Precision Farming in Paddy as an option to increase Resource Use Efficiency

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Abstract

Precision Farming helps in dealing with the challenge of accurate agricultural management practices with improved technology which have the potential to benefit the farmer financially through proper and effective management of soil and crop variability with the use of information technology. Precision Farming differs from conventional farming that is based on uniform treatment across a field. It involves application of technologies like mapping and analyzing field variability and linking spatial relationships to management action, thereby allowing farmers to look at their farms, crops and practices from an entirely new perspective. Considering its benefits, in the present paper an attempt has been made to analyze the productivity of various resources in production of paddy under precision farming over non-precision farming in the study area where precision farming has been implemented. Cobb-Douglas type of production function was fitted to the farm level data to study the efficiency of various inputs in precision and non-precision farming of paddy. The allocative efficiency in the use of each resource was calculated by constructing the ratio of Marginal Value Product (MVP) to the Marginal Factor Cost (MFC). Results indicated that there was excess utilization of N and K_2O fertilizers under non-precision farming. Increasing returns to scale was noticed in precision farming whereas diminishing returns to scale was noticed in non-precision farming. There is a need to popularize the precision farming method of cultivation of paddy among the farming community considering its benefits like savings in resources and thereby reduction in cost of cultivation.

Introduction

India has moved from an era of chronic food shortages during 1960s to food self-sufficiency and even food exports from 1990s. The demand for food and agricultural commodities in India has been increasing at a high rate. The sole pursuit of high productivity in order to meet the ever growing demand for agricultural products, has resulted in indiscriminate utilization of resources while neglecting the critical linkage between agriculture and the environment which has posed a threat to the future of Indian agriculture on a sustainable basis. In the present days of increasing input costs,

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decreasing commodity prices and environmental concerns, farmers and government authorities are looking for new ways to increase efficiency of resources, cut down costs and subscribe to sustainable agriculture. Currently, agricultural production is facing significant challenges such as escalating costs of production, shortage of irrigation water and increased public concern about the impacts of agricultural production on the environment. The focus on enhancing the productivity during the Green Revolution coupled with total disregard for proper management of inputs without considering the ecological impacts has resulted in environmental degradation (Singh 2010).

Many factors like topography, ancient earthworks, drainage patterns and exposure to shade, all influence the soil characteristics in a particular area. Since differences in the soil affect crops and thus yield, it is clear that more accurate agricultural management practices with improved technology have the potential to benefit the farmer financially. Precision Farming (PF) helps in dealing with this challenge through proper and effective management of soil and crop variability with the use of information technology. PF is also known as prescription farming, Variable Rate Technology (VRT) and Site Specific Crop Management (SSCM). It is considered as the agricultural system of the 21st century, as it symbolizes a better balance between reliance on traditional knowledge, information and management-intensive technologies.

According to Robert *et al.* (1995), precision farming is defined as information and technology based agricultural management system to identify, analyze and manage site-soil, spatial and temporal variability within fields for optimum profitability, sustainability and protection of the environment. Raj Khosla stated that precision agriculture is, doing the right thing, in the right place at the right time. PF differs from conventional farming that is based on uniform treatment across a field. It involves application of technologies like mapping and analyzing field variability and linking spatial relationships to management actions, thereby allowing farmers to look at their farms, crops and practices from an entirely new perspective.

The technology has been implemented in Karnataka state under the RKVY funded project on precision farming in selected field crops since 2011. The project was implemented through three State Agricultural Universities in the state with UAS, Raichur as the leading centre to guide the other two Agricultural Universities (UAS, Dharwad and UAS, Bangalore) in the project activities. Farmer participatory approach was adopted to execute the project at the farmers' fields in Raichur, Kalaburgi and Koppal districts, covering an equivalent of 100 acres each in cotton, pigeonpea and paddy crops respectively, that represent major field crops of the North-Eastern Karnataka zone, along with on-farm research demonstration plots (5 acres in each crop) at four research stations of UAS, Raichur (Patil *et al.* 2013). In the present paper, an attempt has been made to analyze the productivity of various resources in production of paddy under precision and non-precision farming situations.

Methodology

Locale of the study: The study was conducted in Karnataka state with a focus on the North Eastern Karnataka region in the jurisdiction of UAS, Raichur. However, the study area was confined to village Jangamarakalgudi of Gangavathi taluk, Koppal district of North Eastern Karnataka as RKVY- Precision Farming project has been implemented in this district.

Sampling procedure: The precision farming adopted farmers refer to those who are the beneficiaries of precision farming project of UAS, Raichur. The precision farming non-adopted farmers refer to those who did not participate in precision farming but were growing the same crop in the same area. The number of farmers who adopted precision farming for paddy were 38. An equal number of non-adopted farmers were selected in the same criterion. In all, the total sample size consisted of 76 farmers.

Data source: Primary data were collected from the farmers who have adopted precision farming techniques in paddy since the last three years and also from conventional farmers. i.e. non-adopters of precision farming in the same area. The interview schedule was pre-tested which led to adequate modification of the instrument. The data were collected from the sample farmers by personal interview method using the pretested schedule during the period of January and February for the agricultural year 2014-15.

Resource Use Efficiency

In functional analysis, it would be essential to choose an appropriate form of production function with the consideration of data to be analyzed and objective which is to be achieved. With this perspective, in order to analyze the resource use efficiency, Cobb-Douglas type of production function was fitted to the farm level data in order to know the efficiency of various inputs in precision and non-precision farming of paddy.

The Cobb-Douglas type of production function being homogenous, provides a scale factor enabling one to measure the returns to scale. The analysis was carried out on per farm basis. The following form of Cobb-Douglas type of production function was used for both precision and non-precision farmers. The analysis was carried out separately for both the situations.

$$Y = a\, X_1^{b1} .\, X_2^{b2} .\, X_3^{b3} .\, X_4^{b4} .\, X_5^{b5} .\, X_6^{b6} .X_7^{b7} .e^u$$

The Cobb-Douglas type of production function was converted into log linear form and parameters (co-efficient) were estimated by employing the Ordinary Least Square (OLS) technique as given below

$$\text{Log } Y = \text{Log } a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 \log x_4 + b_5 \log x_5 + b_6 \log x_6 + b_7 \log x_7 \; u \log e$$

Where,

Y = Gross output per farm (quintals)

X_1 = Land (ha.)

X_2 = Seeds (kg)

X_3 = Human labour (mandays)

X_4 = N (kg)

X_5 = P_2O_5 (kg)

X_6 = K_2O (kg)

X_7 = Plant Protection Chemicals (₹)

a = Constant / intercept term

u = Random variable

e = 2.718

b_1 to b_7 are the elasticity coefficients of respective factor inputs. The regression co-efficient were tested using 't' test at chosen level of significance while the function as a whole was tested using F- test.

$$t = \frac{X_i}{SE(X_i)}$$

Where, X_i = Regression co- efficient of i^{th} input

SE (X_i) = Standard error of i^{th} input

$$F = \frac{(R^2/P)}{(1-R^2)(n-1-P)}$$

Where, R^2= co-efficient of multiple determination (unadjusted)

P= number of parameters in the sample

n= number of observations in the sample

The co-efficient of multiple determination (R^2) was worked out in order to test the goodness of fit of the estimated function by using the formula,

$$F = \frac{\left[1-\left(R^2/P\right)\right]}{\left[(n-1)(n-P)\right]}$$

Allocative Efficiency

Given the technology, allocative efficiency exists when resources are allocated within the farm according to market prices and it implies the proper level of input use in production. Marginal value products for each input are computed in order to decide whether a particular input is used rationally or irrationally on the criteria of coverage of its acquisition cost by the respective input.

Marginal value products for each input were calculated by using the elasticity co-efficient of each input obtained from the production function of respective inputs and the geometric mean levels of each variable by using the formula,

$$\text{MVP of } i^{th} \text{ input} = b_i \frac{\overline{Y}}{X_i} P_y$$

Where, $\overline{Y}$ = Geometric mean of output

X_i = Geometric mean of i^{th} input

b_i = Regression co-efficient of i^{th} input

P_y = Average price per unit of output

The allocative efficiency in the use of each resource was calculated by constructing the ratios of Marginal Value Products (MVP) to the Marginal Factor Costs (MFC).

Results and Discussion

The results of pattern and extent of input usage under precision and non-precision cultivation of paddy indicated that precision farming practicing farmers were found to use more quantity of seeds (68.52 kg/ha), organic manure (3.91 t/ha) and biofertilizers (0.52 kg/ha) which was higher by 7.25 per cent, 28.20 per cent and 85.71 per cent respectively than that of non-participants of precision farming (Table 1). This was due to awareness about importance of organic manure and biofertilizers among the participants of precision farming.

It was observed that there was savings in chemical fertilizers among paddy growers of precision farming to the extent of 64.30 per cent of N, 56.17 per cent of P_2O_5 and 47.58 per cent of K_2O as compared to non-precision farming situation. This was mainly because of the tendency of using more quantity of fertilizers by the farmers under non-precision farming, which was mainly due to lack of awareness about the recommended dose of fertilizer usage among them. Further, there was misconception among the farmers that increased application of fertilizers would lead to higher yield. On the other hand, precision farming practicing farmers have used more quantity of micronutrients (126.89 %). such as zinc, boron, gypsum, magnesium and iron as compared to farmers under non-precision farming. Grid soil sampling and soil analysis were carried out at the beginning of every season only in case of precision farming. Hence fertilizers were applied as per the soil analysis report across the grids. This indicated the variable rate of application of fertilizer under precision farming. Therefore it was observed that there was savings with respect to N, P_2O_5 and K_2O and increased application of micronutrients. A similar observation was also made by Swinton and Lowenberg-DeBorer (1998). They reported that the application of major nutrients decreased, while the micronutrients increased slightly. Synder (1996) and Ahmad *et al.* (1997) concluded in their studies that there was savings with respect to quantity of fertilizer application due to variable rate of application as compared to uniform application of fertilizers across the field.

Table 1: Comparative Material Input Use Pattern in Precision and non-Precision Cultivation of paddy

(N = 76)

Sl. no.	Particulars	Units	Precision farming	Non-precision farming	% change
1	Seeds	kg/ha	68.52	63.89	7.25
2	Organic manure	t/ha	3.91	3.05	28.20
3	Biofertilizers	kg/ha	0.52	0.28	85.71
4	Fertilizers				
a)	N	kg/ha	73.21	205.06	-64.30
b)	P_2O_5	kg/ha	59.44	135.62	-56.17
c)	K_2O	kg/ha	47.40	90.42	-47.58
d)	Micronutrients	kg/ha	26.63	11.74	126.89

It is clear from the results presented in Table 2 that the R^2 was 0.98 and 0.97 under precision and non-precision farming respectively. This indicated the suitability of the model under both the situations. Further, it also indicated that variables included in the model had explained 98 per cent and 97 per cent of variation in gross output of paddy under precision and non-precision farming respectively and thereby best fit of the specified model. Similar results were reported by Maheswari *et al.* (2008), wherein the observed R^2 value was 0.79 and 0.55 under precision and non-precision farming respectively in brinjal production.

On the other hand, there was considerable difference in the extent of contribution of different inputs on the production of paddy under precision and non-precision farming. All the inputs considered were found to influence the yield of paddy significantly and positively under precision farming except N (0.0278). In non-precision farming, the yield of paddy was significantly and positively influenced by seeds (0.7832) and P_2O_5 (0.7059) and negatively influenced by K_2O (-0.6874). This indicated that under non-precision farming, farmers were using more than required quantity of K_2O and increase in amount of K_2O leads to decrease in yield of paddy. The regression co-efficients of area, human labour, N and PPC were non-significant in non-precision farming. The regression co-efficient of N was negative (-0.3543) indicating that there was indiscriminate use of N fertilizer by farmers under non-precision farming. This might be due to the tendency of farmers to assume that increased application of fertilizers would lead to higher yield. Hence, there is a need to educate the farmers under non-precision farming about the benefits of grid soil sampling and soil analysis so that they could save fertilizers and utilize other resources effectively.

The sum of output elasticities under precision farming (1.9075) was found to be more than one, indicating increasing returns to scale i.e., one per cent increase in all the inputs simultaneously, would result in increase in the yield of paddy by 1.90 per cent. This was mainly due to significant and positive influence of all factors except nitrogen in precision farming. These increasing returns to scale indicate that there is a lot of scope to increase the technology component in production of paddy by increasing respective factors, whereas in non-precision farming, due to negative contribution of N and K_2O, the sum of output elasticity was found to be (0.8053) less than one. This indicates that simultaneous increase in all factors considered, will decrease the output of paddy by 0.80 per cent.

To analyze the allocative efficiency of various resources in precision and non-precision farming, the MVP of the resources were compared with the respective MFC. The results of allocative efficiency (Table 3) revealed that the MVP to MFC ratio was more than one in precision farming for all the resources except plant protection chemicals (0.08). This indicates that the resources were underutilized and there is a scope for increasing the use of these resources.

Table 2. Estimated Elasticity Coefficient of different resources in Precision and non - Precision cultivation of paddy (N = 76)

Sl. no.	Particulars	Parameters	Precision farming	Non-precision farming
			Reg. coefficients	Reg. coefficients
1	Intercept	a	-2.2108 (0.6668)	0.9592 (2.433)
2	Land (ha.)	b_1	0.1792*** (0.0627)	0.1059 (0.2728)
3	Seeds (kg)	b_2	0.4227*** (0.9030)	0.7832*** (0.1566)
4	Human labour (Mandays)	b_3	0.7421*** (0.1420)	0.1290 (0.3079)
5	N (kg)	b_4	0.0278 (0.0318)	-0.3543 (0.3346)
6	P_2O_5 (kg)	b_5	0.2086*** (0.0581)	0.7059* (0.3586)
7	K_2O (kg)	b_6	0.1605** (0.0642)	-0.6874** (0.2643)
8	PPC (₹)	b_7	0.1663** (0.0616)	0.1228 (0.1603)
9	Co-efficient of determination (R^2)		0.98	0.97
10	F value		307.29	224.47
11	Returns to scale ($\sum b_i$)		1.9075	0.8053

Note: Figures in the parentheses indicate standard error.

*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

Table 3. Allocative efficiency of different resources in Precision and non-Precision cultivation of Paddy (N = 76)

Sl. no.	Particulars	Variables							
		Yield (Y)	Land (X_1)	Seeds (X_2)	Human labour (X_3)	N (X_4)	P_2O_5 (X_5)	K_2O (X_6)	PPC (X_7)
Precision farming									
1	Geometric mean	4.32	0.02	4.21	4.55	9.77	4.90	4.70	8.73
2	Marginal product		37.12	0.43	0.71	0.01	0.18	0.15	0.08
3	MVP		59396.81	694.07	1128.93	19.69	294.77	236.26	0.08
4	MFC		10875.00	25.00	250.00	10.00	23.00	15.00	1.00
5	MVP:MFC		5.46	27.76	4.52	1.97	12.82	15.75	0.08
Non-precision farming									
1	Geometric mean	4.94	0.70	4.90	5.34	10.16	5.71	5.31	9.64
2	Marginal product		0.74	0.79	0.12	-0.17	0.61	-0.64	0.06
3	MVP		1190.61	1264.42	190.96	-275.57	977.10	-1023.33	0.06
4	MFC		10875.00	25.00	250.00	10.00	23.00	15.00	1.00
5	MVP:MFC		0.11	50.58	0.76	-27.56	42.48	-68.22	0.06

It was interesting to note that MVP to MFC ratio was less than one for plant protection chemicals in case of precision farming, while in case of non-precision farming, the ratio was more than one for seeds (50.55) and P_2O_5 (42.48) which indicated the scope for increasing the use of these resources. The ratio for resources like land, human labour and plant protection chemicals were less than one denoting the over utilization of resources and hence scope to reduce the use of these resources. The ratio was negative for N (-27.56) and K_2O (-68.22) in case of non-precision farming, which indicated the excess use of the N and K_2O fertilizer by the farmers under non-precision farming.

Conclusion

Precision farming is "doing the right thing, at the right place, at the right time". Precision farming is an agricultural system that has the potential of dramatically changing agriculture in this 21^{st} century. It lends itself to most agricultural applications and can be implemented at whatever levels required. It is based on information technology, which enables the producer to collect information and data for better decision making.

The blanket application of chemical fertilizers without considering the in-field variability in case of non-precision farming resulted in negative elasticity of co-efficients for inputs N and K_2O indicating the excess utilization of N and K_2O fertilizers. Further, overall increasing returns to scale was noticed in precision farming whereas in non-precision farming diminishing returns to scale was noticed. This indicates that there is a need for reallocation in both the situations.

It was emphasised that the existing technology (precision farming) would give importance to creating awareness among the farmers about the judicious use of inputs. The resources were efficiently utilized in precision farming as compared to non-precision farming and through variable rate of application of fertilizers the soil health can be maintained. Thus, savings were made in chemical fertilizers and PPC also. Hence there is a need to encourage and popularize this technology with the support of line departments, SAUs and other extension agencies. There is a need for transfer of technology through extension agencies about the benefits of precision farming at the farm level. This would ensure efficiency in the use of resources and this may help reduce the cost of cultivation by increasing the efficiency of resources.

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