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Empirical analysis of weather risk management in agricultural sector: Study of rain-fall volatility in Gwalior-Chambal region

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Abstract
Indian Economy is agriculture driven economy, It contributes around 14.5% of GDP and employs 51% of the labour force, has got multiplying effect on industry and service sector performance. Monsoons directly impacts agriculture and in turn the Indian economy. In this research paper we have analysed the monsoon rainfall data for last 100 years by applying Mean, Standard Deviation, Coefficient of variance, ANNOVA and found that monsoon rainfall is too much volatile in Gwalior-Chambal Region. This volatility is increasing in recent past.

Keywords: monsoon rain-fall volatility, weather risk, ANNOVA

1. Introduction

The prospects of Indian economy depend on monsoon outcome. Monsoons directly impacts agriculture and in turn the Indian economy. It contributes around 14.5% of GDP and employs 51% of the labour force, has got multiplying effect on industry and service sector performance. The timely arrival of the monsoon and sufficient rains is the key for Indian economic growth. Agriculture, hydro-electric power generation and agriculture industry in India are heavily dependent on the performance of the summer monsoon which provides 75-90% of annual rainwater potential over most parts of India. Besides, livestock-poultry, cattle etc, sports events like cricket, football, golf, skiing etc, entertainment industry like water theme parks, construction, tourism, transport, retailing, energy firms are subjected to rainfall risk. The monsoon risk is a recurring phenomenon. Robust risk absorption mechanisms need to be designed and deployed based on thorough research inputs. The proposed research project aims to give lead to the policy and academic debates concerning securitization of monsoon risk for its broad-based absorption by the capital markets.

Agriculture, especially in developing countries, is a sector which is vulnerable to risks of various types. Most importantly, weather-related risks play a major role in affecting agricultural income. These would include extreme rainfall, both high and low, which result in floods/droughts, as well as extreme temperature events.

Poor, small farmers are especially susceptible to income variability because of weather-related risks to their crops. In fact, even those rural poor who are not directly involved in agricultural production get affected because their incomes are often tied to the success of the agricultural production (Barnett and Mahul, 2007) [1].

Besides agriculture, with climate change becoming an accepted phenomenon the world across, attention is increasingly being paid to the effects of weather on businesses. At the same time, it is obvious that whatever the type of weather, or whatever the effects of climate change on weather, there will always be some businesses, which would gain, and some which would suffer considerable losses. Rain, for example, could be beneficial to agriculture; while at the same time could adversely affect the business of an event management company.

In general, whenever risk of any kind is to be hedged, various instruments have been developed and have been used in the past. For protection against financial loss of some kind there have been various instruments used for hedging. One of these is derivatives. A derivative can be defined as a product whose value depends on the risk factors of one or more assets. These instruments can be used as a means of protection against possible adverse market movements through offsetting exposures or shifting risks. They are particularly useful during periods of volatility.

Monsoon in India

As per Indian Meteorological Department (IMD), the monsoon months from June to September bring three-fourth of India‘s annual rainfall. Studies show that it is erratic in four out of every ten years. Yet farmers rarely get any useful warning of shortfalls. For the last year as late in June, 2016 India‘s meteorologists were predicting a normal monsoon. However, Punjab and Haryana, two north-western agricultural states, received rains below average. Six western states have issued drought warnings.

India being predominantly rural, over 600m out of 1.24 billion Indians rely directly on farming. Nearly two-thirds of Indian fields are rain fed. A one-off drought is tolerable. But the concern is the signs of long-term changes in summer rains. It would arrive late more often, yield less water, become more sporadic, or dump rain in shorter, more destructive bursts as evidenced two years ago in Pakistan, where the Indus basin disastrously flooded. In June 2013 in Uttarkhand Pilgrimage centers in the region Gangotri, Yamunotri, Kedarnath and Badrinath were flooded and about 70,000 pilgrims were struck due to road blocks and washed off of bridges and roads.

Monsoon in Gwalior-Chambal Region

Table 1: Region-wise seasonal and annual rainfall (mm)-Year 2016

REGIONS	WINTER	PRE-MONSOON	MONSOON	POST-MONSOON	ANNUAL
COUNTRY AS A WHOLE	17.9	130.3	864.4	70.6	1083.2
NORTH WEST INDIA	24.7	113.6	585.6	16.6	740.5
CENTRAL INDIA	8.2	32.5	1035.7	68.6	1145.0
SOUTH PENINSULA	5.1	109.8	660.3	109.7	884.9
EAST & NORTH EAST INDIA	41.2	393.8	1292.0	130.2	1857.2

***Source*:** India Meteorological Department (www.imd.gov.in/)

The rainfall statistics for monsoon months and season for the country is given at Table 2. Also, the monthly and seasonal observed and normal rainfall and, the percent departures of observed rainfall from their normal rainfall have been depicted in charts at Figure 5 and Figure 6 respectively. During the monsoon season, country was deficient in rainfall at -3% departures from Normal. It may be observed that, the country was in rainfall deficiency for all the monsoon months except for the month of July.

Table 2: All India Rainfall –SW Monsoon 2016

RAINFALL (mm) FOR THE COUNTRY: SOUTH WEST MONSOON SEASON - 2016			
MONTH	OBSERVED	NORMAL	% DEPARTURES FROM NORMAL
JUNE	147.6	163.6	-10%
JULY	309.2	289.2	7%
AUGUST	239.6	261.3	-8%
SEPTEMBER	168.0	173.4	-3%
MONSOON	864.4	887.5	-3%

***Source*:** India Meteorological Department (www.imd.gov.in/)

For the Gwalior-Chambal region, the rainfall for the monsoon season was 89 % of its long period average (LPA). It comprises 66 % in Gwalior, 99 % in Shivpuri, 159 % in Datia, 63 % in Bhind, 72 % in Morena, 94 % in Sheopur.

Table 3: % Departures of Gwalior-Chambal region seasonal and annual rainfall – 2016

Districts	Winter	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
Gwalior	-74%	305%	-33%	-50%	-29%
Shivpuri	-82%	-10%	8%	-49%	3%
Guna	-52%	-54%	35%	-46%	28%
Datia	-61%	272%	-31%	-32%	-27%
Bhind	-55%	120%	-20%	-80%	-23%
Morena	-99%	34%	-25%	-53%	-27%
SHEOPUR	-100%	-32%	-4%	-48%	-8%

***Source*:** India Meteorological Department (www.imd.gov.in/)

It can be noticed that in Pre-monsoon, Monsoon and annually there are two districts in Gwalior-Chambal region (Guna and Shivpuri) have normal or excess rainfall. Annually, 4 districts show large deficiency in rainfall. So it is again proved that the rainfall is unpredictable and variable across the Gwalior-Chambal region and months. So Gwalior-Chambal experiences the rainfall risk and hence risk mitigation is necessary.

2. Literature Review

Skees, *et al*, (2001) [5] analyzed the improvement of weather products in light of precipitation to insure against dry spell in four Mexican states viz., "Durango, Jalisco, Tamaulipas and Zacatecas". The plausibility study had two primary segments. To start with, it analyzed the relationship amongst precipitation and yield to decide the misfortune because of absence of rain. Second, it composed a model precipitation contract and inspected how this agreement influences the change of incomes from these yields

(Pauline, 2006) [2] expressed that weather risk is likewise more a high recurrence - low seriousness chance. In this way, standard insurance does not appear to be the most proper arrangement. The ideal length of the database relies on upon the normality of climate information (drift, consistent regularity) and somewhere around 10 and 30 years is considered as the standard.

Barnett and Mahul, (2007) [1], in his article states that over one-half depend on agriculture or agricultural labor as their primary source of livelihood. Thus, poor rural households are particularly susceptible to the financial consequences of weather-related natural disasters. In principle, traditional insurance instruments, including crop insurance, can be used to transfer the risk of extreme weather events. However, insurance markets are underdeveloped and often nonexistent in rural areas of lower income countries due to poor contract enforcement; asymmetric information, high transaction costs, and high exposure to spatially covariate risks (Skees and Barnett 2006). These problems are particularly acute for crop insurance.

Rao and Bockel, (2008) [3], proposed that weather index

insurance has comparable points of interest to those of region yield insurance. This program gives convenient remuneration made on the premise of weather index, which is normally precise. All people group whose livelihoods are reliant on the weather can purchase this insurance.
Crop insurance in India has been on discussion agendas ever since independence in 1947 (AIC, 2007) [6]. A special study was commissioned in 1947- 48 to go into and recommend the approach that should be adopted. A major bone of contention, which emerged was whether we should use an Individual Approach or a Homogeneous Area Approach, where the area comprises villages, which are homogeneous in respect of production of a particular crop. The special study pointed out that the individual approach would be difficult to administer and implement. Administrative costs would be considerably higher since fixing of premiums on actuarially sound basis would require a large number of reliable data of crop yields of individual farmers. The issue of moral hazard would also arise and could have a large effect on premiums.
Raju and Chand (2009) [4] opined that agriculture production and farm incomes in India are affected by one or the other natural disasters such as droughts, floods, cyclones, storms, landslides and earthquakes. Susceptibility of agriculture to these disasters is compounded by the outbreak of epidemics and anthropogenic disasters such as fire, sale of spurious seeds, fertilizers and pesticides, price crashes etc. All these events severely affect farmers through loss in production and farm income, and they are beyond the control of the farmers. The question is how to protect farmers by minimizing such losses. For a section of farming community, the minimum support prices (MSP) for certain crops provide a measure of income stability. But most of the crops and in most of the state‘s MSP is not implemented. In recent times, mechanisms like contract farming and futures trading have been established which are expected to provide some insurance against price fluctuations directly or indirectly. But, agricultural insurance is considered an important mechanism to effectively address the risk to output and income resulting from various natural and manmade events. Agricultural Insurance is a means of protecting the agriculturist against financial losses due to uncertainties that may cause agricultural losses arising from named or all unforeseen perils beyond their control. Unfortunately, agricultural insurance in the country has not made much headway even though the need to protect Indian farmers from agriculture variability has been a continuing concern of agriculture policy.

3. Research Methodology
3.1 Objectives of the study
1. To evaluate the monsoon rain-fall volatility across Gwalior-Chambal region.

3.2 Data Collection
Monthly Rainfall Data of last 30 years have been collected from the website of Indian Meteorological Department (IMD) and it has been analysed by using following statistical tools.

a) Standard Deviation (SD) and Coefficient of Variance (CV): Monthly rainfall data of different districts of Gwalior-Chambal region for last 50 years has been analysed to study the rain-fall volatility. Rain-fall volatility can be calculated by using standard deviation (SD) and coefficient of variation (CV %).

$$SD = \frac{1}{N}\sum_{i=1}^{N}(Ri - R)^2 \qquad \text{...............Eq 1}$$

Where N number of period, Ri is rainfall for the month, R is the average rainfall

$$CV = \frac{SD}{R} \qquad \text{..............Eq 2}$$

Where SD is standard deviation of rainfall during the period, R is average rainfall, CV is coefficient of variation

b) One Way-ANOVA test will be applied to test the significant variation in the rainfall volatility across different districts of Gwalior-Chambal region.
The formula for the ANOVA *F*-test statistic is:

$$F = \frac{between\ group\ variability}{within\ group\ variability} \qquad \text{.................Eq 3}$$

Between- group variability is

$$\sum_{i=1}^{K}\frac{n_i(Yi-Y)^2}{(K-1)} \qquad \text{................Eq 3.1}$$

Where Yi is sample mean of i^{th} group, n_i is number of observations in i^{th} group. Y denotes the overall mean of the data, and K denotes the number of groups.
Within group variability is

$$\sum_{i=1}^{K}\sum_{j=1}^{ni}\frac{(Y_{ij}-Y_i)^2}{(N-K)} \qquad \text{.................Eq 3.2}$$

Where Y_{ij} is the j^{th} observation in the i^{th} out of K groups and N is the overall sample size
The rainfall index will be prepared for all districts of Gwalior-Chambal region by using the historical data

$$RIX = \frac{\sum r_{it}}{\sum R_{it}} \qquad \text{...................Eq 4}$$

Where r_{it} represents cumulative rainfall for end of i^{th} month of the t^{th} season; R_{it} represents historical average cumulative monthly rainfall for end of i^{th} month of the t^{th} season; and 1000 is the multiplier value (Rainfall is measured equivalent to 1/1000th of a met, i.e., in mm).

4. Analysis and Interpretations
To understand the behaviour of monsoon over the Gwalior Chambal region, an analysis of rainfall data is carried out here. Homogenous monthly rainfall data sets have been downloaded from year 1901 to 2016 from the website of www.indiawaterportal.org.
The data has been rearranged for time periods like 100, 50 and 30 years of monsoon month (June to September) and descriptive statistics of the rainfall are carried out. The results are in tables 4 to 6

4.1 Descriptive Statistics of rainfall data

Table 4: Descriptive statistics for monsoon rainfall (mm) of 100 years (1917-2016)

Statistics	Gwalior	Shivpuri	Guna	Datia	Bhind	Morena	Sheopur
Max	318.54	338.79	418.80	343.87	300.66	300.79	286.23
Min	94.18	114.56	109.93	101.63	87.97	89.05	77.88
Mean	199.80	212.46	200.77	210.37	189.83	186.06	186.01
SD	52.01	50.30	52.94	56.55	55.28	50.97	46.09
CV %	26.0%	23.7%	26.4%	26.9%	29.1%	27.4%	24.8%

***Source*:** Compiled from the rainfall data taken from www.indiawaterportal.org

Table 4 provides the descriptive statistics on volatility of rainfall for 7 district of Gwalior-Chambal regions for the past 100 years (1917-2016). It is observed that the maximum rainfall recorded is for Guna (418.80 mm) and minimum rainfall recorded is for Sheopur (77.88 mm). The average rainfall is highest for Shivpuri (212.46 mm) and it is least for Sheopur (186.01 mm). So there is much variation of rainfall in this region.

Table 5: Descriptive statistics for monsoon rainfall (mm) of 50 years (1967-2016)

Statistics	Gwalior	Shivpuri	Guna	Datia	Bhind	Morena	Sheopur
Max	316.06	338.79	418.80	343.87	298.74	280.14	270.38
Min	94.18	119.18	109.93	101.63	87.97	89.05	77.88
Mean	185.36	199.75	198.26	192.79	174.69	174.20	176.79
SD	50.10	49.63	61.80	56.72	56.17	50.01	46.98
CV %	27.0%	24.8%	31.2%	29.4%	32.2%	28.7%	26.6%

***Source*:** Compiled from the rainfall data taken from www.indiawaterportal.org

Table 5 highlights the descriptive statistics on volatility of rainfall for 7 district of Gwalior- Chambal region for the past 50 years (1967-2016). It is observed that the maximum rainfall recorded is for Guna (418.80 mm) and minimum rainfall recorded is for Sheopur (77.88 mm). The average rainfall is highest for Shivpuri (199.75mm) and it is least for Morena (174.20 mm). So there is large variation of rainfall in India.

Table 6: Descriptive statistics for monsoon rainfall (mm) of 30 years (1987-2016)

Statistics	Gwalior	Shivpuri	Guna	Datia	Bhind	Morena	Sheopur
Max	316.06	338.79	418.80	343.87	298.74	280.14	270.38
Min	94.18	119.18	109.93	101.63	93.28	89.05	77.88
Mean	175.05	192.20	203.24	179.60	162.69	164.90	169.42
SD	50.08	52.77	74.11	57.67	57.76	51.39	51.58
CV %	28.6%	27.5%	36.5%	32.1%	35.5%	31.2%	30.4%

***Source*:** Compiled from the rainfall data taken from www.indiawaterportal.org

Table 6 highlights the descriptive statistics on volatility of rainfall for 7 district of Gwalior- Chambal region for the past 30 years (1987-2016). It is observed that the maximum rainfall recorded is for Guna (418.80 mm) and minimum rainfall recorded is for Sheopur (77.88 mm). The average rainfall is also highest for Guna (203.24 mm) but it is least for Bhind (162.69 mm).

From the above 3 tables, it is evident from the descriptive statistics of rainfall for the past 100 years, 50 years and 30 years that there is variation of rainfall among district of Gwalior- Chambal region.

4.2.1 Average Rainfall over Time Periods

Average rainfall across the Gwalior Chambal Region is extracted from the previous descriptive statistics table to know the changes in the average rainfall occurred during different time periods.

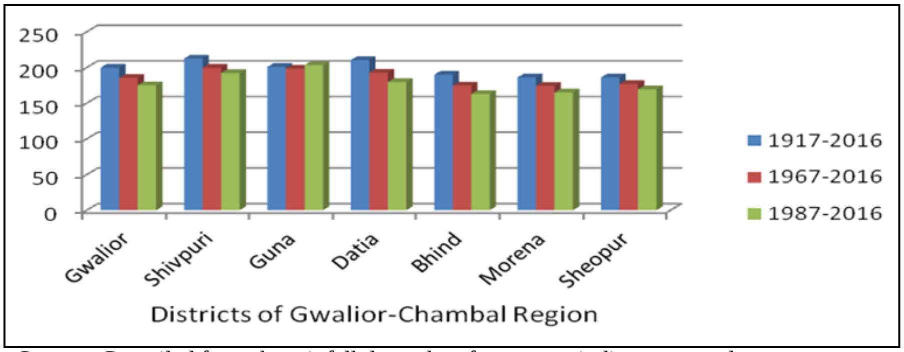
Table 7: Mean values of total monsoon rainfall (mm) for various periods

No of Years	Period	Gwalior	Shivpuri	Guna	Datia	Bhind	Morena	Sheopur
100	1917-2016	199.8	212.46	200.77	210.37	189.83	186.06	186.01
50	1967-2016	185.36	199.75	198.26	192.79	174.69	174.2	176.79
30	1987-2016	175.05	192.2	203.24	179.6	162.69	164.9	169.42

***Source*:** Compiled from the rainfall data taken from www.indiawaterportal.org

From the Table 7, we see that average rainfall among the 7 district of Gwalior-Chambal Region, Shivpuri has highest rainfall for last 100 and 50 years, and Guna has highest average rainfall for last 30 years period. If we observe the lowest average rainfall, Sheopur has lowest for 100 years period, Morena for 50 years period and Bhind for 30 years period. Average rainfall is coming down for each district except Guna, where it decreased from 200.77 mm to 198.26 mm for time period of last 100 years to 50 years and increased to 203.24 mm for last 30 years.

Such unpredictable behaviour of rainfall is vital from the point of risk and needs to be addressed for risk mitigation. The mean values rainfall behavior is graphically represented in below Figure 1.



Source: Compiled from the rainfall data taken from www.indiawaterportal.org

Fig 1: mean values of rainfall (in mm) for different period

4.2.2 Standard Deviation of Rainfall over Time Periods

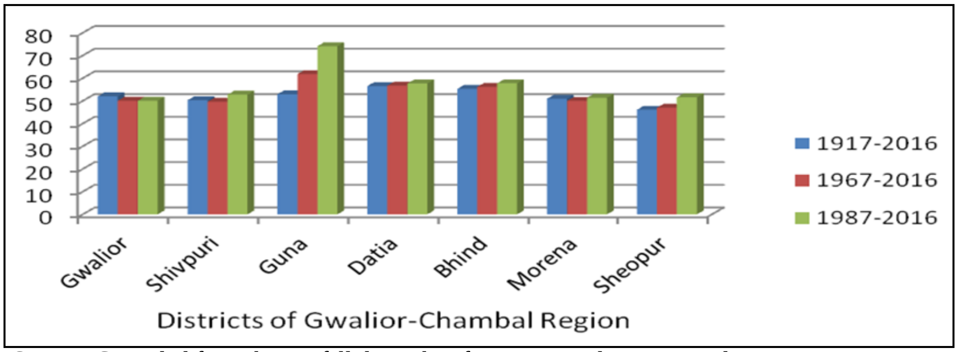
From the table 8 we see that standard deviation of rainfall among 7 districts is highest for Datia in 100 years and for Guna for in 50 and 30 years time period. Standard deviation is lowest for Sheopur in 100 and 50 years and for gwalior in 30 years period. Standard deviation is showing Increasing trend for Shivpuri, Guna, Datia, Bhind, Sheopur and Decreasing trend for Gwalior and it has oscillated for Morena.

Table 8: Standard Deviation values of total monsoon rainfall (mm) for various periods

No of Years	Period	Gwalior	Shivpuri	Guna	Datia	Bhind	Morena	Sheopur
100	1917-2016	52.01	50.3	52.94	56.55	55.28	50.97	46.09
50	1967-2016	50.1	49.63	61.8	56.72	56.17	50.01	46.98
30	1987-2016	50.08	52.77	74.11	57.67	57.76	51.39	51.58

Source: Compiled from the rainfall data taken from www.indiawaterportal.org

The Standard deviation of rainfall is graphically represented in below Figure 2



Source: Compiled from the rainfall data taken from www.indiawaterportal.org

Fig 2: standard deviation of rainfall (in mm) for different period

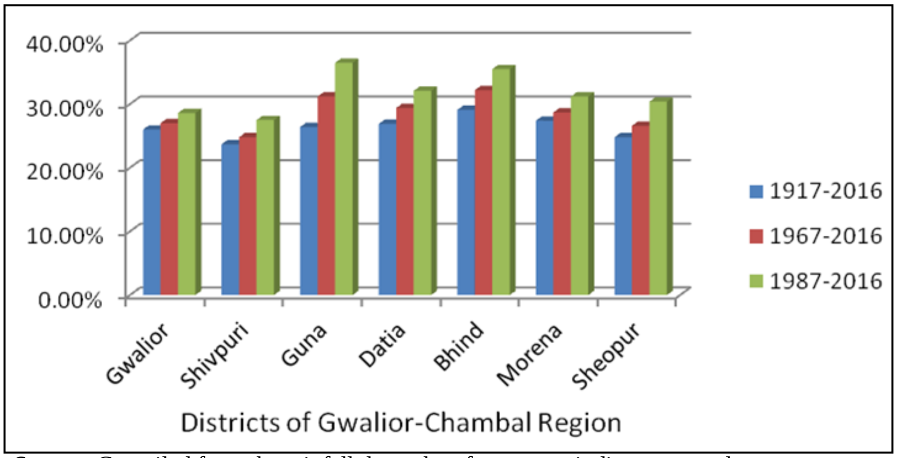
4.2.3 Coefficient of Variation of rainfall over time periods

Table 9: CV (%) values of total monsoon rainfall (mm) for various periods

No of Years	Period	Gwalior	Shivpuri	Guna	Datia	Bhind	Morena	Sheopur
100	1917-2016	26.00%	23.70%	26.40%	26.90%	29.10%	27.40%	24.80%
50	1967-2016	27.00%	24.80%	31.20%	29.40%	32.20%	28.70%	26.60%
30	1987-2016	28.60%	27.50%	36.50%	32.10%	35.50%	31.20%	30.40%

Source: Compiled from the rainfall data taken from www.indiawaterportal.org

From table 9 we see that CV(%) of rainfall among the 7 district of Gwalior Chambal region is highest for Bhind District in 100 years and 50 years time period and for Guna in 30 years time period. It is lowest for Shivpuri for all the 3 time periods. The CV(%) is showing increasing trend for all the districts. The CV (%) is graphically represented in Figure 3.



***Source*:** Compiled from the rainfall data taken from www.indiawaterportal.org

Fig 3: CV (%) of rainfall (in mm) for different period

From the above analysis, it is implied that the rainfall has variability and unpredictability in all the districts of Gwalior-Chambal region. For de-risking the economy statistically lower CV values are recommended as they show the consistency with the rainfall under study.

4.3 Testing of 1st Hypothesis

$H1_1$: There is significant difference in the monsoon rainfall volatility across the Gwalior-Chambal region.

On the basis of 3 time periods of rainfall (100 years, 50 years and 30 years) the above hypothesis is grouped and tested as follows.

4.3.1 For 100 year period rainfall data (1917-2016)

For the purpose of testing, the following null and alternative hypotheses are formulated.

H0.1.1: "The monsoon rainfall volatility during 100 years period (1917-2016) does not vary across the Gwalior-Chambal region"

Ha.1.1: "The monsoon rainfall volatility during 100 years period (1917-2016) does vary across the Gwalior-Chambal region"

Table 10: ANOVA for 100 year rainfall data

Rainfall					
	Sum of Squares	Df	Mean Square	F	Sig.(p)
Between Groups Within Groups Total	73254.542 1836778.755 1910033.297	6 693 699	12209.090 2650.474	4.606	.000

As shown in table 10 the F value and p value are 495.38 and 0.000 ($p<0.05$) respectively. Hence there is a significant variability of rainfall during 100 years period (1917-2016) across Gwalior- Chambal region, as the observed significance value is less than 0.05.

After analyzing the results of ANOVA, the decision is to accept the alternative hypothesis "*The monsoon rainfall volatility during 100 years period (1917-2016) does vary across the Gwalior-Chambal region"* and to reject the null hypothesis.

4.3.2 For 50 year period rainfall data (1968-2017)

For the purpose of testing, the following null and alternative hypotheses are formulated.

$H_{0.1.2}$: "*The seasonal volatility of rainfall during 50 years period (1967-2016) does not vary across the Gwalior-Chambal region*"

$H_{a.1.2}$: "*The seasonal volatility of rainfall during 50 years period (1962-2011) does vary across the Gwalior-Chambal region*"

The above hypothesis is tested using ANOVA and the results are in Table 11 As shown in table 11 the F value and p value are 3.167 and 0.046($p<0.05$) respectively. Hence there is a significant variability of rainfall during 50 years period (1967-2016) across Gwalior-Chambal region, as the observed significance value is less than 0.05.

After analyzing the results of ANOVA test, the decision is to accept the alternative hypothesis "The seasonal volatility of rainfall during 50 years period (1967-2016) does vary across the Gwalior-Chambal region" and to reject the null hypothesis.

Table 11: ANOVA for 50 year rainfall data

Rainfall					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups Within Groups Total	36905.795 973746.437 1010652.232	6 343 349	6150.966 2838.911	3.167	.046

4.3.3 For 30 year period (1987-2016) rainfall data

For the purpose of testing, the following null and alternative hypotheses are formulated. H0.1.3:"*The seasonal volatility of rainfall during 30 years period (1987-2016) does not vary across Gwalior-Chambal region*"

Ha.1.3:"*The seasonal volatility of rainfall during 30 years period (1987-2016) does vary across the Gwalior-Chambal region*"

The above hypothesis is tested using ANOVA and the results are in Table 12.

Table 12: ANOVA for 30 year rainfall data

Rainfall					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	39888.843	6	6648.141	2.46	.041
Within Groups	659699.998	203	3249.754		
Total	699588.841	209			

As shown in Table 12, the F value and p value are 2.46 and 0.041 ($p<0.05$) respectively. Hence there is a significant variability of rainfall during 30 years period (1987-2016) across Gwalior-Chambal region, as the observed significance value is less than 0.05.

After analyzing the results of ANOVA test, the decision is to accept the alternative hypothesis "*The seasonal volatility of rainfall during 30 years period (1987-2016) does vary across the Gwalior-Chambal region*" and to reject the null hypothesis.

5. Conclusion

It is evident from the above analysis that monsoon rain-fall is volatile in nature in Gwalior-Chambal region and the volatility of rain fall is increasing in recent years. Farmer has to bear huge amount of loss due to this volatile monsoon, which is cause of concern for Government. The loss of farmers can be reduced with the help of implementation of good hedging tool like: Crop Insurance, Weather insurance, Weather Derivatives etc. In our further research we will try to compare the various hedging tools rainfall volatility and how it can be implemented in this region.

6. References

1. Barnett BJ, Mahul O. Weather Index Insurance for Agriculture and Rural Areas in Lower Income Countries". American Journal of Agricultural Economics. 2007; 89(5):1241-1247.
2. Pauline Barrieu. Various comments on the weather derivatives Market, A presentation, NICE, 2006.
3. Rao, Bockel. Risk Management as a Pillar in Agriculture and Food Security Policies. India case study Policy Brief, Easypol Module. 2008; 209.
4. Raju, Chand. Raju. S.S., and Ramesh, Chand.,(2009), ― Agricultural Insurance in India Problems and Prospects‖ NCAP Working Paper No. 8, National Centre for Agricultural Economics and Policy Research (Indian Council of Agricultural Research, 2009.
5. Skees JR, Gober S, Varangis P, Lester R, Kalavakonda V. Developing rainfall-based index insurance in Morocco, Policy research working paper, World Bank, 2001. ISSN: 1813-9450
6. www.aicofindia.nic.in, History of Crop Insurance in India, Accessed, 2007.
7. www.aicofindia.nic.in, National Agricultural Insurance Scheme, Accessed, 2007.
8. www.indiawaterportal.org.
9. http://www.imd.gov.in