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How Does Rainfall Influence Annual Agricultural Growth Rates in India?

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Abstract

In this article, we explore the key factors that influence the annual growth rates in agricultural outputs of India. We find that the percentage difference in annual rainfall from the previous year is a major determinant of the annual agricultural growth rate. The second most important factor is the percentage difference in the irrigated area from the previous year. This hypothesis was also tested for Gujarat which is an agriculturally highly dynamic state experiencing remarkable year to year variation in annual rainfalls and high volatility in annual agricultural outputs.

Key Words: India, Gujarat, Rainfall, Irrigated Area, Agricultural Output

1. Introduction

In India, the practice of predicting agricultural growth rates is as old as its independence. The predictions are made before the onset of monsoon, once the IMD forecasts of the country's rainfall become available. The agricultural growth prediction for the ensuing crop year mainly takes into consideration, whether the rainfall would be normal or above or below normal. Since it is a widely believed fact that agriculture in India is still a 'gamble with monsoon', the short-term (mainly annual) agricultural growth rate is linked to annual rainfall, suggesting a good monsoon would ensure high agricultural growth rate during the year concerned. An extension of this logic was that a low annual growth rate in agriculture sector is attributed to the failure of monsoon during that year. More strangely, an impressive growth rate in agriculture in the medium term is attributed to the high performance of the sector in terms of technology adoption, policy frameworks, and institutional interventions.

But two questions remain unanswered. First: whether it is appropriate to link the performance of the agriculture sector in terms of growth rate to the aggregate predictions of monsoon rainfall in a country like India. Here, the underlying argument is that India has several rainfall zones (IMD itself had defined 36 rainfall zones) the mean annual rainfall in India, varies widely spatially from as low as 200mm in Jaisalmer to as high as 11,000mm in Cherrapunji and therefore large downward deviation of rainfall in one low rainfall region (like the north-western part of India) can be made up by a small upward deviation of rainfall in a high rainfall zone (like the northeast or western Ghats). Second: even if the rainfall does influence agricultural growth rates, how can the average rainfall of a single year alone cause wide year to year fluctuations in the agricultural growth rate noticed in the country?

In the past, the absence of long-term data on (spatial) average annual rainfall made it difficult to develop a more nuanced and empirical understanding of this vexed issue. Now such data are available for a considerably-long time duration from the Indian Meteorological Department. In this article, we first analyzed the historical agricultural growth trends and trends in (spatial) average annual rainfall in India and examined whether any useful inferences on annual agricultural growth rate during a year can be drawn on the basis of the annual rainfall data. Thereafter, we explored the key factors which actually drive short-term agricultural growth rates and drew implications for analyzing the impact of national agricultural policies.

The hypothesis was also tested for Gujarat which is an agriculturally very dynamic state experiencing very significant year to year variations in annual rainfalls and a high volatility in annual agricultural growth performance. Considering the fact that there will be differential effect of a certain degree of departure of annual rainfall from the normal values on agricultural outputs with difference in mean annual rainfall and contribution to the overall agricultural output[1], such analyses become very crucial for regions where the effects of such variations on the trends in agricultural growth rate are likely to be less. Though the state shows regional variation in the magnitude of mean annual rainfall, water resources endowment and irrigation facilities (Kumar and Perry, 2019), these variations are much less as compared to the variations that exist at the national level.

2. Historical Agricultural Growth Trends in India

Following is the analysis of historical growth rates in agricultural GDP of India since 1955-56. The agricultural outputs in value terms grew from INR 1683.61 billion to INR 7645.10 billion[2] in 2012-13 in real terms (Figure 1). The annual agricultural growth rates ranged from -12.77 per cent during 1979-80 to a highest of 15.24 per cent during 1988-89 (Figure 1). The analysis shows that the variation in annual agricultural growth rate is wide. While there had been considerable long-term growth in agricultural outputs in value terms, the outputs had considerably dropped in some years as compared to the previous years. Such drops in agricultural output during a year as compared to the previous year is considered as a result of drought, and any major jump in agricultural output is attributed to a bountiful monsoon received during the year. However, there were no attempts so far to really analyze the influence of rainfall on agricultural growth rate. One reason for this is the lack of availability of long-term data on average spatial rainfall at the country level on an annual basis.

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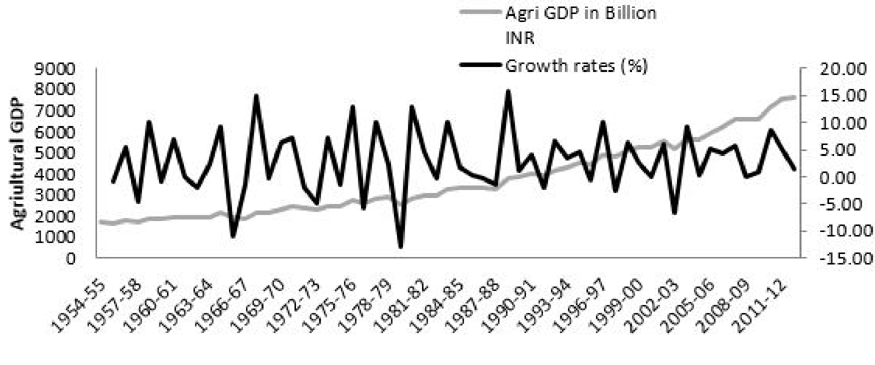
[1] The effect of a 25% decline in annual rainfall from normal value on agricultural output in a region with a mean annual rainfall of 1,600-2,000mm will be much less than that caused by the same degree of departure in a region where the annual rainfall is in the range of 400-500mm and which contributes more significantly to the agricultural output in value terms.

[2] 1USD equals INR 70.

Figure 1: Agricultural GDP and the growth rates in India

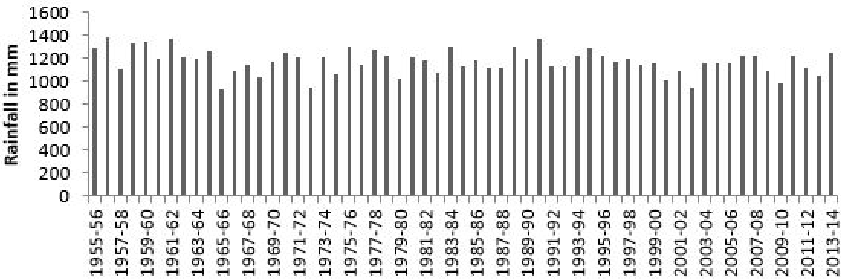


The availability of spatial average of rainfall at the country level as well as divisional level for several years has enabled us to analyze the linkage between the two variables, i.e., rainfall and annual agricultural output growth. As per the IMD estimates, the (spatial) average annual rainfall in India for the period from 1955-56 to 2012-13 ranged from a lowest of 925 mm during 1965-66 to a highest of 1380.5mm during 1956-57 (Figure 2). The mean annual rainfall of the country was estimated to be 1175mm for the 58-year period considered.

Regression analysis of annual average rainfall in different years (expressed as a percentage departure from the mean value) and the annual agricultural growth rates of the country for the corresponding years show a somewhat weak relationship. The R2 value was only 0.31 though significant at five per cent level. Many years with excessively high average rainfall (equal to and above 1300mm) clocked very dismal agricultural performance in terms of output growth in comparison to the previous year, while some such wet years experienced two-digit growth rates. At the same time, many years with less than normal rainfall (1175 mm) recorded annual agricultural growth rates in the range of 5-10 per cent, which is very impressive. In one case, the annual growth rate touched 15 per cent. From such trends, it can be inferred that obtaining a good monsoon is neither a necessary condition nor a sufficient condition for securing high agricultural growth during a year in relation to the previous year. Wide variation in agricultural growth rates (in percentage terms) between years (-

5.78% and 14.75%) which experienced more or less the same quantum of average rainfall (around 1150mm) suggests that there are factors other than annual rainfall which influence the agricultural growth rates.

Figure 2: Average annual rainfall of India: 1955-56 to 2013-14



3. What Drives Agricultural Growth?

The agricultural output in value terms is a function of the following: types of crops grown in terms of their value in the market; total area under each crop; number of different types of livestock and their productivity; price of livestock products; crop productivity (yield per ha); and the produce prices. The productivity of the crop is influenced by whether it is irrigated or not as irrigated crops generally yield higher than rainfed crops. The productivity of crops would also depend on the level of inputs such as fertilizer and pesticides, seed varieties and labour inputs for agronomic practices. Therefore, even if the total cropped area remains the same, greater proportion of the area under irrigation would mean higher agricultural outputs. Shift towards high-value crops would also help enhance the agricultural outputs in value terms. Total factor productivity growth, resulting from the introduction of high yielding crop varieties, would also ensure high agricultural growth even without any expansion in area under irrigation and increase in input use (Kumar et al., 2010). This explains how the agricultural outputs in value terms had increased substantially over the years. Basically, over the decades, there has been greater adoption of high yielding crop varieties and greater proportion of the cultivated area brought under high-value crops in addition to expansion in cropped area and greater proportion of the area coming under irrigation.

Kannan and Sundaram (2011) estimated a regression model for predicting the value of crop outputs of the country and found that two key parameters, viz., rainfall and gross irrigated area explained growth performance of major crops at the national level to an extent of 70 per cent. The study dealt with the long-term growth performance of the crop sector.

But in the short run, area cropped and yield keep fluctuating for many crops between years depending on the monsoon occurrence. The gross cropped area in a particular year can be less than that of the previous year, and so is the yield and total production for many crops if the rainfall during the year was less than that of the previous year, as the effect of crop technology, crop shift, etc. will not be significant during such short time spans. The vice versa can happen if a particular year happens to be wetter than the previous year. For certain high-value crops, the prices can fluctuate between years depending on the market conditions influenced by the supply of produce and the demand situation. Hence the short-term trends can be different from the long-term trends and can be influenced by the situation in the current year vis-à-vis rainfall, market conditions, etc., in relation to the previous year.

A univariate regression analysis was carried out to assess the influence of the rainfall of the previous year as well as the current year on agricultural output growth rates. For this, the 'increase/decrease in rainfall in a particular year over the previous year as a percentage of the previous year rainfall' was estimated for all the years from 1956-57 onwards. The percentage increase in rainfall varied from (-) 26.83 to (+) 28.60. Hence the range in annual rainfall change is very wide. The annual agricultural growth rate varied from (-) 12.77 to (+) 15.24. Here again, we find that the fluctuation in the growth rate is wide.

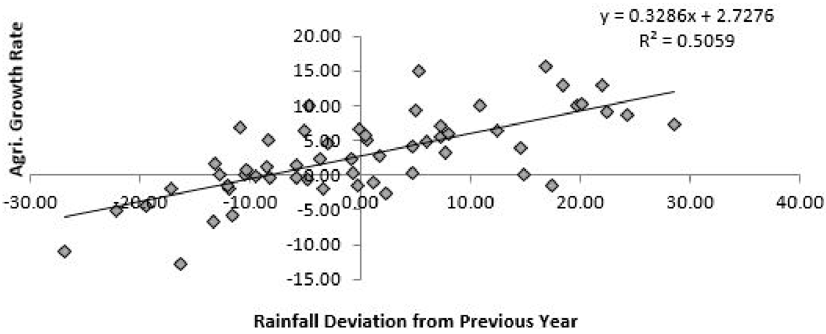
The analysis shows that the rate of growth in annual agricultural output in a particular year is heavily influenced by the percentage difference in rainfall of that year over the previous year. The rainfall difference (from the previous year) as a percentage of the previous year rainfall explained the change in annual agricultural growth rate to an extent of 51 per cent (Figure 3).

The regression model is Y = 0.328* X + 2.727, where Y is the annual growth in agricultural output (%), 'X' is the percentage change in rainfall.

A high percentage increase in rainfall over the previous year results in high agricultural growth and a high percentage decline results in very low growth and often resulting in negative growth. This is quite comprehensible as good monsoon rainfall ensures sufficient soil moisture for the production of *kharif* (monsoon) crops without irrigation and good recharge of aquifers and sufficient inflows into reservoirs that can be used for intensifying cropping during the subsequent seasons. Nevertheless, it is important to observe that there was never a situation in which there was a negative growth in annual agricultural output even with a positive change in rainfall, while the vice versa was observed. In many years, the agricultural growth rate was impressive in spite of them not being high rainfall years. This was because the preceding years were very low rainfall or drought years. Likewise, many wet years did not experience high agricultural growth rates as they were preceded by equally wet years or normal years. Also, there are some years in which the agricultural growth rate was positive in spite of the percentage change in rainfall over the previous year being negative. This is in line with the model prediction. As per the model, when the decline in rainfall becomes very large (above 8.29%), the growth becomes negative.

Needless to say, there are many complex factors, that if put together, should explain the remaining 49 per cent. One of them is spatial variation in rainfall. As regards the potential effect of this on the accuracy of model predictions, it is quite possible that even at the aggregate level, the country receives very good monsoon, some of the regions contributing to agricultural outputs significantly might have experienced below-normal rainfall, and this "anomaly" can reduce the effect of increase in aggregate rainfall. What matters is in which region the rainfall departure actually takes place and the contribution of that region to the overall agricultural output of the country in value terms. A 100-200 mm downward deviation in annual rainfall from the normal value in north western India, which receive low to medium rainfall (450-600mm) but having high agricultural productivity, will have a much larger impact on overall agricultural output of the country than a 100-200 mm downward deviation in rainfall in eastern India which receive very high rainfall but having low agricultural productivity. Every year, the regions which experience rainfall departure in India can keep changing, making the relationship between average annual rainfall and agricultural output more complex. These nuances are not captured in the weighted average of rainfall available for the country as a whole from IMD.

Figure 3: Annual agricultural growth rate vs rainfall deviation from previous Year in India



Nevertheless, it is very unlikely that the trend in the spatial average rainfall at the country level does not conform to the rainfall trend in the majority of the geographical area. That being the case, we have theoretically explained how an increase in rainfall from the previous year contributes to higher agricultural output.

The other factors that can drive agricultural growth are agricultural inputs (seeds, irrigation water, labour/machinery, fertilizers, and pesticides), crop diversification, especially adoption of high-value crops, and adoption of new crop technologies (with high yielding varieties). A positive change in these factors help maintain a low annual agricultural growth rate even when the change in rainfall is negative.

That said, it is also important to note that it is with good monsoon or with improved access to irrigation water, the farmers are encouraged to apply optimum dosage of fertilizers and pesticides, use good seed varieties, and put in sufficient labour, as without water from precipitation or irrigation to crops, none of these inputs will have effect on agricultural outputs. As a result, in the statistical analysis, the effect of many of these independent variables gets subsumed as the effect of change in 'rainfall' which is the primary driver of agricultural growth. It is only in situations when the farmers previously did not have sufficient knowledge of the importance of using optimum level of inputs such as fertilizers and agronomic practices and now start accruing and using such knowledge or when they introduce some new high yielding varieties that their 'differential effects' on agricultural output growth would be pronounced.

Analysis was also carried out to assess the influence of irrigation on agricultural growth rate, which showed statistically significant influence of irrigation growth (estimated as the percentage increase in gross irrigated area in a particular year over the previous year irrigated area). The R2 value was 0.17 (Figure 4). Subsequently, a multivariate analysis was performed using rainfall departure (in percentage terms) and irrigation growth (in percentage terms) as independent variables against agricultural growth rates as a dependent variable. The R2 value increased to 0.55 and both the parameters were found to be significant at 5% level (Table 1). The model was found to be quite significant statistically. The estimated regression equation is:

Annual agricultural growth rate = 1.6245 + 0.476 X Irrigation Growth (%) + 0.3075 X Percentage Difference in Annual Rainfall from the previous year

Figure 4: Agricultural growth rate vs irrigation growth rate in India

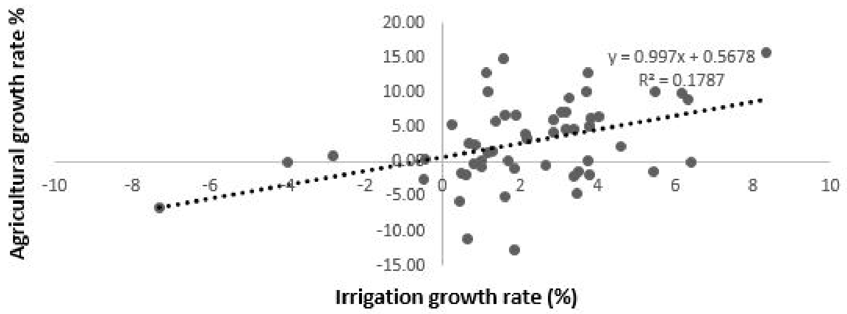


Table 1: Regression Results (Rainfall Difference, Irrigation Growth, and Annual Agricultural Growth Rate

Predictor	Coefficient	SE Coefficient	T Value	P
Constant	1.6245	0.7589	2.14	0.032
Irrigation Growth	0.4762	0.2362	2.02	0.049
Difference in Average Rainfall over the Previous Year	0.3075	0.04762	6.46	0.000

One reason for the only marginal improvement in R2 value is that a large part of the possible variation in irrigated area between two consecutive years is due to rainfall variation. Therefore, the effect of irrigated area change on agricultural output is largely subsumed in the model as the effect of rainfall. Even the irrigation potential already created does not become utilizable in the absence of good monsoon precipitation, as the aquifers remain in depleted condition, and reservoirs do not get sufficient inflows. As a result, probably the effect of irrigation shown by the model is only the effect of additional irrigation potential created and not the additional area irrigated, due to the effect of rainfall. Only in a few situations, there is an increase in irrigated area over a short time period (in this case one year) which is not explained by an increase in rainfall. This is mainly from increased investment for building infrastructure that tap the available water resources for irrigation expansion or for water distribution from the existing irrigation system. The analysis suggests that for agricultural growth rates can become significant or high, under two conditions. First: there is a high percentage increase in rainfall over the previous year. Second: there is a high percentage increase in irrigated area over the previous year. As the model suggests, under the current conditions, a 20 per cent increase in rainfall would ensure a 6 per cent higher growth in annual agricultural outputs in India. Similarly, a 5 per cent increase in irrigated area over one year would ensure a 2.35 per cent higher growth in agricultural output. Though the beta coefficient for irrigation growth is higher than that of rainfall difference (+ive), a careful look at the historical growth rates in irrigation in India shows that the maximum value of annual irrigation growth rate ever obtained was 8.6 per cent (during 1988-89) whereas the maximum value for increase in rainfall obtained was 28.6 per cent (1973-74). Hence, in reality the extent to which the rainfall fluctuations drive agricultural growth rates up and down is much higher than that of change in irrigated area.

Further multivariate analysis was done with two more variables, viz., average annual rainfall (expressed as a percentage departure from mean value), and the actual gross irrigated area. All the four variables were found significant at 5 per cent level. However, this improved the R2 value only marginally to 0.573. More importantly, ‘percentage departure of rainfall from normal’ had a much lower effect on agricultural growth rate, with a beta coefficient of 0.10, than ‘percentage increase in rainfall over the previous year’ which has a beta coefficient of 0.25. Further as one would expect, the extent to which the rainfall can depart from normal value is lower than that of departure from the previous year value. The departure of annual rainfall from mean value ranges from -20.25 per cent to 17.50 per cent. Hence its actual effect on agricultural growth rate would be much less. The coefficient for irrigation growth in the new model was 0.48. The least significant variable was the gross irrigated area of the year, with a beta coefficient of 0.000040.

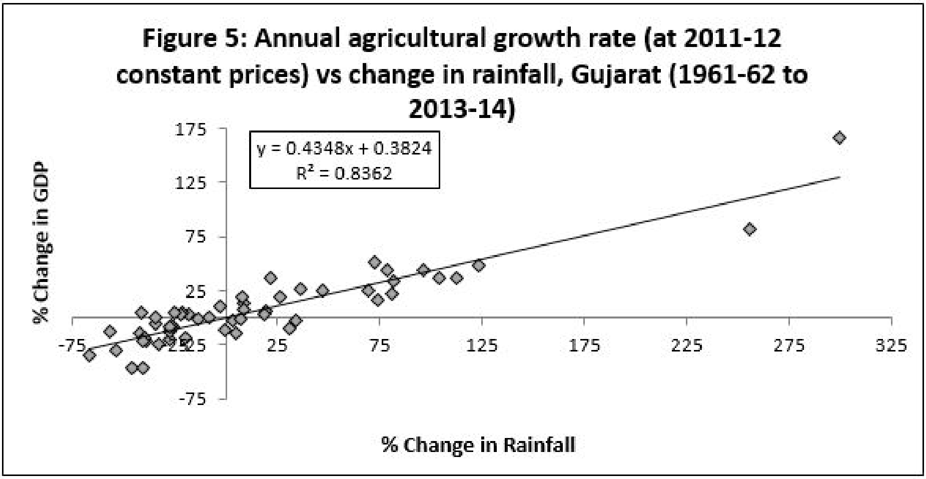
4. Explaining Agricultural Growth in Gujarat

Gujarat is one state which experience high volatility in agricultural performance with very high year to year variation in annual growth rates of agricultural GDP. Figure 5 shows the annual agricultural growth rates in the state during the period from 1961-62 to 2013-14. It is also a state which experiences high year to year variation in annual rainfalls. But the rainfall conditions are not uniform across the state. There is a large regional variation in the average annual rainfall (Kumar and Perry, 2019). Variations in water resources endowment and irrigation facilities are also significant (Jagadeesan and Kumar, 2015), though much less as compared to the variations that exist at the national level, and therefore the anomaly caused by such variations in defining the effect of change in rainfall on agricultural growth rates will be less.

Since 2002-03, Gujarat has achieved an average annual growth rate of 9% (at 2011-12 constant prices) in its agricultural GDP. Several narratives have been presented to explain this trend. One of these attributes this to the increase in gross cropped area which was an outcome of the availability of water for supplementary irrigation from the numerous small water harvesting structures in the state and the highly productive well irrigation (Shah et al., 2009). However, data and analysis presented by them in favour of their arguments were insufficient to drive any meaningful inference. For instance, Shah et al (2009) explained agricultural growth in Gujarat by comparing agricultural output in a drought year (2000) with the seven-year period post-2002, four of which either received normal rainfall or were wet years. But Kumar et al. (2010) found that the growth trend observed by Shah et al. (2009) was actually a good recovery from a major dip in production that occurred during the drought years of 1999 and 2000, facilitated by higher rainfall and introduction of large volume of water for irrigation from Sardar Sarovar project which began in 2002. Analysis presented by Kumar and Perry (2019) re-emphasised the role of rainfall in improving groundwater conditions in the state almost during the same period, which in their opinion, had influenced the agricultural performance of the state. However, it was necessary to explain empirically the extent to which annual rainfall fluctuations influence annual agricultural growth rates.

In this analysis, we tried to extend the hypothesis established at the National level for explaining the agricultural growth trend in Gujarat. For the statistical model, data sets for the value of annual agricultural output from 1961-62 to 2013-14 (at factor cost) obtained from the Reserve Bank of India report (2019) and Dholakia and Sapre (2013) were adjusted to 2011-12 constant prices (the latest series). Thereafter, the annual growth rates in state agricultural GDP was estimated. Also, the values of spatial average annual rainfall from 1961-62 to 2013-14 were estimated using the monthly rainfall figures from the two different regions in Gujarat, viz., mainland Gujarat and Saurashtra and Kachchh. The contribution of each region to the state's annual rainfall was ascribed in proportion to the area covered by each region.

A regression model between the annual agricultural growth rate (as dependent variable) and percentage difference in annual rainfall from the previous year (as independent variable) returned an R square value of 0.83 (Figure 5). This means that a change in rainfall explained the variation in the annual agricultural growth rate in Gujarat to an extent of 83 per cent. The relationship between percentage change in rainfall between two consecutive years and the growth rate in agricultural GDP between the two years is stronger for Gujarat. This is as per the expectations as the regional variations in rainfall and water endowment, which have the potential to eclipse the effect of rainfall change on agricultural growth rates and cause an anomaly in the relationship, is much less in Gujarat as compared to the variations at the national level. For instance, in Gujarat, the mean annual rainfall varies from 350mm in Kachchh to around 2000mm in Dangs and Valsad in south Gujarat. At the national level, however, the rainfall varies from as low as 200mm in Jaisalmer (western Rajasthan) to around 11,000mm in certain pockets of Meghalaya in the north east, with most parts of north east receiving more than 3,000mm of annual precipitation. The climate varies from hyper arid in western Rajasthan to cold and humid in most parts of the north east.



As in the case of national-level aggregate analysis, the model was expanded to include change in gross irrigated area over the previous year as the second independent variable. Since the data for the gross irrigated area in Gujarat was available for 1985-86 to 2013-14, the other two variables were also adjusted for the same time period. The multiple regression model shows that the relationships between annual agricultural growth rate and the change in rainfall and change in gross irrigated area is statistically significant, the p-values for the independent variables are less than the 5% significance level (Table 2). Further, the R square value increased to 0.92, confirming that the regression model is robust with the considered variables. The poor effect of annual growth in irrigation (gross irrigated area) on agricultural growth rate could be because the rainfall variation causes similar variation in actual irrigated area, and the effect of changes in irrigated area is largely captured by the effect of change in rainfall. The state of Gujarat had experienced a very high degree of water resources development over the past many decades both on the groundwater front and surface waterfront. As a result, higher rainfall resulting in a higher amount of recharge increases the potential of the wells. Similarly, higher rainfall, resulting in a larger amount of inflows into existing minor, medium and major reservoirs of the state, results in a larger proportion of the existing surface command area being brought under irrigation. In low rainfall years, just the opposite happens. Having said that the differential effect of irrigation (5%) can be explained by the additional irrigation facilities built during the year in areas where resource endowment is favorable increasing the irrigation potential created.

Table 2: Results from the regression analysis

	Coefficients	Standard Error	t Stat	P-value
Intercept	-1.24442	2.210276	-0.56301	0.578249
X Variable 1 (Difference in Average Rainfall over the Previous Year)	0.393819	0.052009	7.57209	4.88E-08
X Variable 2 (Irrigation Growth)	1.022592	0.355157	2.87927	0.007874

5. Conclusions

For long, agricultural economists and planners in India believed that the quantum of monsoon rainfall in a particular year (or its departure from mean values) would mainly determine the annual agricultural growth rate that the country would achieve in that year. This was basically the logical extension of the valid concept that agricultural output of the country in a particular year can change with the monsoon rainfall which ensures sufficient moisture for the *kharif* (monsoon) crops and adequate inflows in reservoirs and replenishment of aquifers for irrigation. The absence of long-term data on average annual rainfall on the country's landmass, however, made it difficult to test this hypothesis. But such views ignore the fact that at times there can be wide fluctuations in agricultural outputs between two consecutive years due to large variations in the corresponding rainfall, and as a result, the value of agricultural outputs can be less than that of the previous year. Poor agricultural growth performance observed in certain years was attributed to the inadequate rainfall of that year and high growth rates observed in certain other years was attributed to effective policy interventions and good monsoon. The influence of the preceding year's rainfall in determining agricultural growth performance of a year was largely ignored.

Our analysis suggests that that obtaining a good monsoon is neither a necessary condition nor a sufficient condition for securing high agricultural growth during a year in relation to the previous year. Wide variation in agricultural growth rates between years which experienced more or less the same quantum of rainfall suggests that there are factors other than annual rainfall which influence the agricultural growth rates.

Further analysis suggests that the annual agricultural growth performance (rate) of the country is mainly explained by two key factors: 1] the percentage difference in average rainfall of the year under consideration from the previous year; and, 2] the percentage increase in gross irrigated area over the previous year. These two variables explain agricultural growth performance to an extent of 55 per cent at the national level. This was further validated by similar analysis carried out for Gujarat, in which case, rainfall change explained annual agricultural growth rate to the extent of 92 per cent. The factors such as level of agricultural inputs, crop diversification and introduction of new high yielding varieties along with the spatial variation in rainfall should explain the remaining. Higher the percentage increase in average annual rainfall of a year over the previous year, higher the chances of obtaining high growth rates. Higher the percentage increase in gross irrigated area over the previous year, again higher would be the chances of obtaining high agricultural growth rates during the year. The average rainfall of the year (expressed as percentage departure from mean value) has a much smaller effect on annual agricultural growth rates in reality.

Based on this analysis, we argue that too much is made out of the annual agricultural growth rates in planning and policy circles. Poor agricultural growth performance in a year may not be because of the poor performance of the monsoon during that year. Instead, it can as well be due to the very good performance of monsoon or abnormally wet conditions during the previous year. Likewise, very high agricultural growth performance (agricultural growth rate) during a year may neither be because of good monsoon performance nor because of any policy reforms. It may as be due to the poor performance of monsoon during the previous year.

Given the wide fluctuations in average annual rainfall in the country, the estimates of annual agricultural growth rates can often be misleading when they are used for drawing inferences on agricultural sector performance, both at the national level and at the state level. The future focus should be on assessing medium-term growth rates which carefully picks up the base year in which the magnitude of annual rainfall is quite close to that of normal rainfall.

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