# THE POTENTIAL OF A PROPOSED RAINFALL OPTION AT COTTON HARVEST <br> <br> Steven W. Martin <br> <br> Steven W. Martin <br> Mississippi State University <br> Mississippi State, MS 


#### Abstract

Producers have been faced with greater needs for risk protection since the passage of the 1996 FAIR Act. This paper will illustrate how a rainfall option contract might be used as a tool to manage producer risk at cotton harvest. While there are forms of weather options available for nonagricultural purposes, rainfall options for agricultural purposes are not yet widely available. In the event that they do become available, it is hoped that this paper will be a useful guide in determining how they fit into a total risk management package.


## Introduction

Several new crop insurance products have been developed with the purpose of helping to manage producer risk. These include Crop Revenue Coverage (CRC), Income Protection (IP) and Revenue Assurance (RA). At present, CRC is the only revenue insurance product available for cotton throughout much of the mid-South. Problems still exist with current crop insurance programs. Current programs require losses to be at least $25 \%$ before triggering indemnity payments, i.e., a $25 \%$ deductible.

The premiums charged in the mid-South are historically higher than for other regions. The high premium rates have been attributed to moral hazard and adverse selection (Barnett, Coble and Spurlock). Moral hazard occurs when, after purchasing insurance, individuals act differently than they would without insurance. Adverse selection is the inability of the insurer to accurately classify a potential policyholder's risk exposure. The lack of full indemnification and high premiums makes crop insurance less attractive, which results in poor participation rates. Additionally, traditional crop insurance products are based on yield or yield/price combinations. Cotton producers are paid on pounds of lint at a predetermined quality level. While the per pound lint price may not be low enough to trigger an indemnity payment, the actual price producers receive as a result of lowered quality may result in significant losses for the producer.

## Weather Derivatives

Some of the latest risk management products being developed are based solely on weather phenomena. These are often referred to as weather derivatives (Turvey). These products use various types of weather data such as the level of rainfall or heat degree units as an index on which to base the policy. Thus, the products have also been referred to as index options. All options are financial derivatives that specify a right but not an obligation to undertake a particular action during a specified time. Index options are slightly different from "regular" options because they are cash settled. That is, index options are not based on the price of any one underlying asset (stock/commodity), but instead on changes in an underlying index. Index options are settled based on the level of the underlying index. For weather derivatives, the index is usually based on data from an objective weather station. The fact that these products are based on an objective source such as weather station data provides benefits for the writer of the policy. These benefits are the lack of moral hazard and adverse selection problems associated with traditional crop insurance products. This can, in turn, provide incentives for producers in the form of lower premium costs.

Similar to other options, index options also have basis risk. In the case of a proposed rainfall index option, the basis risk is the difference in rainfall amounts at the weather station and observed rainfall amounts at the insured's location. The decision for producers then is whether the product provides the needed coverage for their particular situation. Traditional crop insurance products must be purchased prior to crop planting. While rainfall options would likely have advance purchase requirements, they could likely be purchased closer to harvest. The opportunity to purchase rainfall options later in the growing season would provide farmers the added benefit of more accurately determining the value of the crop they are protecting. Additionally, because cumulative rainfall inversely affects quality (Williford et. al.), the ability to purchase closer to harvest allows the farmer to estimate the value of his crop given perfect harvest conditions. For example, 30 days prior to harvest, the only thing standing between the producer and the full value of his crop is the uncertainty associated with harvest conditions. The purpose of this paper is to demonstrate how a rainfall option contract might work for cotton producers at harvest. This will be accomplished by comparing break-even premium costs for a proposed rainfall index option to the per acre potential losses from excessive rainfall.

The premium purchasers pay is determined by the premium rate multiplied by the level of liability. Liability is determined a priori (by the producers) and therefore can be considered a constant. The premium rate will typically include allowances for overhead, administrative costs, profits, etc. (referred to as loading), as well the expected loss cost of the option.

Assuming loading is constant across policies, the only variable is expected loss cost (See Appendix). Therefore, the expected loss cost of a rainfall option contract for different hypothetical situations will be determined and compared to the possible losses due to rainfall occurrences.

## Conceptual Framework

Cotton harvest in the mid-South is generally centered on the period from mid-September until the end of October. This time period is generally characterized by low levels and magnitudes of rainfall (Spurlock et. al.) However, in the event of rainfall, losses can be costly. These losses can come from lost yield and/or lower quality (Williford et. al.).

Using historical rainfall data as an index on which to base the policy, the loss cost for a rainfall call option can be simulated for a particular time period, ranging from one day to one year. Historical rainfall data is site specific, i. e.; those observations at one location may vary from other sites or from the producer's actual levels. Therefore, producers should pick weather stations that most adequately represent their farm. This will presumably be the station nearest them. However, producers may desire to spread their liability across several weather stations. Producers should be aware that rainfall levels on their particular farm may vary from those at the weather station(s), on which the policy is based, thus creating the "basis" risk discussed earlier.

Once producers have determined the relevant weather station and time period, the indemnity function can be expressed as:
$\{0$, if $x \leq$ strike;
Indemnity $=x$-strike/limit-strike, if strike $<x<$ limit; and 1 , if $x \geq$ limit $\}$

* Liability
where x is the actual level of rainfall. The liability level is the dollar amount of protection the producer wishes to purchase. The liability level will vary among producers depending on the number of acres and the value of the crop. Next a "strike" level of rainfall can be chosen. This "strike" will be the level of rainfall that initially represents damage or loss to the producer. The producer then selects a "limit." The "limit" could be the level at which the farmer experiences a total loss or it could just be the level at which the farmer wishes to receive the full indemnity (this choice is made by the producer given desired protection levels and premiums). The term in brackets above is the loss cost schedule. The loss cost schedule states that if the actual rainfall level is less than the strike then no indemnity payment is forthcoming. The loss cost schedule also states that if the actual rainfall level is above the strike but less than the limit, then the payout or indemnity will be determined by the stated equation. This equation allows the indemnity to increase as additional actual
rainfall above the strike is incurred. This equation will be equal to 1 when the rainfall level equals the limit and hence the indemnity will be equal to the liability for rainfall levels equal to or greater than the limit. Therefore, the expected loss cost or break-even premium can be determined as a function of the strike and limit levels and the historical rainfall data. Because cotton producers will be concerned with rainfall above a certain level during harvest, the above indemnity function is similar to a call option. Rainfall above the strike will trigger payment of the indemnity and rainfall above the limit will constitute payment of the full indemnity. Readers desiring a more detailed discussion on establishing and rating rainfall option contracts are referred to the work of Martin, Barnett, and Coble.


## Data and Methods

Historical daily observations of rainfall data from the National Oceanic and Atmospheric Administration (NOAA) were obtained for Stoneville, MS for the period 1936 to 1995. Missing observations were replaced with the mean value for that day from 1936 to 1995. The expected loss cost schedule was estimated by both non-parametric and parametric methods. Previous research (McWhorter; Pote et. al.) has suggested that rainfall follows a gamma distribution. However, it is important to use both methods. Using only the parametric procedure leaves open the question, "Is the underlying distribution really a gamma?" Using only the non-parametric procedure raises the question, "Are the historical data representative of the true population?" Nonparametric procedures rely on assumptions that are less restrictive than parametric procedures. If the assumptions underlying the parametric procedures are violated, the nonparametric procedure is more accurate. On the other hand, if the assumptions of the parametric procedure are met then the parametric procedure will be more efficient than the nonparametric method (Goodwin and Ker). Incorrect distributions could lead to over/under estimated premiums. Because companies issuing these contracts will most likely seek to protect their interests, the most conservative (highest premiums) of the two methods will be presented in the findings.

## Application

There are infinite possibilities for rainfall losses at harvest. However, as an example of the losses due to rainfall, consider the previous work of Williford et. al. The authors' research revealed losses of 11 pounds of lint per acre per inch of accumulated rainfall for mid-Delta farms. Quality losses, in the form of lint grade, were found to increase dramatically after 4 inches of accumulated rainfall. Other results are possible depending on soil types, cotton varieties, yield and other weather conditions. Using the authors' results, 1 inch of rainfall represents a loss of $\$ 6.60$ per acre based on $\$ 0.60$
lint prices. Two inches of rainfall would cause $\$ 21.42$ per acre losses, which consists of a 22 pound per acre lint loss and a $97.5 \%$ grade index. Four inches represents a $\$ 53.49$ loss per acre, while 6 and 8 inches represent losses of $\$ 74.64$ and $\$ 93.26$, respectively. This loss information is summarized in Table 1 and shown graphically in Figure 1.

As an example, consider a 1,000-acre farm with a 650 lb /acre average yield. Producers under this scenario could purchase rainfall options for the time period September 23 through October 23. Pure premium costs for various strikes and limits are summarized in Table 2. For example, to insure against a $\$ 50,000$ loss $($ Table 1, strike $=$ limit $=4)$, the pure premium cost would be $25 \% \times \$ 50,000$ or $\$ 12,500$. This is a cost of $\$ 12.50$ per acre versus the possible loss of $\$ 53.49$. Producers can "stretch" this by choosing higher limits. By choosing 8 inches as the limit (strike $=4$, limit $=8$ ), the pure premium costs would be $10.6 \% \times \$ 50,000$ or $\$ 5.30$ per acre. There is a significant difference in these two policies. The first policy would be an "all or nothing" type policy that pays the full indemnity when rainfall exceeds 4 inches. The second policy starts paying an indemnity when rainfall exceeds 4 inches but does not pay the full indemnity until rainfall reaches 8 inches. Figure 2 shows a graphical illustration of how an option with strike $=4$, limit $=8$ would payout.

Figure 3 was obtained by combining Figures 1 and 2. Figure 3 shows how the indemnity payout for an option with strike $=4$, limit $=8$ follows the loss schedule in Table 1. As can be seen in Figure 3, at rainfall levels below 7 inches, the option would allow the producers to recoup part of their losses. Above 7 inches of rainfall the option basically covers all losses for the example illustrated. The indemnity of the option above the limit ( 8 inches of rainfall) would be constant at the level of liability (in this case $\$ 100,000$ ). Losses from rainfall above 8 inches, however, would probably increase.

Another scenario shows that rainfall at the 8-inch level would result in a $\$ 93,260$ loss. A policy covering $\$ 100,000$ of liability for 8 inches of rainfall as an "all or nothing" policy could be purchased for $4.4 \% \times \$ 100,000$ or $\$ 4,400$. This would equate to $\$ 4.40$ per acre versus the possible loss of $\$ 93.26$. The producer could also "stretch" this policy by choosing a higher limit. A policy where strike $=8$, limit $=10$ would have pure premium costs of $3.0 \%$ or $\$ 3.00$ per acre.

## Summary

Farmers face many types of uncertainty. Rainfall options are but one of many methods of offsetting some of these risks. Used with the proper knowledge of potential yield and potential yield losses, rainfall options may provide a valuable new source of risk protection. Most companies issuing rainfall options would probably require purchase of the
contract prior to the effective time period. This will be required to avoid adverse selection potential. However, producers will probably have a good idea prior to harvest of the estimated value of their crop. Additionally, actual premiums would be marginally higher than those shown here due to loading. Producers should remember that their rainfall levels may vary from those at the weather station on which the policy is based. The amount of risk producers are willing to accept as well as their financial situation will ultimately determine whether rainfall options will fit into their total risk management package. At present, rainfall options are not widely available. However, it is hoped that if they do become available, this research will be a helpful guide in assessing their effectiveness as a risk management tool.

## References

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## Appendix.

## Derivation of Loss Cost

Premium can be calculated as:
(1) Premium $=$ Premium Rate $*$ Liability.

Liability will vary between options depending on the farmer's desired dollar amount of coverage. It is known a prior. Thus, the variable of interest is the premium rate. Equation (1) can be restated as :
(2) Premium rate $=$ Premium/Liability.

The break even premium rate is that at which expected premiums equal expected indemnities and can be established as :
(3) Premium/Liability (Premium Rate) = E (Indemnity)/Liability.

This equation states that the break even premium rate will be equal to the expected indemnity divided by the liability. Since
(4) Indemnity/Liability $=$ Loss Cost,

Equation (3) can be rewritten as :
(5) Break Even Premium Rate $=\mathrm{E}$ (Loss Cost).

Table 1. Per Acre Losses Due to Rainfall.

| Rainfall | 1 inch | 2 inches | 4 inches | 6 inches | 8 inches |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $\$$ yield loss | $\$ 6.60$ | $\$ 12.20$ | $\$ 24.40$ | $\$ 39.60$ | $\$ 52.80$ |
| \$ quality loss | 0 | $\$ 9.42$ | $\$ 29.09$ | $\$ 35.04$ | $\$ 40.46$ |
| Total loss/acre | $\$ 6.60$ | $\$ 21.62$ | $\$ 53.49$ | $\$ 74.64$ | $\$ 93.26$ |
| Total losses on |  |  |  |  |  |
| 1000 acres | $\$ 6600$ | $\$ 21,620$ | $\$ 53,490$ | $\$ 74,640$ | $\$ 93,260$ |

Table 2. Pure Premium Costs, Stoneville, MS, Sept. 23Oct.23.

| Strike | Limit | Cost |
| :--- | :--- | :--- |
| 4 | 4 | $25.0 \%$ |
| 4 | 6 | $15.1 \%$ |
| 4 | 8 | $10.6 \%$ |
| 5 | 5 | $14.1 \%$ |
| 5 | 6 | $11.7 \%$ |
| 5 | 8 | $8.3 \%$ |
| 6 | 6 | $9.6 \%$ |
| 6 | 8 | $6.2 \%$ |
| 6 | 10 | $4.8 \%$ |
| 8 | 8 | $4.4 \%$ |
| 8 | 10 | $3.0 \%$ |



Figure 1. Total Losses per Acre Due to Accumulated Rainfall


Figure 2. Indemnity per Acre


Figure 3. Comparison Indemnity vs. Losses

