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Introduction

Abstract

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)

Decomposition analysis of factors contributing to

yield gap of wheat in Ganganagar district of

Rajasthan

The present investigation was conducted to analyse the factors responsible for yield gap in wheat in

Ganganagar district of Rajasthan. Ganganagar is a major wheat producing district in the state but the

productivity of wheat 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 Ganganagar district was estimated as 0.50 which was significant at 1

per cent level of significance. Share of cash crops has increased overtime and it became almost half of

For analyzing the yield gaps in wheat and its decomposition, primary data for the year 2014-15 and 2015-16 were used. Potential yield of wheat was taken from (KVK) Krishi Vigyan Kendra of that district. Three types of yield gaps were worked out for wheat. 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 11 percent. During decomposition of various factors Cultural practices

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 gap is 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 Ganganagar district, Kendall's coefficients of concordance was estimated and tested for their significance.

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The analysis was done for major crops covering 90 percent area under cultivation in Ganganagar district in Rajasthan. To measure the cropping pattern index, the value productivity per hectare in the Ganganagar 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:

$$CIj = \frac{\sum_{i=1}^{i} (a_{ij}Y_iP_i)}{\sum_{i=1}^{i} a_{ij}} \times \frac{\sum_{i=1}^{i} (A_i)}{\sum_{i=1}^{i} (A_iY_iP_i)}$$

Where

CI_i= Cropping pattern index for the jth district

 a_{ij} = Area under the ith crop in the jth district, Y_i = State average yield of the ith crop

 P_i = State average price of the ith crop, A_i = State average area under the ith 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:

 $H_{\mbox{\scriptsize o}}$. 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 ith 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,

 $\chi^2 = m$ (n-1) W with n-1 degrees of freedom.

This technique was used by Marjana beegum, 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, Ganganagar 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.

Ecom-position 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 wheat Bisaliah (1977) ^[6] model of decomposition was used. The following functional form was specified:

 $[log (b_0/a_0)] + [(b_1-a_1) log S_1 + (b_2 - a_2) log F_1 + (b_3 - a_3) log M_1 + (b_4 - a_4) log H_1 + (b_5 - a_5) log B_1 + (b_6 - a_6) log M_1 + (b_7 - a_7) log I_7 + (b_8 - a_8) log I_{R_3}] + [b_1 log (S_2/S_1) + b_2 log (F_2/F_1) + b_3 log (M_2/M_1) + b_4 log (H_2/H_1) + b_5 log (B_2/B_1) + b_6 log (M_{a_2}/M_{a_1}) + b_7 log (I_2/I_1) + b_8 log (Ir _2/Ir_1)] + [U_2-U_1] Equation (1)$

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

 b_0 = Constant of research farm

 a_0 = 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 & Ma₂ = Machine labour (Rs.) on research farm and average farm, respectively

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

 $I_1 \& I_2 = Insecticide charges (Rs.) on research farm and average farm, respectively$ $Ir <math>_1 \& Ir_2 = Irrigation charges (Rs.) on research farm and average farm, respectively$

II [CII 2 – IIIIgation charges (KS.) on research farm and eveness form, 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 Ganganagar district was 1093 thousand hectares and net sown area was 784 thousand hectares in TE 2015 (Table 1). Net sown area showed 21.54 per cent change over TE 2003. The gross irrigated area of the district increased at a compound growth rate of 2.99 per cent per annum and showed 42.92 per cent change over TE 2003.

Gross cropped area has increased at 2.86 per cent per annum. The cropping intensity in the district has increased from 137.90 per cent in TE 2003 to 159.06 per cent in TE 2015. Availability of irrigation facilities from canal system, wells and tube wells for the cereal, pulses and oilseed crops throughout the year resulted in increased cropping intensity.

 Table 1: Changes in net sown area, gross cropped area, gross irrigated area and cropping intensity in Ganganagar district (Area in thousand hectare)

Particulars	TE 2003	TE 2015	Per Cent Change	Compound Growth Rate
Reporting Area (RA)	96	1093	13.80	1.01
Net Sown Area (NSA)	645	784	21.54	1.72
Gross Cropped Area (GCA)	890	1247	40.19	2.86
Gross irrigated area (GIA)	7368	1053	42.92	2.99
Cropping Intensity (%)	137.90	159.06	15.34	1.11

Source: Rajasthan agriculture statistics at a glance 2001 to 2003, 2013 To 2015.

Eight major crops covering 90 per cent area grown in the district were ranked according to the area under each crop in each year. Wheat crop was the major cereal crop and maintained its higher crop position throughout the study period. Ganganagar district possessed highest area grown of wheat crop in the state though position of wheat according to area within district was second or third during the last 15 years. During the early period of study period rapeseed and mustard was on first rank and from the year 2012-13 it was seen that cluster bean replaced rapeseed and mustard in the relative area and attained first rank in the Ganganagar district due to its economic importance. Another cereal crop barley also grown on major portion of the GCA of the district and ranked 7th and 8th during the study period. Pulse crops like green gram and gram grown in the district remained at fifth to eighth rank throughout the study period. Oilseed crop rapeseed and mustard was the major crop of the district occupied first rank as per the area under cultivation from 2001 to 2012 but after this period cluster bean replaced this crop and occupied first rank as per the area under cultivation in the district. Cash crops like cotton and cluster bean were cultivated as the major crops in the district and cluster bean crop became first ranked crop in the later part of the study as per the highest area under the cultivation overtime. As per the ranking of crops according area under cultivation, this district has more area under wheat crop than any other district of the state but during last 15 years area under cluster bean has increased tremendously from Seventh rank to First rank showed that shifting trend of cropping pattern of the district.

Kendall's coefficient of concordance: The total change in cropping pattern over the last 15 years was examined by estimating the Kendall's coefficient of concordance (W). The coefficient of concordance for Ganganagar district was estimated as 0.50 and Chi square (χ^2) value as 60.26 which was significant at 1 per cent level of significance. High significance coefficient revealed major shifting of cropping pattern in the entire period.

Changes in cropping pattern and growth and relative share of crop groups

Table 2. Depicts the growth and changes in area under major crop groups in the district. In the study period area under cash crops have increased in absolute terms showing a growth of 103.79 per cent between TE 2003 and TE 2015. The share of cash crops which was 33.39 per cent of gross cropped area in TE 2003 has increased to 48.54 per cent in TE 2015 which was almost half of gross cropped area. The relative share of cereals has increased by 4.62 per cent compound growth rate per annum for the year 2001-2015 as their share remains almost stable in gross cropped area of the district between TE 2003 and TE 2015. Though the relative share of oilseed was 25.13 per cent of gross cropped area in TE 2003 which decreased to 17.34 per cent in TE 2015 with negative(-0.43 % per annum) compound growth rate. 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 during TE 2015. Other crops group comprised of bajra, sesamum, sugar and taramira were decreased with -4.75 per cent compound growth rate during the study period.

Crop Groups	TE 2003	TE 2015	Per Cent Change	Compound Growth Rate	Increased or Decreased
Cereals	190291 (21.39)	318473 (25.53)	67.36	4.62	(+)
Pulses	87077 (9.79)	89250 (7.16)	2.50	2.01	(+)
Oilseeds	223541 (25.13)	216325 (17.34)	-3.23	-0.43	(-)
Cash crops	297082 (33.39)	605416 (48.54)	103.79	6.25	(+)
Other	91694 (10.31)	17801 (1.43)	-80.59	-4.75	(-)
Gross Cropped Area	889685 (100)	1247256 (100)	40.19	2.86	(+)

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

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 rapeseed and mustard (25.13 per cent) but its share has reduced to 17.34 per cent of gross cropped area in TE 2015. In TE 2015 maximum share of gross

cropped area i.e almost half was under cluster bean (43.16 per cent). Cluster bean crop showed highest compound growth rate 15.92 per cent per annum for the year 2001-2015 with 370.59 per cent growth during the study period. Barley crop showed compound growth rate of 14.04 per cent per annum

with 464.20 per cent growth in TE 2015. The relative share of wheat showed minor increase in cropped area between TE 2003 and TE 2015. The relative share of cotton showed decrease in area from 20.53 per cent in TE 2003 to 5.38 per

cent in TE 2015. Thus relative share of traditional crops in the cropping pattern of district has been replaced by cash crops like cluster bean during the study period and reason behind this was better prices and export opportunities after processing.

Pable 3: Changes in area unde	r major crops ir	n Ganganagar district ((Area in hectares)
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Crops	TE 2003	TE 2015	Per Cent Change	Compound Growth Rate	Increased or Decreased
Green gram	8517 (0.96)	21274 (1.71)	149.79	13.35	(+)
Cotton	182684 (20.53)	67067 (5.38)	-63.29	-6.95	(-)
Cluster bean	114399 (12.86)	538349 (43.16)	370.59	15.92	(+)
Wheat	180757 (20.32)	264684 (21.22)	46.43	3.65	(+)
Barley	9534 (1.07)	53789 (4.31)	464.20	14.04	(+)
Gram	78559 (8.83)	67967 (5.45)	-13.48	-0.47	(-)
Rapeseed& mustard	223541 (25.13)	216325 (17.34)	-3.23	-0.43	(-)

Yield gaps in wheat

Wheat is mostly grown as irrigated crop in the state. The analysis was done for Ganganagar district as the Ganganagar district is having the highest area under the wheat crop in Rajasthan. Demonstration plot was conducted at Krishi Vigyan Kendra, Sriganganagar. The potential yield and average yield of wheat as existing in the district as shown in Table 4. The average potential yield of wheat on research farms (Y_R) in Sriganganagar district was 5475 kg/ha during the study period. There was considerable gap between yield of best farmers and average farmers yield in both the years i.e 2014-15 and 2015-16. The average yield gap between research farm (Y_R) and demonstration plot (Y_D) was approximately 16.31 per cent (Gap-I). Average yield at best farmers field (Y_B) was 3.58 per cent lower than yield at research farm plot (Y_R). There was considerable gap between yield of best farmers and average farmers yield in the both the

years. The average farmers yield was 3715 kg per hectare in Ganganagar district during the study period. The total yield gap (Y_T) between research farms and average farmers yield was 35.71 per cent and 27.89 per cent in the year 2014-15 and 2015-16 respectively and average total yield gap was 31.80 per cent during the same period. The lowest yield gap was between best farmers field and demonstration plot (Gap II). This implied that the best farmers adopted the recommended technology for wheat like suitable high yielding variety, timely sowing with treated seeds, timely irrigation, required dose of fertilizers use, field preparation and use of plant protection measures. The average gap between yield of the best farmer and average farmer (Gap-III) was 659.5 kg/ha during the study period which was 11.90 per cent of yield of research farm. With these efforts the yield of wheat can be further increased by 17.86 per cent.

Table 4: Yield gaps in wheat crop in Ganganagar district of Rajasthan (2014-16)

Particulars	2014-15	2015-16	Average
1. Average Yield levels (kg / ha)			
a) Research Farms (Y_R)	5680	5270	5475.0
b) Demonstration Plots (Y _D)	4829	4340	4584.5
c) Best Farmers Field (Y _B)	4529	4220	4374.5
d) Average Farmers Field (Y _A)	3651	3779	3715.0
2. Yield Gap (kg / ha)			
Gap-(I) Y _R - Y _D	851(42)	930(63)	890.5(52.50)
Gap-(II) Y _D -Y _B	300(15)	120(7)	210.0(11.00)
Gap-(III) Y _B - Y _A	878(43)	441(30)	659.5(36.50)
Total	2029(100)	1481(100)	1755.0(100)
3. Yield Gap (% of Y _R)			
Gap- (I) Y _R - Y _D	14.98	17.64	16.31
Gap- (II) $Y_D - Y_B$	5.28	1.89	3.58
Gap- (III) Y _B - Y _A	15.45	8.36	11.90
Total	35.71	27.89	31.8
4. Yield Gap (% of Y _A)			
Gap- (I) Y _R - Y _D	23.31	24.61	23.96
Gap- (II) Y _D -Y _B	8.22	3.18	5.70
Gap- (III) Y _B - Y _A	24.05	11.67	17.86
Total	55.57	39.45	47.51

Figures in parenthesis indicates percentage to total yield gap

Geometric mean levels of input use in wheat: Geometric mean is a mean or average, which indicates the central tendency or typical value of a set of numbers by using the

product of their values as opposed to the arithmetic mean which uses their sum.

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

Sr. No	Variables	Avg. Farmers Farm	Research /KVK Farm
1	Seed (kg) X ₁	152.02	118.33
2	Fertilizer (kg) X ₂	122.14	181.45
3	Human Labour (hrs.) X ₄	503.84	275.92
4	Bullock Labour (Pair hrs.) X ₅	12.66	12.96

5	Machine labour (Rs)X ₆	3471.03	4619.61
6	Irrigation (Rs)X ₈	3241.50	4309.99

The average farmer used seed and human labour in excess of the recommended levels and fertilizer, machine labour and irrigation less than the recommended doses (Table 5). As the cultivation on research farm were carried out as per the recommended package of practices, so it was considered as the optimum input use. The difference in input use level was more pronounced in the case of human labour hours. Quantity of seed used was higher in average farms (152.02 Kg) than research/KVK farms (118.33 Kg).

Decomposition of sources of yield gap of wheat between research/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. In this study yield gap was decomposed using the Bisaliah (1977) ^[6] model of output decomposition. In the present study, the yield gap between research /farm and average farmers farm was to the tune of 31.33 per cent (Table 6).

 Table 6: Decomposition of yield gap of wheat between research/

 KVK farms and average farmers

Sr. No	Sources of difference	Difference (%)
1	Yield	31.33
2	Cultivation Practices	25.39
3	Level of input use	5.94
	i) Seed (kg) X ₁	-10.88
	ii) Fertilizer (kg) X ₂	17.18
	iii) Human Labour (hrs.) X4	-26.15
	iv) Bullock Labour (Pair hrs.) X5	1.01
	v) Machine labour (Rs)X6	12.41
	vi) Irrigation (Rs)X8	12.37

Among other sources of yield gap, cultural practices (25.39 %) turned out to be the major contributor. Thus, without incurring extra expenditure on required inputs, only by adopting the recommended cultivation practices, the yield can be increased by 25.39 per cent in wheat. The appropriate usage of inputs can reduce the yield gap between research/KVK farms and average farmers farm to the extent of 5.94 per cent. Among the inputs use of seed and human labour was more than the recommended practices. On the other hand inputs like fertilizer, irrigation and machine labour should be increased to get the higher yields on average farmer's field. Thus the role of technology regarding how the different cultural practices are being done was more important to fill the yield gap in case of wheat.

Conclusion

In Ganganagar district eight major crops were ranked according to their area during the study period in which wheat, barley showed improvement in area and cotton showed decrease in area. The coefficient of concordance for Ganganagar district was estimated as 0.50 which was significant at 1 per cent level of significance. Share of cash crops increased to become almost half of total gross cropped area while share of Pulse crop group declined. Cluster bean reported highest increase in area cultivated followed by rapeseed and Mustard. The average value productivity of the district has increased from Rs.14925 per hectare in 2001 to 2005 to Rs.45569 per hectare in the year 2011-15. Cropping

pattern index of the district was 0.44 in 2001-05 which increased to 0.79 in 2011-2015. Cluster bean, barley and green gram showed highest increase in the area in the district between TE 2003 and TE 2015. The lowest yield gap was between best farmers field and demonstration plot. The highest yield gap was between demonstration plot and research farm. During decomposition of various factors Cultural practices contributed 25.39 per cent turn out to be the major contributor. Decomposition of sources of yield gap in wheat, cultivation practices and input used contributed to the total yield gap of 31.33 per cent during the study period.

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