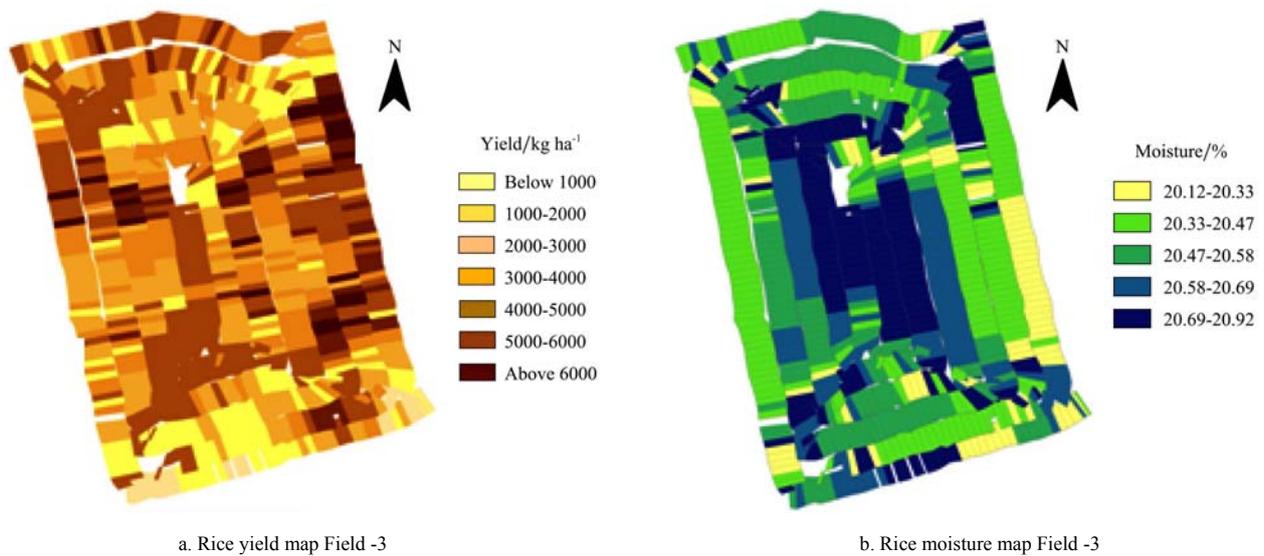


Figure 4 Yield and moisture content variations of Field no.3

The area of 0.0120 ha (3.75%) harvested was having maximum yield range i.e. above 6,000 kg ha<sup>-1</sup> with an average yield of 6,752.5 kg ha<sup>-1</sup> and average moisture content of 20.36%. The average yield for field no. 3

was 3,443.95 kg ha<sup>-1</sup> with variation in yield having S.D. of 1,391.3 kg ha<sup>-1</sup> and C.V. of 40.39%. The minimum moisture range of 20.126%-20.339% with average moisture content of 20.26% was in 0.0328 ha of the total

harvested area and the maximum moisture range of 20.697%-20.927% with an average moisture content of 20.77% was in 0.0756 ha of harvested area. The overall average moisture content of field no. 3 was 20.42% (wet basis). The variation in the results may be due to the non uniformity of crop germination, variations in combine forward speed especially during turning, undulations or slope in the field and different size of harvested field.

#### 4 Conclusions

An automated yield monitoring system consisting of a yield sensor, moisture sensor, global positioning system (GPS) and field computer with custom software, was mounted on a self propelled indigenous grain combine harvester for measurement of real-time rice crop yield along with moisture content. By means of optical sensors (light emitter and detector), the height of the rice grains on the elevator paddles were measured. The total area harvested by using indigenous combine harvester

fitted with yield monitor and moisture sensor was 0.84 ha comprising three fields having areas 0.3, 0.22 and 0.32 ha respectively. On an average, the yield for all the three fields (1, 2 and 3) were 4,325.91, 5,093.14 and 4,287.66 kg ha<sup>-1</sup> with moisture content of 21.42%, 22.78% and 20.42% recorded respectively. On an average, yield variations recorded for the all the three fields (1, 2 and 3) were having 30.59%, 40.80% and 40.39% coefficient of variation respectively. The minimum and maximum yield recorded within all the fields harvested was 577.08 and 7,661.48 kg ha<sup>-1</sup> with an average yield of 4,287.66 kg ha<sup>-1</sup> having 37.26% coefficient of variation (CV) in the yield.

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