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# Decomposition analysis of factors contributing to yield gap of moth bean in Churu district of Rajasthan

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**Abstract**
Moth bean yield gap analysis was done for Churu district in Rajasthan. 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. For analyzing the yield gaps in moth bean and its decomposition, primary data for the year 2014-15 and 2015-16 were used. Potential yield of moth bean was taken from (KVK) Krishi Vigyan Kendra of that district. Three types of yield gaps were worked out for moth bean. 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. Total average yield gap percentage was 45.76 per cent during the study period and yield of green gram can be increased by 91.56 per cent to bring it to potential yield level.

**Keywords:** Cropping pattern, Kendall`s coefficients, value productivity and gross cropped area, yield gap, decomposition, elasticity

## Introduction
It is well known that increasing agricultural productivity or yield is critical to economic growth and development. This can be achieved by using improved agricultural technologies and management systems. Yield gap is calculated by subtracting achieved average yield from the yield potential (Lobell *et al.*, 2009) [8]. 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. 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) [8]. According to Lobell *et al.* (2009) [8], 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)

## Methodology
To assess the changes in cropping pattern over the years in Churu 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 Churu district in Rajasthan. To measure the cropping pattern index, the value productivity per hectare in the Churu 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 $\chi^2$ defined as,
$\chi^2$= m (n-1) W with n-1 degrees of freedom.
This technique was used by Marjana beegum KK (2014) 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 Churu 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.
1. Gap- (I) = $Y_R$ –$Y_D$…………. (i)
2. Gap- (II) = $Y_D$- $Y_B$…………. (ii)
3. 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**
To examine the decomposition of yield gap between Research /KVK farms and average farmers farm for Churu Bisaliah (1977) [4] model of decomposition was used. The following functional form was specified:

$$\log (Y_2/Y_1)=$$

[log ($b_o/a_o$) ] + [ ($b_1$-$a_1$) log $S_1$ + ($b_2$ - $a_2$) log $F_1$ + ($b_3$ – $a_3$) log $M_1$ + ($b_4$ -$a_4$) log $H_1$+ ($b_5$ - $a_5$) log $B_1$+ ($b_6$ - $a_6$) log Ma $_1$+ ($b_7$– $a_7$) log $I_7$ + ($b_8$– $a_8$) log $Ir_8$ ] + [ $b_1$ log ($S_2$/ $S_1$)+ $b_2$ log ($F_2/F_1$) + $b_3$ log ($M_2/M_1$) + $b_4$ log (H2/$H_1$)+$b_5$ log ($B_2/B_1$)+ $b_6$ log ($Ma_2/Ma_1$)+ $b_7$ log ($I_2/I_1$) + $b_8$ log (Ir $_2$/$Ir_1$) ] + [ $U_2$-$U_1$ ] 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**
Total reporting area of district was 18,85,903 hectares and net sown area was 11,51,099 hectares in TE 2015. Which showed 20.49 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 10.93 per cent per annum for the year 2001-2015 and showed 236.84 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 2.56 per cent per annum for the year 2001-2015. The cropping intensity in the district has increased from 107.69 per cent in TE 2003 to 123.34 per cent in TE 2015.

**Table 1:** Changes in Net Sown Area, Gross Cropped Area, Gross Irrigated Area and Cropping Intensity in Churu District (Area in hectares)

| Particulars | TE 2003 | TE 2015 | Per Cent Change | Compound Growth Rate |
|---|---|---|---|---|
| Reporting Area (RA) | 1277332 | 1385903 | 8.50 | 0.50 |
| Net Sown Area (NSA) | 955341 | 1151099 | 20.49 | 1.54 |
| Gross Cropped Area (GCA) | 1028854 | 1419737 | 37.99 | 2.56 |
| Gross Irrigated Area(GIA) | 55369 | 186505 | 236.84 | 10.93 |
| Cropping Intensity (%) | 107.69 | 123.34 | 14.52 | 1.00 |

***Source*:** Rajasthan Agriculture Statistics at a Glance 2001 to 2003 and 2013 to 2015.

## Growth and Relative Share

**Table 2:** Changes in Area under Major Crop Groups in Churu District (Area in hectares)

| Crop Groups | TE 2003 | TE 2015 | Per Cent Change | Compound Growth Rate | Increased or Decreased |
|---|---|---|---|---|---|
| Cereals | 422570 (41.07) | 337954 (23.80) | -20.02 | -1.86 | (-) |
| Pulses | 296095 (28.78) | 487127 (34.31) | 64.52 | 3.80 | (+) |
| Oilseeds | 24991 (2.43) | 83939 (5.91) | 235.88 | 9.84 | (+) |
| Cash crops | 267204 (25.97) | 491426 (34.61) | 83.91 | 4.57 | (+) |
| Others | 18001 (1.75) | 19291 (1.36) | 7.17 | 11.90 | (+) |
| Gross Cropped Area | 1028861 (100) | 1419737 (100) | 37.99 | 2.56 | **(+)** |

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

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 235.88 per cent between TE 2003 and TE 2015.The share of oilseed crops which was 2.43 per cent of gross cropped area in TE 2003 has increased to 5.91 per cent in TE 2015. The relative share of cereals has decreased by -1.86 compound growth per annum rate for the year 2001-2015 as their share declines from 41.07 to 23.80 per cent in gross cropped area of district between TE 2003 and TE 2015. Though the relative share of cash crop was 25.97 per cent of gross cropped area in TE 2003 which increased to 34.61 per cent in TE 2015 with 4.57 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 and also relative share of pulse crop in gross cropped area has increased from 28.78 to 34.31 per cent during study period.

## Area under Major Crops

**Table 3:** Changes in Area under Major Crops in Churu District (Area in hectare)

| Crops | TE 2003 | TE 2015 | Per Cent Change | Compound Growth Rate | Increased or Decreased |
|---|---|---|---|---|---|
| Pearl millet | 411016 (39.95) | 305187 (21.50) | -25.75 | -2.47 | (-) |
| Green gram | 40369 (3.92) | 54546 (3.84) | 35.12 | 2.33 | (+) |
| Moth bean | 199365 (19.38) | 192400 (13.55) | -3.49 | -1.62 | (-) |
| Groundnut | 6925 (0.67) | 46514 (3.28) | 571.71 | 16.84 | (+) |
| Cluster bean | 264354 (25.69) | 479333 (33.76) | 81.32 | 4.34 | (+) |
| Wheat | 11554 (1.12) | 32767 (2.31) | 183.61 | 9.22 | (+) |
| Gram | 56361 (5.47) | 240180 (16.92) | 326.15 | 9.76 | (+) |
| Rapeseed & mustard | 18067 (1.75) | 37425 (2.64) | 107.15 | 5.02 | (+) |
| Methi | 2850. (0.28) | 12103 (0.85) | 324.67 | 16.53 | (+) |
| Other | 18001 (1.75) | 19291 (1.36) | 7.17 | 11.90 | (+) |
| Gross Cropped Area | 1028861 (100) | 1419737 (100) | 37.99 | 2.56 | (+) |

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

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 pearl millet (39.95 per cent) and its share has decreased to 21.50 per cent of gross cropped area in TE 2015. In TE 2015 maximum share of gross cropped area was under cluster bean crop. Cluster bean crop showed compound growth rate 4.34 per cent per annum for the year 2001-2015 with 81.32 per cent growth during the study period. Groundnut crop showed highest compound growth rate of 16.84 per cent per annum with 571.71 per cent growth in TE 2015. The relative share of rapeseed and mustard showed minor increase in cropped area between TE 2003 and TE 2015. The relative share of moth bean showed decrease in area from 19.38 per cent in TE 2003 to 13.55 per cent in TE 2015. The relative share of wheat showed increase in cropped area from 1.12 in TE 2003 to 2.31 in TE 2015. The growth in absolute and relative share in gross cropped area of the district was reported by gram crop with 326.15 per cent growth per annum with compound growth rate of 9.76 per cent per annum for the year 2001-2015. Thus relative share of traditional crops like pearl millet in cropping pattern of district has been replaced by oilseed crops like groundnut, cash crop like cluster bean during the study period and reason behind this was better prices and export opportunities after processing and high yielding verities. These results provide evidence to conclude that pearl millet, moth bean are being replaced by groundnut and cluster bean in the district.

## Value Productivity of Crop-mix

The average value productivity of the district has increased from Rs.1401 per hectare in 2001 to 2005 to Rs.13470 per hectare in the year 2011-15 and cropping pattern index of the district was 0.56 in 2001-05 and it was 0.75 during the period 2011-15. This increase in average value productivity was because of increase in yield levels and by rise in prices of output.

**Table 4:** Yield Gaps in Moth bean Crop in Churu District of Rajasthan (2014-16)

| Particulars | 2014-15 | 2015-16 | Average |
|---|---|---|---|
| **1. Average Yield levels (kg / ha)** | | | |
| a) Research Farms ($Y_R$) | 623 | 665 | 644 |
| b) Demonstration Plots ($Y_D$) | 589 | 595 | 592 |
| c) Best Farmers Field ($Y_B$) | 526 | 468 | 497 |
| d) Average Farmers Field ($Y_A$) | 403 | 291 | 347 |
| **2. Yield Gap (kg / ha)** | | | |
| Gap- (I) $Y_R$ - $Y_D$ | 34(15) | 70(19) | 52(17.00) |
| Gap- (II) $Y_D$ – $Y_B$ | 63(29) | 127(34) | 95(31.50) |
| Gap -(III) $Y_B$- $Y_A$ | 123(56) | 177(47) | 150(51.50) |
| **Total** | 220(100) | 374(100) | 297(100) |
| **3. Yield Gap (% of $Y_R$)** | | | |
| Gap- (I) $Y_R$ - $Y_D$ | 5.45 | 10.52 | 7.98 |
| Gap -(II) $Y_D$ – $Y_B$ | 10.11 | 19.09 | 14.6 |
| Gap -(III) $Y_B$- $Y_A$ | 19.74 | 26.61 | 23.17 |
| **Total** | 35.30 | 56.22 | 45.76 |
| **4. Yield Gap (% of $Y_A$)** | | | |
| Gap -(I) $Y_R$ - $Y_D$ | 8.44 | 24.05 | 16.25 |
| Gap- (II) $Y_D$ – $Y_B$ | 15.63 | 43.64 | 29.64 |
| Gap -(III) $Y_B$- $Y_A$ | 30.52 | 60.82 | 45.67 |
| **Total** | 54.59 | 128.52 | 91.56 |

Figures in parenthesis indicates percentage to total yield gap

The analysis was done for Churu district as the Churu district is having the highest area under moth bean crop in Rajasthan. Research experiments were conducted at Krishi Vigyan Kendra, Churu. The gap between potential yields and existing yields in the district are shown in Table 4. The average potential yield of moth bean on research farms ($Y_R$) in Churu district was 644 kg/ha during the study period. The average yield at demonstration plot ($Y_D$) was approximately 7.98 per cent lower than the research farm, while average yield at best farmers field ($Y_B$) was 14.60 per cent lower than yield at research farm plot. There was considerable gap between yield of best farmers and average farmers yield in the both the years. The average farmer's yield was 347 kg per hectare in Churu district between 2014 to16 respectively which is 45.76 per cent lower than the potential yield. The Yield gap (Gap-I) between research farm and demonstration farm was more in 2015-16 (70 kg/ha). On percentage basis these figures are presented in Fig.19. This may be due to climatic condition for that particular year. At average farmers field this crop is mostly grown unirrigated while at research farm and demonstration farms recommended number of irrigation were given. The gap between best farmer and demonstrated yield was only 14.6 per cent because of adoption of the technological package and management practices. The technological package for this crop includes better varieties, fertilizers, pesticides and timely sowing with these package of practices the yield of moth bean can be improved upto 91.56 per cent. Usually the moth bean crop is sown if the commencement of rains is delayed beyond third week of July. If there are timely rains, farmers prefer to sow pearl millet, green gram and cowpea.

## Geometric Mean Levels of Inputs Use in Moth Bean

The geometric mean levels of inputs used are presented in Table 5. The results presented in the table revealed that use of seed rate on average farmers' farm was less than recommended seed rate which resulted in less plant population than optimum plant population required. Quantity of seed used was less than recommended dose in average farms (15.17 Kg) than research/KVK farms (18.82 Kg) which was as per recommended package of practices under the controlled condition. Use of other inputs like manure, human labour, machine labour and lifesaving irrigation applied was far less than the recommended dose which was used on research farm which resulted in increasing yield gap and caused difficulty in achieving potential yield.

**Table 5:** Geometric Mean Levels of Inputs Use in Moth Bean Crop per Hectare

| S. No. | Variables | Avg. Farmers Farm | Research/KVK Farm |
|---|---|---|---|
| 1 | Seed (kg) $X_1$ | 15.17 | 18.62 |
| 2 | Manure (kg) $X_3$ | 616.45 | 1342.86 |
| 3 | Human Labour (hrs.) $X_4$ | 182.22 | 300.14 |
| 4 | Machine labour (Rs)$X_6$ | 583.41 | 882.34 |
| 5 | Irrigation (Rs)$X_8$ | 145.12 | 214.25 |

## Decomposition of Sources of Yield Gap of Moth Bean between Research/KVK Farms and Average Farmers Farm

In this study yield gap was decomposed using the Bisaliah (1977) [4] model of output decomposition. In the present study, the yield gap between research/KVK farm and average farmers farm was to the tune of 85.04 per cent. (Table 6)

**Table 6:** Decomposition of Yield Gap of Moth bean between Research/KVK Farms and Average Farmers Farm

| S. No. | Sources of Difference | Difference (%) |
|---|---|---|
| 1 | Yield | 85.04 |
| 2 | Cultivation Practices | -14.19 |
| 3 | Level of input use | 99.23 |
| | i) Seed (kg) $X_1$ | 8.88 |
| | ii) Manure (kg) $X_3$ | 33.81 |
| | iii) Human Labour (hrs.) $X_4$ | 21.67 |
| | iv) Machine labour (Rs)$X_6$ | 17.96 |
| | v) Irrigation (Rs)$X_8$ | 16.91 |

In decomposition process of moth bean among the sources of yield gap, level of input use (99.23%) turned out to be the major contributor for increasing yield gap. Thus, in this crop intensive cultural practices (-14.19 per cent) were carried out on average farmers farm which was not as per recommended package of practices, which resulted in increased costs on cultural practices. The appropriate usage of inputs can reduce the yield gap between research/KVK farms and average farmers farm to the extent of 99.23 per cent. Which was mainly due to less use of inputs like seed, manure, human labour, machine labour and lifesaving irrigation than the recommended dose followed on the research farm and resulted in achieving potential yield. The total yield gap between average farm and research farm was found 85.04 per cent i.e. yield at research farm is 85.04 per cent more than the average farm.

## Conclusion

Ten major crops cultivated in Churu district when it ranked according to the area in each year, crops like cluster bean maintained its ranking and gram and pearl millet have decreased in their rankings in respect to area under cultivation in the district overtime. The coefficient of concordance for Churu district was estimated as 0.68 which was significant at 1 per cent level of significance. Cash crop share in the district was increased to 34.61 per cent in TE 2015 with 4.57 per cent compound growth rate per annum. Groundnut crop showed highest compound growth rate of 16.84 per cent per annum with 571.71 per cent growth in TE 2015. Average value productivity of the district has increased from Rs.1401 per hectare in 2001 to 2005 to Rs.13470 per hectare in the year 2011-15 and cropping pattern index of the district was 0.56 in 2001-05 which increased to 0.75 in 2011-2015.

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