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Decomposition analysis of factors contributing to yield gaps of soybeanin baran district of Rajasthan

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Abstract
The present investigation was conducted to analyse the factors responsible for yield gap in soybean in Baran district of Rajasthan. Baran is a major soybean producing district in the state but the productivity of soybean in average farmer's farm is well below its potential yield. Changes in cropping pattern and crop groups were also analyzed for the period 2001 to 2015. Kendall`s coefficients of concordance was estimated for analyzing the change in cropping pattern and tested for their significance. The coefficient of concordance for Baran district was estimated as 0.70 which was significant at 1 per cent level of significance. Share of cash crops has increased overtime and it became almost half of total gross cropped area, while share of pulse crop group decreased.
For analyzing the yield gaps in soybean and its decomposition, primary data for the year 2014-15 and 2015-16 were used. Potential yield of whey was taken from (KVK) KrishiVigyan Kendra of that district. Three types of yield gaps were worked out for soybean. Where Gap-I denotes technology gap, Gap- II denotes package of practice gap and Gap- III gives resource constraint gap. Decomposition of yield gap was done with the Bisaliah (1977) model of decomposition. The gap between average farmer's farm and best farmer's farm was 65.37 percent. During decomposition of various factors level of input use contributed 180.68 per cent turn out to be the major contributor.

Keywords: Cropping pattern, kendall`s coefficients, value productivity and gross cropped area

Introduction
The agricultural land devoted to different crops in a region or state or country at a particular point of time is called as the cropping pattern. The growth of population leads to change in land use and cropping pattern. (Vinod kumar; 2016) [17] Features of changing crop-pattern in India are the dominance of food crops over non-food crops. At the time of independence, more than 75 per cent of the total area sown in the country was devoted to the production of food crops. Gradually with commercialization of agriculture, farmers in India have started shifting area to non-food crops. Relative share of area under food crops has declined from 76.7% during 1950-51 to 62.85% during 2013-2014. This trend shows commercialization of agriculture in India. Climate-rainfall, temperature, humidity; soils, size of farms, availability of fertilizer, good quality of seeds, irrigation facilities and price incentives are the factors which effect cropping patterns. (Agriculture statistics at a glance 2014) [1]
India's population is expected to reach 1660 million in the year 2050, for which 349 million tonnes of food grains will be required. To meet this requirement, there is a need to double the productivity of agricultural crops from the existing level. Yield gapis calculated by subtracting achieved average yield from the yield potential (Lobell *et al*., 2009) [11]. Understanding yield gap is very crucial as it can assist in crop yield predictions, since yield potential shows the probable future productivity to be achieved. Also, information on determinants of yield gap can be used in policy interventions for enhancing crop production. Conventionally, yield potential is measured by simulation model of plant metabolic activities which produce the likely highest yield (Gommes, 2006; Lobell *et al.*, 2009) [11]. According to Lobell *et al.* (2009) [11], the "model" yield gap (YG_M), "experimental" yield gap (YG_E), and "farmer" yield gap (YG_F) are linked as follows: $YG_F \leq YG_E \leq YG_M$. YG_F can be smaller compared to YG_E as well as YG_M. Technological and input use differentials, which together contributed to the total productivity difference of crop. (Basavraj *et al*; 1990) [4]

Methodology

To assess the changes in cropping pattern over the years in Baran district, Kendall`s coefficients of concordance was estimated and tested for their significance. The analysis was done for major crops covering 90 percent area under cultivation in Baran district in Rajasthan. To measure the cropping pattern index, the value productivity per hectare in the Baran district was worked out for last 15 years. Finally to assess the position of a district in comparison to the state in terms of value productivity, the cropping pattern index was worked out by using the following formula:

$$CIj = \frac{\sum_{i=1}(a_{ij} Y_i P_i)}{\sum_{i=1} a_{ij}} \times \frac{\sum_{i=1}(A_i)}{\sum_{i=1}(A_i Y_i P_i)}$$

Where

CI_j= Cropping pattern index for the j^{th} district

a_{ij}= Area under the i^{th} crop in the j^{th} district, Y_i= State average yield of the i^{th} crop

P_i= State average price of the i^{th} crop, A_i = State average area under the i^{th} crop

Kendall`s coefficient of concordance

Kendall`s coefficient of concordance is an important non parametric measure of relationship. It was used in the study for determining the degree of association among ranking of area under crops in different years. For this purpose, the underlying hypothesis were as follows:

H_o: There is no significant agreement among the ranking of area under crops in different years.

H_1: There is a significant agreement among the ranking of area under crops in different years.

To observe the changes in cropping pattern, Kendall`s coefficient of concordance was worked out after calculating the ranks of different crops over time by using the following formula. (Sidney Siegel, OP. Cit, pp.229-238)

$$W = \frac{\sum_{i=1}^{M}(\bar{X} - X_i)2}{\frac{1}{12} m^2(n^3 - n) - m \sum_T T}$$

Where,

W= Coefficient of concordance, n =Number of crops

m = Number of years, x_i = Total of ranks over years for i^{th} crop

$$\bar{X} = \frac{m(n+1)}{2}$$

T = correction factor which is equal to

$$\frac{\sum(t^3 - t)}{12}$$

Where t =number of observations in a group tied at a given rank and indicates the sum over all groups of ties with in any one of the m ranking.

The significance of W was observed by finding out χ^2 defined as,

χ^2= m (n-1) W with n-1 degrees of freedom.

This technique was used by Marjanabeegum, K.K (2014) [12] for Temporal and Spatial analysis of cropping pattern in Kerala.

For analyzing yield gaps and its decomposition, data for the year 2014-15 and 2015-16 were used. For yield gap analysis primary data was used. From KVK, Baran district and farmer's fields.

Yield gap analysis

Three types of yield gaps, as detailed below were worked out for selected crops of different crop groups. Where Gap-I denotes technology gap, Gap- II denotes package of practice gap and Gap- III gives resource constraint gap.

i) Gap- (I) = $Y_R - Y_D$…………(i)

ii) Gap- (II)= Y_D- Y_B…………(ii)

iii) Gap- (III) = Y_B-Y_A……….....(iii)

Total Gap Y_T= Gap- (I) +Gap- (II) +Gap- (III)=Y_R-Y_A .. (iv)

Where,

Y_R = yields at research station

Y_D= yields at demonstration plot

Y_B= yields at best farmers field

Y_A= yield at average farmers field.

Decomposition of sources of yield gaps

Log (Y_2/Y_1) = To examine the decomposition of yield gap between Research /KVK farms and average farmers farm for soybean Bisaliah (1977) [6] model of decomposition was used. The following functional form was specified:

[log (bo/ao)] + [(b1-a1) log S1 + (b2 - a2) log F1 + (b3 – a3) log M1 + (b4 -a4) log H1+ (b5 - a5) log B1+ (b6 - a6) log Ma 1+ (b7– a7) log I7 + (b8– a8) log Ir8] + [b1 log (S2/ S1)+ b2 log (F2/F1) + b3 log (M2/M1) + b4 log (H2/H1)+b5 log (B2/B1)+ b6 log (Ma2/Ma1)+ b7 log (I2/I1) + b8 log (Ir2/Ir1)] + [U2-U1] Equation (1)

Y_2 and Y_1 = Output of main produce (Q/ha),

b_o = Constant of research farm

a_o = Constant of average farm, b_1 to b_8 = Elasticities of research farm production

a_1 to a_8 = Elasticities of average farm production,

S_1 & S_2 = Seed (kg/ha) on research farm and average farm, respectively

F_1 & F_2= Fertilizer (kg/ha) on research farm and average farm, respectively

M_1 & M_2 = Manure (kg/ha) on research farm and average farm, respectively

H_1 & H_2 = Human labour (hrs.) on research farm and average farm, respectively

B_1 & B_2 = Bullock labour (Pair hrs.) on research farm and average farm, respectively

Ma_1 & Ma_2 = Machine labour (Rs.) on research farm and average farm, respectively

I_1 &I_2= Insecticide charges (Rs.) on research farm and average farm, respectively

Ir_1 & Ir_2 = Irrigation charges (Rs.) on research farm and average farm, respectively

U_1 & U_2= Error term on research farm and average farm, respectively

Equation (1) was used for decomposing the yield gap. The summation of 1^{st} and 2^{nd}terms in square bracket on the right hand side represented the yield gap, attributable to the difference in the cultural practices. The 3^{rd} term represented the yield gap attributable to the difference in the input use (Input gaps) between Research /KVK farms and Average farmers farm. The last term represented the random disturbance.

Results and Discussion

Cropping intensity and seasonal pattern

Total reporting area of district was 6,99,461 hectares and net sown area was 3,46,005 hectares in TE 2015.Which showed 26.40 per cent change in the net sown area between TE 2003 and TE 2015. The gross irrigated area of district has increased at a compound growth rate of 4.13 per cent per annum for the year 2001-2015 and showed 58.34 per cent change in gross irrigated area from TE 2003.Thus increase in gross irrigated area of the district resulted in increase in gross cropped area at a 2.79 per cent per annum for the year 2001-2015. The cropping intensity in the district has increased from 139.92 per cent in TE 2003 to 155.68 per cent in TE 2015. Due to government efforts and schemes this district becomes one of the developed district of Rajasthan as the average productivity has increased.

Kendall's coefficient of concordance

The coefficient of concordance for Baran district was estimated as 0.70 and Chi square (χ^2) value 105.08 which was significant at 1 per cent level of significance. High significance of coefficient revealed shifting of cropping pattern in the entire period. This means cropping pattern of district has changed significantly during the study period. Cropping pattern was mainly influenced by physical, economic, technological and institutional factors such as capital and market location and price of the crop at harvest time.

Table 1: Changes in net sown area, gross cropped area, gross irrigated area and cropping intensity in Baran district (Area in hectares)

Particulars	TE 2003	TE 2105	Per cent Change	Compound Growth Rate
Reporting Area (RA)	381417	699461	83.31	3.97
Net Sown Area (NSA)	273726	346005	26.40	1.62
Gross Cropped Area (GCA)	382988	538661	40.64	2.79
Gross Irrigated area (GIA)	216992	343549	58.32	4.13
Cropping Intensity (%)	139.92	155.68	11.26	1.14

***Source* –** Rajasthan agriculture statistics at a glance 2001 to 2003 and 2013 to 2015.

Growth and relative share

Table 2 depicts the growth and changes in area under major crop groups in the district. In the study period area under oilseed crops have increased in absolute terms showing a growth of 77.87 per cent between TE 2003 and TE 2015.The share of oilseed crops which was 46.24 per cent of gross cropped area in TE 2003 has increased to 58.48 per cent in TE 2015 which was more than half of gross cropped area. The relative share of cereals has increased by 8.76 per cent compound growth rate per annum for the year 2001 to 2015 as their share remains almost stable in gross cropped area of district between TE 2003 and TE 2015. Though the relative share of cash crop was 19.16 per cent of gross cropped area in TE 2003 which decreased to 11.25 per cent in TE 2015 with -1.21 compound growth rate per annum for the year 2001-2015. Area under pulse crop showed increase in area in absolute term between TE 2003 and TE 2015 but relative share of pulse crop in gross cropped area has decreased to 3.31 per cent during TE 2015.

Table 2: Changes in area under major crop groups in Baran district (Area in hectares)

Crop Groups	TE 2003	TE 2015	Per Cent Change	Compound Growth Rate	Increased or Decreased
Cereals	73257 (19.13)	99907 (18.55)	36.38	8.76	(+)
Pulses	14160 (3.70)	17841 (3.31)	26.00	5.66	(+)
Oilseeds	177099 (46.24)	315013 (58.48)	77.87	3.94	(+)
Cash crops	73391 (19.16)	60578 (11.25)	-17.46	-1.21	(-)
Others	45081 (11.77)	45322 (8.41)	0.53	4.04	(+)
Gross Cropped Area	382988 (100)	538661 (100)	40.64	2.79	**(+)**

Figures in the parentheses are the percentages of gross cropped area.

Area under major crops

The results for share of individual crops in the district are presented in Table 3. In TE 2003 highest share of gross cropped area was under soybean (25.76 per cent) and its share has increased to 43.56 per cent of gross cropped area in TE 2015. In TE 2015 maximum share of gross cropped area i.e. almost half was under soybean crop. Soybean crop showed compound growth rate 7.47 per cent per annum for the year 2001-2015 with 137.79 per cent growth between TE 2003 to TE 2015. Garlic crop showed highest compound growth rate of 18.04 per cent per annum with 416.16 per cent growth in the study period. The relative share of urad showed minor increase in cropped area between TE 2003 and TE 2015. The relative share of maize showed decrease in area from 8.11 per cent in TE 2003 to 1.47 per cent in TE 2015. The relative share of rice showed increase in cropped area from 0.71 in TE 2003 to 2.25 in TE 2015.Thus relative share of traditional crops in cropping pattern of district has been replaced by oilseed crops like soybean during the study period and reason behind this was better prices and export opportunities after processing and high yielding varities. These results provide evidence to conclude that maize, rapeseed and mustard, gram and coriander are being replaced by garlic, wheat, rice, soybean and urad in the district.

Table 3: Changes in area under major crops in Baran district (Area in hectares)

Crops	TE 2003	TE 2015	Per Cent Change	Compound Growth Rate	Increased or Decreased
Rice	2739 (0.71)	12118 (2.25)	342.47	13.97	(+)
Maize	31090 (8.11)	7933 (1.47)	-74.48	-10.33	(-)
Urad	3700 (0.96)	9590 (1.78)	159.20	11.27	(+)

Soybean	98676 (25.76)	234641 (43.56)	137.79	7.47	(+)
Wheat	39428 (10.29)	79856 (14.82)	102.54	13.50	(+)
Gram	10460 (2.73)	8251 (1.53)	-21.12	-1.42	(-)
Rapeseed& mustard	78423 (20.47)	80371 (14.92)	2.48	1.03	(+)
Corriander	70211 (18.33)	44169 (8.20)	-37.09	-0.74	(-)
Garlic	3179 (0.83)	16409 (3.05)	416.16	18.04	(+)
Other	45081 (11.77)	45322 (8.41)	0.53	4.04	(+)
Gross Cropped Area	382988 (100)	538661 (100)	40.64	2.79	**(+)**

Figures in the parentheses are the percentages of gross cropped area.

Value productivity of crop-mix

The average value productivity per hectare from all the ten crops grown in the district was calculated for each of the last 15 years.

The value productivity of the district has increased from Rs.9442 per hectare in 2001 to 2005 to Rs.43872 per hectare in 2011 to 2015 and cropping pattern index of the district was 0.97 in 2001-05 and it was 1.01 during the period 2011-15. Though the area under cash crops group in this district was decreasing at the same time value productivity of the district was increased during the study period. This increase in average value productivity of the district was because of increase in area of cereal crops like wheat (13.50 per cent) and rice (13.97 per cent) compound growth rate, yield levels of above crops and also by rise in prices of output of these crops during the study period.

Yield gaps in soybean

The analysis of yield gap in soybean was done for Baran district as this district is having the highest area under soybean crop in Rajasthan. Research plot was conducted at Krishi Vigyan Kendra, Baran. The Yield gap between potential yields and existing yields in the district as shown in Table 4. The average potential yield of soybean on research farms (Y_R) in Baran district was 1618 kg/ha during the study period. There was considerable gap between yield of best farmers and average farmers yield in both the years. The average yield at demonstration plot (Y_D) was 10.09 per cent (Gap I) and average yield at best farmers field (Y_B) was 18.26 per cent (Gap- II) of the yield obtained at research farm. On percentage basis these figures are presented in Fig.16.These gaps were due to difference in soil and climatic condition and management factors. There was considerable gap between yield of demonstration plot and best farmers yield in the both the years. The average farmers average yield was 760.50 kg per hectare in Baran district during the study period which was 24.31 per cent (Gap III) lower than the best farmer and 52.65 per cent lower than the research farm. Thus a total gap more than 50 per cent existed between average yield of soybean and its potential yield. The technology for soybean includes field preparation, suitable high yielding variety, timely sowing with treated seeds, timely irrigation, fertilizers use, and use of plant protection measures. So efforts should be made towards increased awareness among the farmers about advanced technologies like timely irrigation, fertilizer application etc. To minimize the yield gap between research farm and average farm there should be increased extension activities, awareness of farmers regarding new improved technology adoption. Thus ultimate potential yield of soybean crop was yet to be demonstrated under farmer's fields. With proper extension efforts yield of soybean in Baran district could be increased by 128.81 per cent.

Table 4: Yield gaps in soybean crop in Baran district of Rajasthan (2014-16)

Particulars	2014-15	2015-16	Average
1. Average Yield levels (kg / ha)			
a) Research Farms (Y_R)	1576	1660	1618.0
b) Demonstration Plots (Y_D)	1389	1522	1455.5
c) Best Farmers Field (Y_B)	1066	1256	1161.0
d) Average Farmers Field (Y_A)	953	568	760.5
2. Yield Gap (kg / ha)			
Gap -(I) $Y_R - Y_D$	187(30)	138(13)	162.5(21.50)
Gap -(II) $Y_D – Y_B$	323(52)	266(24)	294.5(38)
Gap -(III) $Y_B - Y_A$	113(18)	688(63)	400.5(40.50)
Total	623(100)	1092(100)	857.5(100)
3. Yield Gap (% of Y_R)			
Gap -(I) $Y_R - Y_D$	11.86	8.31	10.09
Gap -(II) $Y_D – Y_B$	20.49	16.02	18.26
Gap -(III) $Y_B - Y_A$	7.17	41.44	24.31
Total	39.52	65.77	52.65
4. Yield Gap (% of Y_A)			
Gap- (I) $Y_R - Y_D$	19.62	24.30	21.96
Gap- (II) $Y_D – Y_B$	33.89	46.83	40.36
Gap-(III) $Y_B - Y_A$	11.86	121.13	66.49
Total	65.37	192.25	128.81

Figures in parenthesis indicates percentage to total yield gap

Geometric mean levels of inputs use in soybean

The mean level of all the important inputs used on research/KVK plots was optimum, compared to that used on the sample farms as the cultivation on research farm was carried out as per the recommended package of practices, so it was considered as the optimum input use for the potential yield. On average farmers farm seed rate was 25 per cent more than recommended seed rate which resulted in increased plant population and competition for nutrient and water in plants resulted in low yield. Quantity of seed used was higher in average farms (97.61 Kg) than research/KVK farms (75.29 Kg). Use of optimum input was key for achieving potential yield on average farmer's farm.

Table 5: Geometric mean levels of inputs use in soybean crop per hectare

S. No.	Variables	Avg. Farmers Farm	Research/KVK Farm
1	Seed (kg) X_1	97.61	75.29
2	Human Labour (hrs.) X_4	356.30	283.01
3	Bullock Labour (Pair hrs.) X_5	9.75	18.00
4	Machine labour (Rs)X_6	2011.23	2202.89
5	Insecticide (Rs) X_7	140.00	699.23
6	Irrigation (Rs)X_8	29.51	305.88

Decomposition of sources of yield gap of soybean between research/KVK farms and average farmers farm

Productivity difference between research farm and farmers field can be attributed to different sources. Change in productivity could be better explained by changes in the parameters which define the production process. With the advancement of technology the output increases but the increase in output cannot be solely attributed to technological change. It may be due to technology change or may be due to use of higher input only. To understand the reason of yield gap on average farmers farm it is imperative to know the contribution of factors responsible for productivity difference. The yield gap between research/KVK farm and average farmers farm for soybean was to the tune of 191.51 per cent whose decomposition was done to know the sources of this yield gap (Table 6).

Table 6: Decomposition of yield gap of soybean between research/KVK farms and average farmers farm

S. No.	Sources of difference	Difference (%)
1	Yield	191.51
2	Cultivation Practices	10.83
3	Level of input use	180.68
	i) Seed (kg) X_1	-11.27
	ii) Human Labour (hrs.) X_4	-10.00
	iii) Bullock Labour (Pair hrs.) X_5	26.62
	iv) Machine labour (Rs)X_6	3.95
	v) Insecticide (Rs) X_7	69.84
	vi) Irrigation (Rs)X_8	101.54

In decomposition of various factors of yield gap in soybean, level of input use (180.68 %) turned out to be the major contributor. Without incurring extra expenditure on required inputs, only by adopting the recommended cultivation practices, the yield can be increased by 10.83 per cent on average farmer's farm. The appropriate usage of inputs can reduce the yield gap between research/KVK farms and average farmers farm to the extent of 180.68 per cent. Use of extra seed and human labour on average farmer's farm resulted in low yield of soybean. Also minimum use of insecticide and irrigation than the recommended practices on average farmer's farm gave low yield of soybean to the farmers. The total yield gap between average farm and research farm was found 191.51 per cent i.e. yield at research farm was 191.51 per cent more than the average farmers farm. Hence, recommended practices should be used on average farm for bridging the yield gap for the soybean production and to achieve potential yield of soybean on average farmer's farm.

Conclusion

Ten major crops grown in the Baran district were ranked according to the area in each year and soybean dominated the ranking. The coefficient of concordance for Baran district was estimated as 0.70 which was significant and showed cropping pattern change. The share of oilseed crops increased to 58.48 per cent in TE 2015 which was more than half of gross cropped area. During study period soybean share has increased to 43.56 per cent of gross cropped area in TE 2015.The value productivity of the district has increased from Rs.9442 per hectare in the year 2001 to 2005 to Rs.43872 per hectare during the period from 2011 to 2015 and cropping pattern index of the district was 0.97 in the year 2001-05 which increased to 1.01 in the year 2011-2015.

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