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**Assessment of the Risk Management Potential of a Rainfall Based Insurance Index
and Rainfall Options in Andhra Pradesh, India**

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Assessment of the Risk Management Potential of a Rainfall Based Insurance Index and Rainfall Options in Andhra Pradesh, India

Abstract

Crop insurance is an alternative risk management technique available to farmers for stabilizing their revenue risk and schemes based on area yield have been in operation for quite some time. Here rainfall based insurance indices and options are suggested as a replacement for the expensive area yield programs. Instead of direct premium subsidies which are distorting, premium subsidy is taken as a function of adverse deviation of rainfall from the mean. A sensitivity analysis at different revenue elasticity levels with respect to rainfall was performed. Potential for private insurer's and reinsurer's participation exists with rainfall based index and options.

Introduction

Indian agriculture accounts for 24 percent of the GDP and provides work for almost 60 percent of the population. The agricultural sector consists of almost 100 million farmers with a gross cropped area of 230 million hectares. Ultimate irrigation potential is 140 million hectares, still leaving 110 million hectares as rainfed. India has two monsoon seasons (Northeast monsoon and Southwest monsoon) and the subdivisions can be classified as those which receive rainfall exclusively from one or the other or both. India has 29 meteorological subdivisions with diverse climatic conditions. Weather impacts all facets of agricultural activity either directly or indirectly, presence of climatic differences within the country makes it possible to swap and share risk between different regions.. Suicide of farmers in Andhra Pradesh, Karnataka, and Punjab in 2001-02 over recurring

crop losses and crop revenue risk highlights the need for income stabilizing programs. The volatility in the input and output prices, supply of inputs and the demand for outputs and also the production levels influence the revenue risk faced by the farmers. Higher dependency of agriculture on rainfall means that successive failures of monsoon could leave the cash starved farmers in a debt cycle. The sheer size of the population involved and the fact that 60 percent of the crop production is done under rainfed conditions makes crop insurance an attractive option for stabilizing the income of the farmers and also to reduce the burden of disaster payments by the government. In a country where the agricultural sector is vital, developing appropriate counter cyclical payment mechanisms to support farmers at times of adversity is important.

Current Insurance Programs

With the introduction of the Pilot Crop Insurance scheme in 1978, crop insurance is available for major crops (paddy, wheat, millets, oilseeds and pulses). Until 1999-2000, schemes targeted the crop loans distributed by the loaning agency. Practically, insurance is not available for non-loaned farmers. Risk is shared by the central and state government at a 2:1 ratio. The latest insurance scheme called “*Rashtriya Krishi Beem Yojana*” launched in 2000 covered all the farmers and the risk was shared equally by the central and state government. This scheme is fairly structured with different levels of indemnity, cutoff dates for payment of premiums, premium rate applicable, designated area for conducting crop cutting experiments to assess the average area yield, and it covered all major crops grown. It worked on a proportional payment basis for yields below the trigger yield. Both the farmer and insurer have roughly equal information regarding the distribution of average yield. The disadvantage in the case of the area yield

index is that if the trigger yield is less than the average yield, a particular farmer whose yield is less than the trigger yield will not receive any payment. The limit for the amount insured is 150 percent of the trigger yield with that above the trigger yield attracting an actuarial premium. This program provided a 50 percent premium subsidy to small and marginal farmers. Losses up to 200 percent of the premium are paid by the insuring agency and above that are covered by a corpus fund set up by the government.

Experiences with the U.S crop insurance programs have shown that the level of participation did not increase even with higher levels of premium subsidies and these premium subsidies provided an incentive for the farmers to take more risky activities; the more risky the activity the more subsidy obtained (Skees, 1999). Area level programs overcome most of the moral hazard and adverse selection problems and also involve very little monitoring.

Evaluating the scheme in the state of Andhra Pradesh showed that, although the scheme is effective in increasing the participation level of the farmers (0.7 million in 1992 to 1.3 million in 1999), on average the compensation payment is 386 percent of the premium collected, with a maximum payment of 680 percent during 1999. These compensation payments covered the bank loan received by the farmers. Although the scheme is beneficial to the farmers, it puts increased pressure on the government finances. Extending the program to include non-loaned farmers is also met with skepticism as the payment rate for them is 3 times that of loaned farmers (Parchure, 2002). The current trend of disinvestment of the public sector means that increasingly government wants to shy away from this spending. If the current insurance numbers are an indication, encouraging private participation in insurance programs will not be a

reality. The performance of the recently established Agriculture Insurance Company with the aim of charging actuarially fair premiums will be truly tested.

Objectives

The crop loss data for the period 1985 to 2002 provided by the General Insurance Corporation's crop insurance cell categorizes drought (70 percent) as the major source of crop loss followed by excess rainfall (20 percent) and the losses due to others including pests and diseases forms the rest. This shows the enormous dependency of crop production on rainfall. Using the elasticity of revenue with respect to rainfall, this study analyses whether rainfall based insurance products can be an economically viable replacement for the current insurance programs in stabilizing the revenue risk faced by the farmers and also explores the insurers and reinsurers participation in the insurance schemes.

Data and Methodology

In this study historic monthly rainfall means for the months June to October from 1871 to 2000 are used for the Coastal Andhra Pradesh subdivision (data provided by Indian Institute of Tropical Meteorology). Rice is the major food crop grown here and most of it is grown during the *kharif* season. Rice crop also has the highest insurance utilization rate of 82.5 percent with an average claim rate of 326 percent. Rice yield, farm harvest price and minimum support price for the period 1981 – 2000 is collected from MoFCA, GOI. Since the rice crop is more sensitive to drought more than flooding the limits were set differently for arriving at the payment percentage for the downside risk (drought) and upside risk (flooding). Whenever the actual rainfall is above or below the strike rainfall loss, payment starts. Rice crop requires 1000 to 1200mm of water: around

250 to 300mm per month if grown completely under rainfed conditions. Less water is required from germination stage to seedling stage and also from grain maturation stage until harvest (150 to 175 mm). From tillering to dough grain stage higher levels of water is required (600 - 800 mm). Due to uneven distribution of rainfall, daily rainfall data should be used to develop the strike values appropriate for each growth stage. Since daily rainfall data for long periods is not available, this article uses historic average monthly rainfall as the strike rainfall for individual months from June to October. In the case of downside risk a limit of half of strike is used to identify full payment and between strike and the limit for all the months a percentage payment is used. In the case of upside risk the payment starts after the deviation in monthly rainfall is greater than twice the strike value for June to August, 1.5 times the strike for September, and 1.25 times the strike for October. Four years moving average yield and the maximum of farm harvest price and minimum support price is used to calculate the liability. Since a producer price index was not available, the wholesale price index for agricultural products is used to normalize the prices. Most of the basic structure of the current insurance program is preserved except that compensation is triggered by rainfall below or above the strike rainfall rather than the actual area yield below the trigger yield. Instead of providing a direct 50 percent premium subsidy as seen in the current programs here premium subsidy will be a function of adverse deviations in rainfall from the mean (Parchure, 2002).

Loading is the hiking of premium to cover losses due to unforeseen events or to build cash reserves or to cover the monitoring cost (Skees et al., 1999). In this study loading is done by adding 33 percent of the standard deviation of the indemnity to the premium. The insurer is assumed to take payment risk up to 1.5 times the premium

collected and reinsures the indemnity amount beyond this limit by paying a premium to the reinsurer. For developing a season based rainfall index one can take the average of monthly payment percentages, but occurrence of extreme losses in a particular month that could destroy the crops may lead to erroneous payment calculations. Hence, here we will consider premium calculation by month.

Skees et al. (1999, 2001), Miranda (1991), Martin et al. (2001), and Mahul (2000) explored the possibility of using rainfall in developing insurance products. The method suggested by Skees et al. (2001) for calculating the payment percentage, indemnity and the premium rate is used here.

$$\text{Payment Percentage} = \left(\frac{\text{StrikeRain} - \text{ActualRain}}{\text{StrikeRain}} \right) \text{ for drought and}$$

$$\left(\frac{\text{ActualRain} - \text{UpperStrikeRain}}{\text{ActualRain}} \right) \text{ for flooding.}$$

$$\text{Indemnity} = \text{Payment Percentage} \times \text{Liability}$$

$$\text{Premium rate} = (\text{Average Indemnity} / \text{Average Liability}) * \text{Loading}$$

The idea of using climatic events for insurance payments is not new; trading based on Heating Degree Days (HDD) and Cooling Degree Days (CDD) are available for quite some time now (Turvey, 1999). This study considers both the upper bound and lower bound risk; the payoff function for the call and put options is slightly modified from the function used by Turvey:

$$\text{Payoff (call)} = \begin{bmatrix} 0 & \text{if } X \leq \text{Strike} \\ X - \text{strike} & \text{if } \text{Strike} < X < L1 \\ L1 - \text{strike} & \text{if } X \geq L1 \end{bmatrix} \times \lambda$$

$$\text{Payoff (put)} = \begin{bmatrix} L2 - \text{Strike} & \text{if } X \leq L2 \\ \text{Strike} - X & \text{if } \text{Strike} \geq X > L2 \\ 0 & \text{if } X > \text{Strike} \end{bmatrix} \times \lambda$$

Where, L2 and L1 are the lower limit and upper limits, respectively, strike is a choice variable, X is the actual value, and λ is the predetermined monetary value of an index.

The same method used for setting monthly strike values for both the upside and downside risk and the limits for the downside risk apply here. In the case of calls the limit is fixed at four times the historic mean for June, July and August monthly options, and 3 and 2.5 times the historic mean for September and October, respectively. For rainfall beyond the limits on both sides the payout will equal the amount at the limit.

$$\text{Premium} = - (\text{EV} + 0.25 \times \text{SD})$$

The premiums charged for these options are calculated based on the expected return of the options (EV) and the option's standard deviations (SD). It is denoted as a negative value as the buyers will not get premiums back.

Results

Studies by Rao, Ray and Rao (1988) give the range of elasticity of output with respect to rainfall for different crops at different states in India (for rice elasticities are in the range of 0.7 to 0.85 during the 1980's). Since the data on revenue elasticity of rice crop with respect to rainfall is not available, sensitivity analysis is performed in this study.

The PDF approximation for individual months is given in figures 1 to 5. As expected, the relative risk of rainfall for the *kharif* season is lower (CV 19.63 percent) than the relative risk for individual months (CV values: June 47.22 percent, July 35.43

percent, August 36.41 percent, September 34.61 percent, October 51.22 percent). The distribution in the case of October has longer tails on both sides; hence, the chances of excessive loss payments are higher than other months. For June, the possibility of loss payment occurrence due to drought has a higher frequency than due to flooding. Based on the strike values and limits considered, the insurer's premium with and without loading and the reinsurer's premium is given in table 1. The actuarially fair premiums and the loaded premiums collected are in the range of 12 percent to 32 percent and 16 percent to 43 percent of the liability, respectively. Assuming the revenue elasticity of 0.5, the actual premium to be collected are half of the loaded premiums and are in the range of 8 percent to 21 percent and are relatively higher when compared to the premium rate charged in the current insurance programs which are in the range of 2 to 4 percent after 50 % premium subsidies. The results are summarized in table 1. The reinsurance premiums collected by the reinsurer from the insurer for protection against excess loss is in the range of 4 percent to 14 percent, 4 percent to 12 percent and 3 percent to 10 percent for revenue elasticities of 0.6, 0.5 and 0.4, respectively.

The premium paid follows a downward slope on either side of the strike for adverse deviations. The more adverse the deviation of rainfall from the mean is, the lower the premium charged by the insurer becomes, thereby acting purely as a counter cyclical payment. The payment mechanism is decoupled in the sense that it neither affects the production decision of the farmers nor their risk orientation. The maximum subsidy payable is limited to the premium collected. As the revenue elasticity increases the decrease in premium paid is steeper for adverse deviations in rainfall from the mean.

If the year 2000 is considered, the average yield of rice in the subdivision was 2,841 kg/ha, and the price per kg was Rs 5.00, and the average revenue obtained was Rs.14,205. If the revenue elasticity with respect to rainfall was 0.6 then the fair premium charged will be 13.0 percent (Rs. 1,847 for the month of July) and if the 50 percent subsidy is considered then the farmer pays Rs. 923.5 as premium and gains an equal amount as income not lost by means of the premium payment, which can influence his production decision. If we consider the increasing premium subsidy schedule with increasing adverse deviation of rainfall from the mean then, a one percent adverse deviation in rainfall causes the revenue to decrease by 0.6 percent. If his income were to decrease by 13.0 percent (full premium paid) then the adverse deviation in rainfall should be 21.66 percent from the mean.

$$21.66 \text{ percent adverse deviation in rainfall} = \text{Rs. } 1847$$

$$1 \text{ percent adverse deviation in rainfall} = \text{Rs. } (1847 / 21.66)$$

$$= \text{Rs } 85.27$$

For every 1 percent adverse deviations in rainfall from the mean the premium paid by the farmer decreases by Rs.85.27 which is given as subsidy to the farmer with the maximum amount equal to Rs.1,847. The higher the revenue elasticity is, the greater is the decrease in premium paid. Results from applying the above method to the investigated data at different revenue elasticity values are given in table 2.

The coefficient of variation of revenue with and without insurance is given in table 3 and the results clearly show that the relative risk decreases with versus without insurance. There is a marginal decrease in relative risk under the fair insurance situation when compared to the loaded insurance outcome. The difference in the CV of revenue

between monthly indices (June, September, and October have higher relative risk than July, August) provides opportunities for swapping risk between months. The payment percentages between months are distributed within a smaller region. These values give an idea about the likely percentage of indemnity to be received from the insurers but nothing more can be inferred from it.

A farmer may not be concerned about excess rainfall, while he wants to protect against revenue loss because of low rainfall. On the other hand, a grain handler will be more concerned about excess rainfall as it will lead to grain spoilage and store losses. Having expressed the adverse deviations in rainfall in monetary terms, rainfall call and put options can meet this demand. Put rainfall options for a farmer who wants to protect against drought would be appropriate and call rainfall options would be appropriate for a farmer who wants to protect against flooding. These are monthly over the counter options and expire by the end of the month with the months possibly representing the crop stages. Price of a unit of rainfall derived using the revenue elasticity estimates earlier are used here. The premium charged for the call and put options and also for swaps is given in table 4. If the actual rainfall for September, 1999 is considered as an example then the indemnity paid for a revenue elasticity of 0.5 will be Rs. 3,663. The premium collected at 21.4 percent is Rs. 2,850 and for protecting against excess losses a premium of 11.0 percent is charged by the reinsurer which is Rs. 588; hence, the insurer's loss is Rs.1,401. This loss is for 1999 alone, if the insurer had created cash reserves then he will be able to cover this loss. Instead, if the insurer had bought combined options (swap of put and call options) at a revenue elasticity of 0.5; then it has to pay a premium of Rs. 229.4, the payout is $(83.3 \times 17) = \text{Rs.}1,416$, and the net income after covering all the indemnity paid

to the farmer is $(1416 + 2850 - 229 - 3663)$ Rs. 374. The payout structure of the call and put options and for a combined payout is shown in figures 6 to 14 for the months June to October. Except in the case of October, the premium for put options is higher than the call options, suggesting a foreseeable demand for protection against drought more than excess rainfall. If the insurers protect against both drought and excess rainfall by a combination of put and call options, then the premium paid by them is less than expected from buying a pure put option. In the case of an individual farmer or grain handler, the number of put or call options bought will be equal to the expected liability over the payoff of the options. Once the options are established, the market will create its own price based on the supply and demand.

Conclusion

Rainfall accounted for around 90 percent of crop losses from 1985 to 1999. High correlation of revenue loss with respect to rainfall motivated interest in rainfall based insurance products in recent years. Widespread availability of reliable data for long periods makes it attractive to private insurers and international reinsurers and helps developing countries explore international markets for risk sharing. Rainfall based indices reduces moral hazard and adverse selection and also avoids the problem of extensive margin. Actuarial premium rates arrived at after accounting for the elasticity of revenue with respect to rainfall is higher than the current premium levels. Instead of a direct 50 percent premium subsidy to farmers, a counter cyclical mechanism given by Parchure (2002) was incorporated into with the premium subsidy received by the farmers, increasing with adverse deviation in rainfall from the mean. As Table 3 showed, the relative risk of revenue with versus without rainfall insurance decreased substantially.

Opportunities for risk swapping between months even within a single locality exist because of the presence of variation in CV between months. Rainfall put and call monthly options were developed to provide opportunity for risk transfer for the insurers. From the insurer's risk perspective, reinsurance of excess loss over that covered by the insurer is compared to that of protecting the excess loss by means of options. Since the loss effect of rainfall on output is predominant and tends to have an even distribution, rainfall options might be better suited to protect against excess loss. Financial institutions and investment bankers can hedge their funds on these rainfall options. Since agriculture occupies a significant part of the economy adverse deviation in rainfall can affect the stock markets and traders can protect themselves by hedging their stock with rainfall options. Some of the numbers given in Parchure's paper provide an idea on the vast untapped potential rainfall options might hold. Government regulation requires that 5 percent (Rs.15 billion) of the premium collected by the general insurance companies should be from the rural areas and 10 percent (Rs.240 billion) of the total investment made by these companies should be in the rural areas. Establishing such a rural network proved a difficult task for the private companies, both Indian and multinational. Availability of rainfall options and bonds would be very attractive to these companies as it satisfies both the regulatory requirements. Hence, an effective secondary market can be developed based on the portfolio principle. Although higher premium rates identified in this article may discourage the demand for insurance products, rainfall based alternatives provide clear benefits over the current area based programs and are also quite attractive to institutional investors and have vast potential in encouraging private participation in crop insurance.

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Table 1. Insurer's and Reinsurer's Premium for Individual Months for Different Revenue Elasticity (RE) Levels.

Months	(Numbers are in percentages)							
	Insurer Premium				Reinsurer Premium			
	Fair	Loaded	RE	RE	RE	RE	RE	RE
			(0.6)	(0.5)	(0.4)	(0.6)	(0.5)	(0.4)
June	29.9	39.7	23.8	19.8	15.9	11.35	10.32	9.10
July	12.9	17.23	10.3	8.61	6.89	4.34	4.05	3.58
August	11.8	15.9	9.54	7.95	6.36	4.95	4.42	3.80
September	32.3	42.9	25.7	21.4	17.1	13.54	11.93	10.07
October	32.4	43.1	21.5	21.5	17.2	13.13	11.47	9.80

Table 2. Decrease in premium paid by the farmer for 1 percent adverse deviation of rainfall from the mean

Month	(Numbers are in Rupees)		
	Revenue elasticity of 0.4	Revenue elasticity of 0.5	Revenue elasticity of 0.6
June	26.76	29.90	33.05
July	20.32	22.57	24.83
August	22.56	24.99	27.42
September	23.13	25.87	28.62
October	35.29	39.85	44.41
Average	25.61	28.64	31.67

Table 3. Payment Percentage and Coefficient of Variation at Different Revenue Elasticity (RE) Levels

(Numbers are in percentages)

	Payment Percentage			CV of revenue		
	RE	RE	RE	RE	RE	RE
	(0.6)	(0.5)	(0.4)	(0.6)	(0.5)	(0.4)
Revenue Without Insurance	--	--	--	49.99	49.99	49.99
Fair Insurance	--	--	--	20.91	20.68	19.86
Revenue With Insurance	13.01	10.80	8.67	20.10	19.95	19.81
Month Wise						
June	13.51	11.26	9.01	35.12	34.45	33.82
July	9.70	8.08	6.46	20.31	20.32	20.14
August	10.44	8.70	6.96	22.14	22.02	21.89
September	11.78	9.80	7.85	35.72	34.98	34.28
October	19.61	16.30	13.07	32.12	31.36	30.64

Table 4. Premium Charged for Call, Put and Swap for Different Monthly Options and Revenue Elasticity (RE) Levels

(Numbers are in Rupees)

Months	RE -0.4			RE - 0.5			RE – 0.6		
	Put	Swap	Call	Put	Swap	Call	Put	Swap	Call
June	497.66	352.57	78.15	556.22	394.05	87.34	614.62	435.42	96.51
July	211.24	1386.86	13.70	234.76	199.19	15.22	258.14	228.34	16.74
August	254.99	223.93	9.36	282.67	244.36	10.38	309.90	272.15	11.38
September	256.17	185.34	97.88	152.70	160.57	109.33	317.09	229.41	121.16
October	151.56	217.35	475.59	171.19	366.45	537.18	190.72	273.51	598.48

Figure 1 PDF Approximation for June

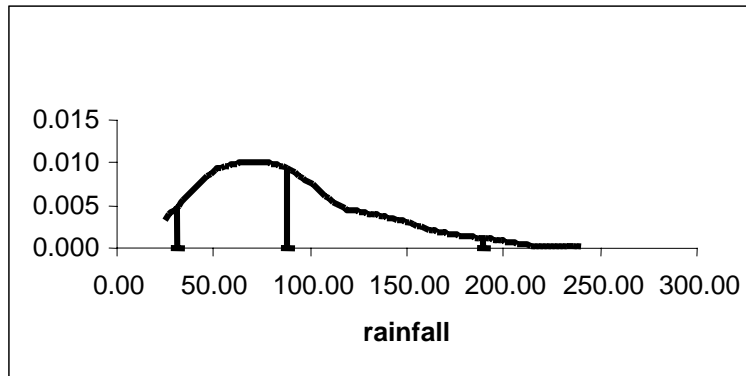


Figure 2. PDF Approximations for

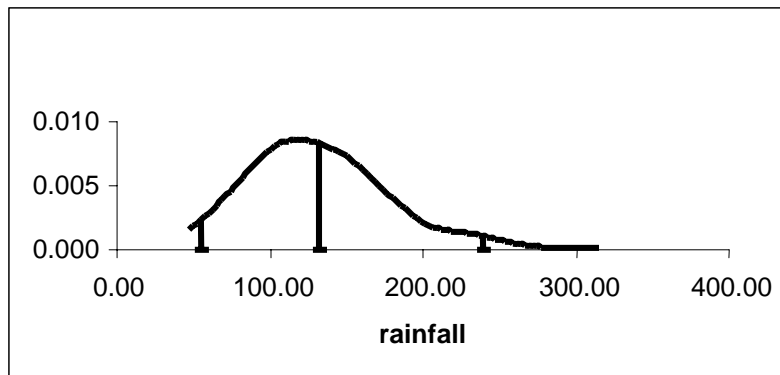


Figure 3. PDF Approximations for

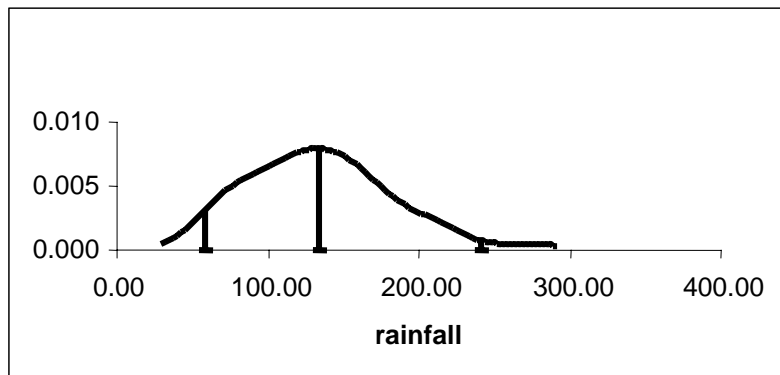


Figure 4 PDF Approximations for September

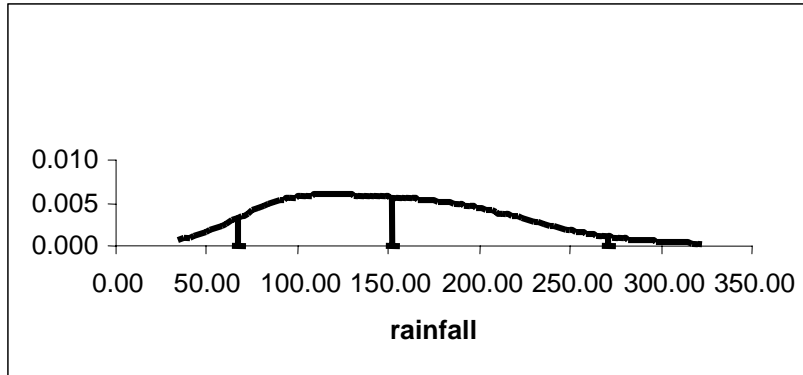


Figure 5 PDF Approximations for October

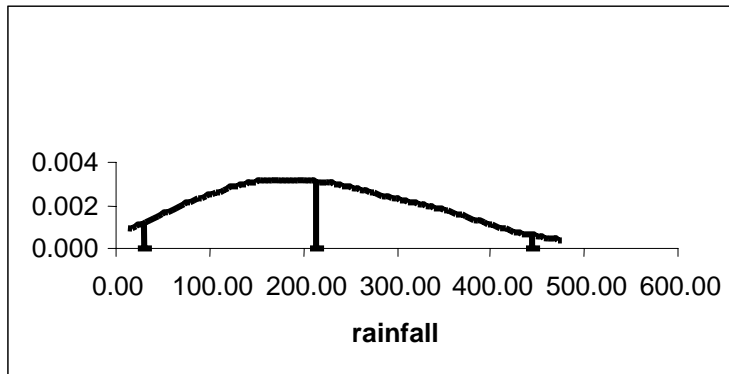


Figure 6 Put and Call Payouts for June

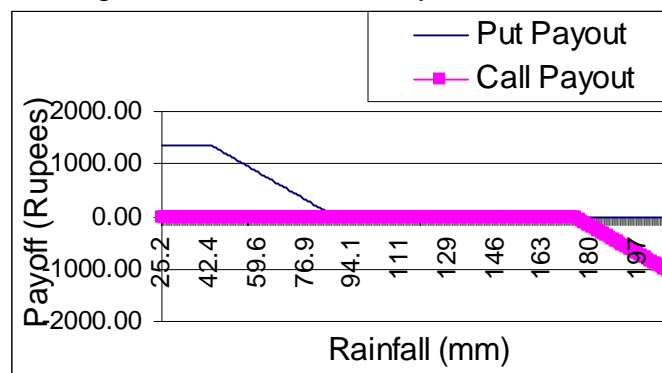


Figure 7. Combined Payout for June

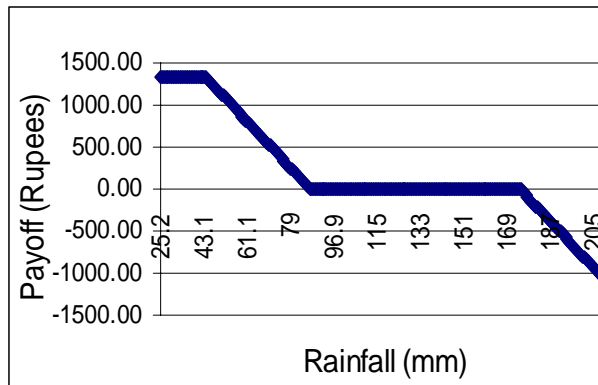


Figure 8. Put and Call Payouts for July

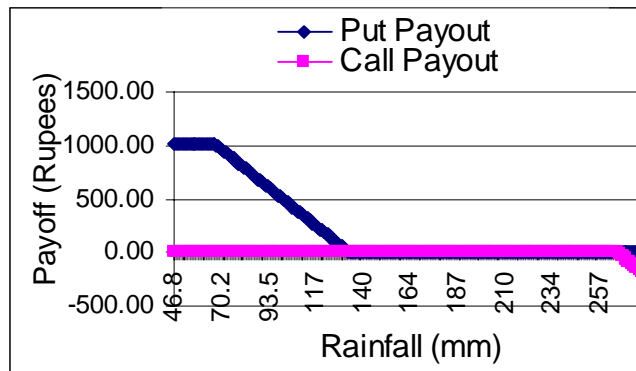


Figure 9. Combined Payout for July

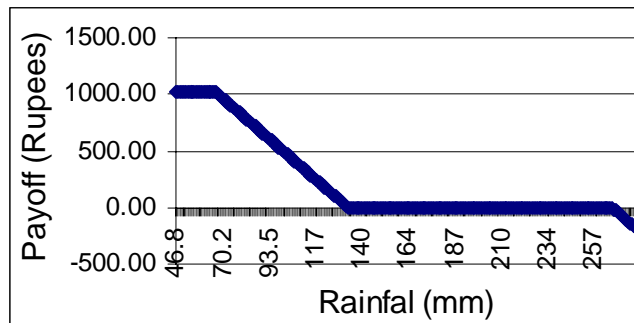


Figure 10. Put and Call Payouts for August

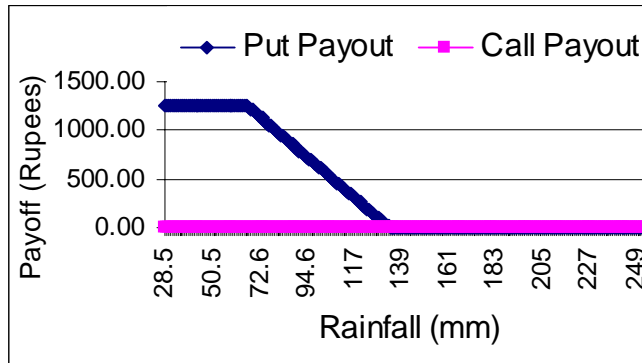


Figure 11. Combined Payout for August

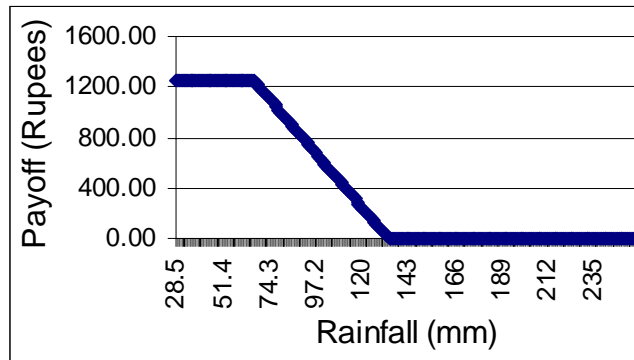


Figure 12. Put and Call Payouts for September

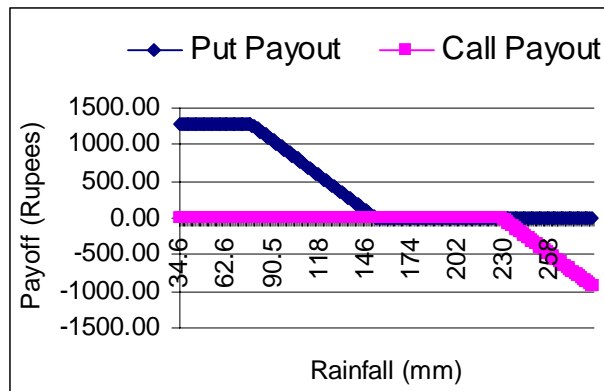


Figure 13. Combined Payoff for September

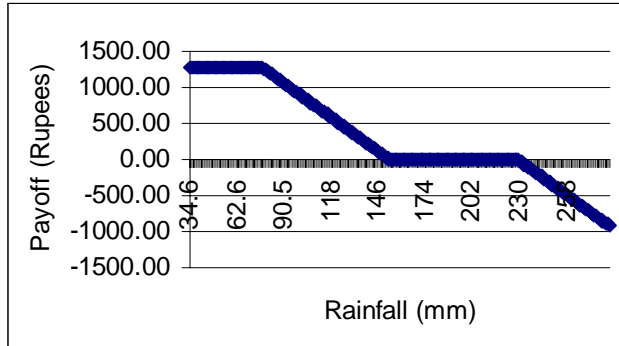


Figure 14. Put and Call Payouts for October

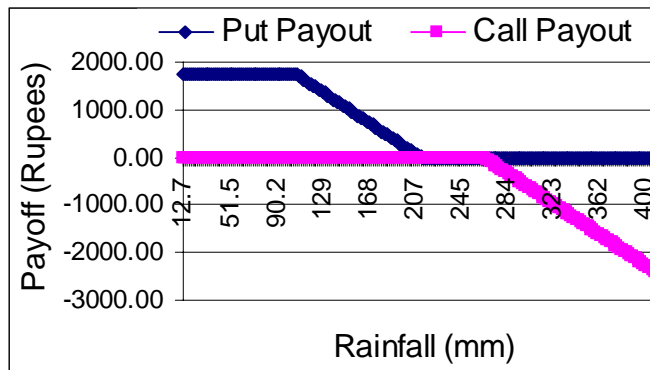


Figure 15. Combined Payoff for October

